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The Danube

The Danube: Environmental monitoring of an international river

By Libor Jansky, Masahiro Murakami, and
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Preface

Building upon the United Nations University research project on the management of transboundary water resources, this work examines the opportunities and constraints related to the use of environmental monitoring as a tool for providing scientific data and information to support decision making for the sustainable management of shared freshwater resources in a conflictual international environment. Based on original documents and research, the study presents an overview of the development of the environmental monitoring in the middle reaches of the Danube, which was established in the course of the escalation of an international dispute over a water management project on the section of the river that flows as a border between Hungary and the Slovak Republic. The work also examines the results from the monitoring and proposes possibilities for its optimization.

The original Gabčíkovo-Nagymaros Project (GNP), the key provision of a treaty signed by the governments of Hungary and Czechoslovakia in 1977 (see Appendix No. 1) was a joint endeavor for the construction of a system of locks for flood control, navigation, and hydropower generation in the middle Danube. The sociopolitical and economic transformations in Hungary and Czechoslovakia, which began in the late 1980s, and the changes of the respective goals and priorities of both countries turned the GNP into a subject of a heated debate on the environmental implications of the water regulations and at the same time into a political dispute. Currently, only the upper "Gabčíkovo" part of the original twin-dam

project is in operation. It was launched as an alternative to the original in 1992, following the freeze on the construction of the lower ''Nagymaros'' part of the project in 1989.

The joint system for monitoring the environmental impacts of the construction and operation of the GNP was developed alongside the political debate between Hungary and the Slovak Republic, which inherited the case after the disintegration of Czechoslovakia in 1993. The legal basis of the joint monitoring was provided by the Agreement on Certain Technical Measures and Discharges to the Danube and Mosoni Danube, signed by the Governments of the Slovak Republic and the Republic of Hungary in 1995. The agreement created an obligation for the two parties to monitor the environmental impacts of the measures implemented in 1995 to mitigate the environmental damages from the construction of the project and to exchange data and information from the monitoring results. While the joint environmental monitoring began officially in 1995, the technical and human capital foundations for the programme were rooted in earlier joint and independent monitoring of the Danube River and of the GNP section of the basin in particular. While seemingly paradoxical, the joint monitoring between the two countries in the midst of the ongoing political and legal dispute between them – a situation which is not uncommon in the history of international water management – draws attention to the possible role of shared water as an agent of cooperation rather than dispute – an issue raised by Jansky (1994), with regard to the GNP before the signing of the technical agreement and the start of the joint monitoring activities, and reiterated by Murakami and Jansky (2002).

The technical agreement between Hungary and Slovakia for the management of the water border between them could be related to the geopolitical history and basis for cooperation between the two countries. Recent historiographic studies on the region, for example, argue for the existence of a common east central European identity shaped by common geopolitical forces and the many centuries of interactions between the Hungarians and Slovaks living on the two sides of the river. The goal of EU membership that has dominated the politics of the two countries over the past decade reflects that argument. To that common goal is ascribed the two nations' agreement in 1993 to submit the GNP case for judgment to the International Court of Justice (Appendix No. 2) – an agreement without precedent in the history of transboundary water management conflicts.

In the past, conflicts over the harmful use of international water systems have been resolved through negotiations exclusively between two riparian states, through mediation by a third party, or within the framework of river basin organizations – intergovernmental bodies created

by riparian states. The mediatory role of the International Court of Justice concerning disputes over international watercourses had not been previously tested. Neither had been tested the possible role of joint environmental monitoring as a tool for implementing the data-and-benefit-sharing approaches to managing shared river basins promoted by the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses.

By presenting an overview of the current status of the GNP case and by integrating it with the history of and the results from the joint environmental monitoring programme in the middle Danubian basin, this study attempts to draw attention to and to illustrate the outcome of the cooperative efforts of the two countries, as well as the associated constraints, and thus to show the realistic possibilities offered by joint environmental monitoring for water management in conflictual international environments.

At the same time, the study hopes to enhance the practical value of the monitoring and the results (which have hitherto remained confined to technical specialists and political authorities within the two states) by making them accessible to the public and drawing attention to possible strategies for optimizing the programme. An updated basis for decision making can facilitate public involvement in the ongoing search for a solution regarding the GNP case that is sustainable and acceptable to the shareholders in the two countries. In this sense, our research can be seen as an input in the process of implementing the European Union Water Framework Directive (EU WFD) – a part of the ongoing EU accession processes in the two countries – and therefore aiming at increasing environmental awareness and encouraging public participation in the Danube River basin management plans at the national and international levels. Public participation in water management, especially in international watercourses, is also an important element of the holistic approach in managing water resources, which is increasingly promoted by regulations at the global level. Studying the development and operation of the local environmental monitoring system in the middle Danube can complement the ongoing efforts to support and integrate developments in regional environmental monitoring, evaluation, and information systems within the framework of the UNDP/GEF Danube Regional Project and the activities of the Monitoring, Laboratory, and Information Management Expert Groups of the International Commission for the Protection of the Danube River (ICPDR).

The study's goals have determined its target audience, namely, nongovernmental, professional, and decision-making stakeholders involved in international freshwater resources management in general, and those with a shared interest in the Danube River, particularly in the part of its basin affected by the GNP.

Chronology of events

18th c. Monitoring of the hydrological characteristics of the middle Danube begins.
1880 First proposal is made for a hydroelectric dam in the middle Danube.
1952 First discussions occur between Hungary and Czechoslovakia for a joint dam project on the Danube.
1954 Serious floods occur in Hungary.
1965 Serious floods occur in Slovakia.
1977 Treaty is signed for the construction of the Gabčíkovo-Nagymaros System of Locks (September 16).
1978 Construction of System starts (completion of Gabčíkovo due in 1986, of Nagymaros in 1989).
1980 Protests against the Gabčíkovo-Nagymaros Project (GNP) begin in Hungary.
1983 Completion date for Gabčíkovo is extended until 1990, for Nagymaros until 1994.
1985 Austria agrees to finance the Hungarian part of the GNP.
1986 Serious anti-dam protests occur in Budapest; biological monitoring of the Danube begins.
1989 The Socialist regime ends in Hungary and in Czechoslovakia.
1989 Hungary and Czechoslovakia agree to extend joint monitoring of surface water quality (April).
1989 Hungarian parliament agrees to suspend construction of Nagymaros and calls for a reassessment of the ecological impacts of the project (October).
1989 Environmental monitoring of the GNP-affected areas in the Slovak Republic begins.

1990 Free elections begin in Hungary and Czechoslovakia.
1991 Slovakio decides to implement the temporary Variant C (July) and authorizes construction (November).
1991 Negotiations on the GNP occur between governmental delegations (April, July, December).
1992 Hungary unilaterally denounces the 1977 Treaty (May 19).
1992 Elections in Czechoslovakia determine the breakup of the country into the Czech Republic and Slovakia (June).
1992 Variant C, phase 1 (the damming of the Danube), is implemented, and the Gabčíkovo hydropower plant and locks are put into operation (October).
1993 January 1 marks the official split of Czechoslovakia into two republics.
1993 The GNP case is referred to the International Court of Justice (July).
1995 The Agreement for Certain Temporary Measures and Discharges to the Danube and Mosoni Danube is signed in April, and the measure is implemented in June.
1997 A judgment is made by the International Court of Justice (September 25).
1997 An agreement is made to prolong the 1995 Agreement until an agreement on the implementation of the ICJ judgment is reached (October).
2001 First meeting of the Joint Working Group on Legal Matters takes place (October).
2001 First meeting of the Joint Working Group on Water Management, Ecology, Navigation, and Energy takes place (November).

1

Introduction

Water – a blessing or a curse

Spilling water before starting an enterprise is an old Slavonic tradition that symbolizes the hope that the endeavor will flow as smoothly as water in a river. However, that old metaphor may losing its force, not only because the free flow of water in nearly all the world's major rivers is now restricted by artificial barriers. The fates of waters both harnessed and still freely flowing seem to depend on the resolutions of two ongoing heated debates: Are existing dams to be or not to be demolished? Are rivers to be or not to be dammed? An illustration of these global debates can be seen in the Gabčíkovo-Nagymaros case, which has been the subject of a continuing dispute in an either-or framework over the past decade. A closer look at the complexity of the issues involved, however, raises the question: Is an either-or framework appropriate for even beginning to address water management issues?

Throughout the course of human history and, in particular, during the recent centuries of intensive development of natural resources for the advancement of human well-being, the natural power of water in rivers and streams has been harnessed through numerous artificial lake constructions, also called reservoirs, impoundments, or dams. These water regulation works were originally designed to provide water for humans and agriculture, to control floods, and to provide waterways for navigation. In more recent times, they have been designed for hydropower

generation, for commercial fisheries, and for water-based sports and recreation. An estimated 800,000 reservoirs were in operation worldwide in 1997, and approximately 1,700 more large reservoirs are currently under construction, mainly in developing countries (World Lake Vision Committee, 2003).

The development of water regulation works has been both aided and constructed by the transboundary nature of water. Water crosses various borders: social, political, economic, cultural, scientific. Thus, it requires communication and cooperation among riparian interest groups over long periods of coexistence. Very often, however, the diverging views of stakeholders on allocation, objectives, standards, and methods to be considered and/or applied in the course of implementing various stages of water resources management turn water into an agent of conflict rather than cooperation (UNESCO, 2001). The transboundary nature of freshwater resources, which are usually shared by multiple groups with different values and needs in regard to water, has long determined the conflictual nature of river management and water exploitation. That water has long been a cause of conflict is suggested by the English word *rival,* which comes from the Latin *rivalis,* meaning "one who uses a river [*rivus*] in common with another." While water-related conflicts have rarely led to violence in the past 4,500 years, acute tensions have escalated on numerous occasions (Uitto and Wolf, 2002) and are expected to turn into the major causes of wars in the future unless a sustainable approach to water resources management is developed and employed (Serageldin, 1995).

International freshwater management: Conflicts and resolution mechanisms

International freshwater management is a particular case of transboundary water management, which is complicated by usually larger disparities and communication barriers among the riparian parties, by limited existing legal frameworks, and by international security considerations. These constraints have led to a much greater use of domestic as opposed to international freshwater resources. Increasing demands and competition for water, due not only to the scarcity and degraded quality of domestic water resources but even more to the poor management and utilization of these resources for growing populations and economic development needs (WEHAB Working Group, 2002; UNESCO, 2001), suggest a possible rise in domestic, social, and political tensions, as well as increased pressure for the development of international waters in the future (Biswas, 1999).

The redrawing of the political maps of Central and Eastern Europe and of Central Asia at the beginning of the 1990s, which led to the internationalization of a number of previously domestic water resources (e.g., the Dnieper, the Don, and the Volga Rivers), and the changes in the political composition of existing international basins (e.g., those of the Danube, the Ob, and the Aral Sea) also suggest a greater potential for tensions over international water management issues that had previously been accommodated domestically or within the relevant Socialist-bloc institutional frameworks which disintegrated together with the regime.

In the past, conflicts concerning international freshwater systems have arisen mainly in developing regions, where water stress, defined in *Global Environmental Outlook* (UNEP, 2002) as water consumption exceeding 10% of renewable freshwater resources, is manifested at the crossroads of socioeconomic, cultural, and political borders and disparities. Notable examples are the conflicts in the Ganges-Brahmaputra-Meghna and the Indus river basins in South Asia, in the Jordan river basin in the Middle East (Murakami, 1996), the Nile river basin in Africa, and, most recently, in the Aral Sea basin in Central Asia. In most cases, conflicts have arisen from accusations by downstream riparian states of harmful uses of shared water resources by upstream ones. Given the nature of these conflicts, they have been resolved by negotiation at the international level, by negotiation exclusively between two riparian states, or through mediation by a third party. River basin organizations – intergovernmental bodies created by riparian states – have also been instrumental in resolving conflicts among basin countries (Nakayama, 1998a).

Historically, international negotiations and institutional frameworks have been successful in resolving disputes over the navigable uses of international rivers. Claims over nonnavigable uses, however, have proved difficult to settle (Biswas, 1999). The constraints to resolving issues of allocation have been aggravated by the increasing legitimization of water needs for ecosystem and habitat preservation. The lack of reliable information about the environmental impacts of different water management policy options and the scientific uncertainty about them has left additional space for value-based judgments. That uncertainty has made transboundary water management and, as Deets (1998) argues, environmental disputes in general particularly prone to politicization and has raised the need for incorporating appropriate tools for limiting uncertainty in the existing mechanisms for resolutions of international water conflicts.

The major framework for sustainable freshwater resources management – Integrated River Basin Management (IRBM) – promotes the coordinated planning and management of all environmental components on

the geographical basis of a river basin. Concrete tools for promoting and ensuring long-term, holistic water management, however, are lacking in most of the cooperation management agreements currently existing in 106 of the world's 263 international basins (Wolf, 2002). In an attempt to fill that lack, the 1997 United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses, the development of which can be traced back to the 1966 Helsinki Rules that laid the foundation for the international principles for shared watercourses (UNEP, 2002), established a legal framework promoting the equitable and reasonable utilization and the protection and preservation of shared water bodies by, among other policies, sharing relevant data and information. The practical value of the Convention, however, has been questioned on the basis of its vague, sometimes contradictory language, and the slow progress toward its legal framework's ratification (Giordano and Wolf, 2002). At the same time, the usefulness of the framework's data development and data-sharing approach can be seen as constrained by the lack of appropriate mechanisms for incorporating the relevant stakeholders and the broader public in data-sharing arrangements and in the decision making about and the implementation of water management policies. Although donors have given lip service to and, in some cases, funded elements of public participation projects, mostly in awareness raising and other public relations efforts, it has been argued that many of those actions have been insufficient or misguided (Bell, Stewart, and Nagy, 2002).

The case of the Gabčíkovo-Nagymaros Project provides insight into the effectiveness of the Convention, both legally and in terms of one of the mechanisms the Convention proposes for the prevention and resolution of disputes over nonnavigable and, in particular, environmental uses of international waters. The GNP case was the first international water dispute taken to the International Court of Justice (ICJ) and addressed within the framework offered by the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses – legally, through the Court's reference to the Convention and, in practice, through the system for joint environmental monitoring and exchange of relevant data and information which was established even before the creation of the UN Convention.

The Gabčíkovo-Nagymaros Project (GNP)

Situated on the borderline of changing institutional structures and public perceptions, the Gabčíkovo-Nagymaros case, born from a half-century-old idea for constructing a system of locks in the middle section of the

Danube flowing between Bratislava and Budapest, the capitals of Slovakia and Hungary, respectively, constitutes a test case of the ability of the existing and potential tools for transboundary water management to respond to the challenges of the rising pressure for the utilization of international water resources. Initially conceived as a joint hydroengineering project, the GNP escalated into a war of words over the environmental consequences of the regulation works on the water resources shared by Hungary and Slovakia. The lack of reliable scientific information in the context of the political and economic transitions progressing at different paces in the two countries allowed for the utilization of the water management debate for political legitimization and led to its transformation into a potentially explosive international security issue (Sukosd, 1998).

International institutions, such as the European Union, with its strong political leverage over the two countries aspiring to membership in the organization, and the International Court of Justice, which examined the case and gave a judgment in 1997, provided the institutional basis for resolution to the dispute. Thus, they filled the post-Socialist institutional vacuum in which the two countries found themselves after the disintegration at the beginning of the 1990s of the formerly existing structures for regional political security and economic cooperation. Ultimately, however, the EU and the ICJ left the water management issues and their actual and potential environmental threats for Hungary and Slovakia to resolve.

A step in the direction of reaching such a resolution on the technical aspects of the water management debate was undertaken by the two countries in 1995 (i.e., before the pronouncement of the ICJ judgment) through an agreement on some temporary technical measures for addressing the most critical environmental consequences of constructing and putting into operation the Gabčíkovo part of the GNP and through the establishment of a system for joint environmental monitoring and exchange of information on the affected areas.

Environmental monitoring: A possible solution?

Environmental monitoring, an integral part of the Environmental Impact Assessment System, is a costly tool for evaluating the environmental impacts of development projects. In conflict-prone environments, however, its cost may be a justifiable and reasonable price to pay to limit opportunities for the much more costly politicization and internationalization of environmental debates. For monitoring to prove a useful tool for sustainable water management in conflictual environments, however, it has

to be conducted or coordinated jointly. A joint endeavor could provide the following:

- a basis for decision making that limits the scientific uncertainty which makes environmental debates prone to distortions;
- an alternative, i.e., nonpolitical, perspective for water management encouraging a benefit-sharing approach by looking at the examined water basin as an ecosystem unity;
- an institutional framework for addressing the technical and practical aspects of water management debates.

Environmental monitoring, however, is hardly a flawless solution. Two major concerns, its scientific and political functions in conflictual environments, need to be taken into account. Limiting factors in the case of the former constitute methodological uncertainties related to the following:

- difficulties in selecting proper indicators because of the complexity of the interlinkages of different factors in the physical environment;
- data interpretation concerns arising from the difficulty in isolating the causes of observed changes in the complexity of the time- and spatial ecosystem dynamics;
- scientific constraints in making future predictions;
- the subjectivity of determining the value of one plant or animal species as opposed to another and thus of policy-relevant data interpretation.

In addition to these scientific limitations, the effectiveness of monitoring programmes is subject to the inevitable dependency on politics of the use of the monitoring results in conflictual environments. Closely related to that dependency is the danger of an unnecessary continual extension of the monitoring programme itself, driven by the prolonged justifiability of such programmes during a continuing political debate or by the vested interests of lobbying scientists involved in a monitoring programme. An example of the extent to which these limitations are surmountable is offered by the GNP case and the joint monitoring programme associated with it on the affected areas.

Why and what?

To sum up, our research was driven by practical considerations related to the current state of international watercourses management and the peculiarities and status of the GNP case itself. The former are related to the potential growth of tension in international watercourses and the possible opportunities for dealing with that tension offered by joint environmental monitoring and data sharing, which have been increasingly promoted as tools for transboundary water management in the context of the inter-

national debate on the socioeconomic and environmental implications of water regulations. The latter are associated with the ongoing efforts toward reaching an agreement on the implementation of the 1997 judgment of the International Court of Justice regarding the GNP case and with the accumulated results from the joint monitoring and earlier independent monitoring of the affected areas that could provide a reasonable basis both for an interim, policy-oriented evaluation of the environmental impact of the GNP and for informed public input in support of it.

The mandate of our work with respect to the broader implications of environmental monitoring for managing shared water resources in conflictual environments is determined by the few existing cases of joint environmental monitoring on international rivers and by the limited attention paid to the opportunities and constraints such programmes offer for dealing with potentially disruptive water management disputes. At the same time, the GNP-specific concerns our work attempts to address are related to the fact that, despite the considerable attention that the GNP case has attracted in the region and among political scientists abroad, scientifically backed, systematic, and comprehensive evaluations of the environmental consequences of the operation of the dam are limited.

The available literature focusing on the environmental aspects of the GNP case offers a fragmented picture. Comprehensive environmental studies based on the independent monitoring conducted in Hungary and the Slovak Republic before 1995 are subject to the political divide between the two countries and inevitably to the respective viewpoints on the case. Results from the pre-1995 monitoring in the Slovak Republic are compiled in *Gabčíkovo Part of the Hydroelectric Power Project: Environmental Impact Review Based on Two Year Monitoring,* published in 1995 by the Faculty of Natural Sciences of Comenius University in Bratislava, which was in charge of coordinating the GNP-related monitoring activities at the time, and the Plenipotentiary of the Slovak Republic for the Construction and Operation of the Gabčíkovo-Nagymaros Hydropower Scheme. A similar report, based on six years of monitoring, was published in 1999. The edited volumes (Mucha, 1995; 1999) constitute compilations of reports by different specialists involved in the monitoring of individual environmental elements on the GNP-affected territories in the Slovak Republic. On the Hungarian side, results from the independent pre-1995 monitoring are compiled in *Studies on the Environmental State of the Szigetköz after the Diversion of the Danube*. Similar to the Slovak publications, the volume edited by Láng, Banczerowski, and Berczik (1997) includes reports based on the results of environmental studies on the affected area and of the monitoring of different environmental indicators presented by the respective specialists involved. As a basis for evaluating the reliability of the independent monitoring practices and

methodology employed by the Hungarian and Slovak specialists, relevant literature from independent sources on the theoretical and practical aspects of the monitoring of the respective components discussed is presented when available.

For the period after 1995, the main sources of the results from the monitoring of the GNP-affected areas and of the environmental impacts of the technical measures jointly agreed and implemented by Hungary and Slovakia in 1995 are the Joint Annual Reports for the years 1996–2001. The reports present information focusing on the short-term changes observed in the environment and are intended for use by the authorities in the two countries who are involved in and well acquainted with the GNP case.

Based on the above main sources, this study presents a history of the development and an overview of the results from the environmental monitoring on the GNP-affected areas. It also provides a synopsis of the legal, technical, as well as hydrogeological and geopolitical aspects of the GNP case, along with relevant original documents, tables, and figures, in order to enable authentic, in-depth studies of specific aspects of the case that are deemed relevant by the individual readers. Such a comprehensive approach is considered necessary in order to provide a reasonable background for understanding the fragmented pieces of the independent and joint environmental monitoring activities and results. The study attempts to put the fragments together with the goal of providing the following:

1) Insight into the practical opportunities and challenges in using joint environmental monitoring and relevant data and information exchange as bases for sustainable management of international watercourses in conflictual environments.
2) An updated basis, accessible to the public, for decision making to support the evaluation of the environmental impact of the GNP and to encourage public participation in the ongoing search for sustainable solutions and for an agreement on the implementation of the 1997 ICJ judgment on the GNP case.

The text is organized as follows. First, a theoretical overview of transboundary river problems synthesizes the major potentially conflictual issues in the management of international rivers. The second section presents an overview of the Gabčíkovo-Nagymaros project, focusing on the current legal status of the case, the history of the project in the context of the changing geophysical and politico-economic characteristics of the region, and a technical description of the GNP. The third section summarizes the genesis and development of the joint environmental monitoring and the relevant results. Finally, the study draws policy-oriented conclusions both in regard to the GNP case and environmental monitoring in the context of transboundary river conflicts in general.

2

Transboundary river problems

The long history of transboundary water conflicts has brought to the forefront the realization of the need for an institutional framework that will regulate the most critical causes of disputes over water. According to Caponera (1996), such a framework should define the principles of freedom of navigation, the criteria commercial establishments must follow in order to operate near rivers, the criteria that will govern joint programmes for the development of ways of communication and relations among those living by a river, the criteria governing joint regulations for utilizing the river or its water, and the criteria governing rights concerning fishing and other river-based activities.

In addition to these major issues, the following frequently occurring but inadequately addressed problems related to local and regional river management need to be taken into account (Beckett, 1997):

- the division of fishing rights (or rights for remaining on the riverbed),
- the adjustment of a country's boundaries when river channels naturally move or are diverted,
- the rights to charge tolls for navigation of the river and to collect duties from those crossing the river,
- the rights to build bridges and charge tolls for the uses of the bridges,
- escaped animals, prisoners, or debtors on or near a river,
- the right to raise the river for mills and the right to build weirs for this purpose,
- not to have the water level lowered,

- the right to draw water for drinking (by animals or humans) or for nonriparian uses (e.g., felling, panning for gold by machine, etc.),
- the right to hunt game from river banks,
- the right not to have water spoiled by sewage or other effluents.

At the national level, these problems are inevitably aggravated by: the rights of noncontiguous lands to use the river for navigation, as well as for the passage of migrating fish, and to exploit the river (e.g., bed sediments). River pollution, the large-scale removal of river water, the diversion of a river (e.g., into an older channel, A, that reaches B and C in a different place from the present channel), as well as rights of transit and refuge or repair in wartime, add to conventional river problems. Various combinations of issues can affect the land, the water, or other interests of riparian parties differently. Many river problems (e.g., flow control and conservation measures) have impacts on the territories downstream, but some problems affect territories upstream as well (e.g., migrating fish and navigation).

Disputes can arise from the above problems, exacerbated by their superimposition on nonriver issues, such as religion, politics, recent aggression, as well as different paces and levels of economic and social development of the parties involved. Different communities are more or less touchy about such matters, depending on their traditions or their perceptions of unequal treatment concerning previous problems. More or less successful ways of solving disputes within communities have been developed. It is interesting, however, to note how such disputes are resolved between villages within the same country or between countries within the same region, with and without a river between them.

Based on examples from the Rhine basin, Wessel (1993) claims that cooperation among basin states can result in a more sustainable development within the basin and in higher water quality. A certain balance, however, is needed in order to reach cooperation between the parties for sustainable development. Such cooperation should involve not only a balance between the interests of upstream and downstream parties and between riparian and nonriparian states but also the integration of conflicting water uses, as well as balances between economy and ecology in transforming societies and between equitable centralization and decentralization tendencies in river basin management – among other balances. These principles currently support the framework of Integrated River Basin Management (IRBM), which has been increasingly promoted as the main approach to the sustainable development of freshwater resources.

Successful approaches to the resolution of transboundary water management conflicts that have arisen from imbalances in some of the above include the following: (a) negotiation exclusively between two riparian states – as in the Ganges River conflict between Bangladesh and India

(Biswas and Uitto, 2001); (b) mediation by a third party – as in the Indus River conflict between India and Pakistan (Nakayama, 1996) and in the Mekong River conflict between Thailand and Vietnam; (c) collaboration of riparian states for establishing river basin intergovernmental bodies and collaboration between riparian states within the established bodies – as within the Mekong River Commission, a successor of the Mekong River Committee (1957) and the subsequent Interim Mekong Committee (1987), since 1995 (Nakayama, 1998a).

The first case in which the International Court of Justice played the role of a mediator in an international freshwater management debate was the Gabčíkovo-Nagymaros dispute between Hungary and Slovakia. The imbalances associated with the conflictual history, the different political and economic situations in the two countries, and the different paces and stages of the transition reforms prevented a bilateral resolution of the dispute over the environmental implications of the water management project raised by public concerns. The limited objective data and the limited public access to relevant information allowed polarization and politicization of the debate. At the same time, the lack of a region-wide mechanism for jurisdiction over matters related to the nonnavigable uses of the Danube (Shmueli, 1999), combined with pressure from the European Union for a peaceful resolution of the GNP dispute, forced the search for an alternative mediation mechanism in the form of the International Court of Justice.

3

The Gabčíkovo-Nagymaros Project

Legal setting

On 25 September 1997 the International Court of Justice heard arguments concerning the protracted dispute between Hungary and Slovakia over the construction and operation of the Gabčíkovo-Nagymaros system of locks on the Danube. The legal issues which the court considered dealt with claims of breaches of the treaty for the construction and operation of the joint project signed by Czechoslovakia and Hungary in 1977 (Appendix No. 1). The GNP aimed for the joint utilization of the water resources of the Bratislava-Budapest section of the river for energy, transport, agriculture, and other sectors of the national economies of the two countries. In 1989, Hungary suspended and subsequently abandoned completion of the project, alleging that it entailed grave risks to the Hungarian environment and in particular to biodiversity in the floodplain and to water quality. Slovakia (which inherited the GNP case after the breakup of Czechoslovakia in 1993) denied these allegations and insisted that Hungary carry out its treaty obligations. Slovakia planned and, in October 1992, put into operation an alternative solution based on the original project and known as Variant C. Although the Variant C system of locks was constructed on the territory of Slovakia, its operation affected Hungary's access to the water of the Danube. Thus, in response, Hungary terminated the 1977 Treaty, which had been used by Slovakia to justify constructing and operating Variant C. In 1993 the two countries

agreed to submit the GNP case for judgment to the ICJ and to use the court's ruling as a basis for solving the dispute (Appendix No. 2).

The agreement between Hungary and Slovakia to use the International Court of Justice as a tool for legal mediation of the GNP case constitutes a precedent in the history of international water management disputes. The ICJ had been suggested as a mechanism for conflict resolution in some cases in the past. The Gabčíkovo-Nagymaros case, however, was the first hearing by the ICJ of an issue involving the non-navigational uses of an international water system. The ICJ, which is, by definition, a court established for the judgment of legal issues among nations, may render a judgment only if all the nations concerned agree to abide by its judgment. In no earlier dispute over international water management issues had the parties agreed to do so. In a conflict over the use of the water resources of the Indus river, for example, India refused Pakistan's proposal to submit the conflict for judgment to the ICJ (Nakayama, 1996). In the GNP case, the European Union, which both Hungary and Slovakia aspired to join, employed its leverage to encourage the two disputing states to refer the case to the ICJ.

The Court's judgment of the GNP case found both states in breach of their legal obligations. It called on both countries to carry out their relevant treaty obligations while taking into account the political and economic changes that had occurred since 1989.

In its judgment, in operative paragraph §155, the Court found as follows (ICJ, 1997):

1. A. By fourteen votes to one, that Hungary was not entitled to suspend and subsequently abandon, in 1989, the works on the Nagymaros Project and on the part of the Gabčíkovo Project for which the Treaty of 16 September 1977 and related instruments attributed responsibility to it;
   B. by nine votes to six, that Czechoslovakia was entitled to proceed, in November 1991, to the "provisional solution" known as "Variant C," as described in the terms of the Special Agreement;
   C. by ten votes to five, that Czechoslovakia was not entitled to put into operation, from October 1992, this "provisional solution";
   D. by eleven votes to four, that the notification, on 19 May 1992, of the termination of the Treaty of 16 September 1977 and related instruments by Hungary did not have the legal effect of terminating them;
2. A. by twelve votes to three, that Slovakia, as successor to Czechoslovakia, became a party to the Treaty of 16 September 1977 as from 1 January 1993;
   B. by thirteen votes to two, that Hungary and Slovakia must negotiate in good faith in the light of the prevailing situation and must take

all necessary measures to ensure the achievement of the objectives of the Treaty of 16 September 1977, in accordance with such modalities as they may agree upon;

C. by thirteen votes to two, that, unless the Parties otherwise agree, a joint operational régime must be established in accordance with the Treaty of 16 September 1977;

D. by twelve votes to three, that unless the Parties otherwise agree, Hungary shall compensate Slovakia for the damage sustained by Czechoslovakia and by Slovakia on account of the suspension and abandonment by Hungary of works for which it was responsible; and Slovakia shall compensate Hungary for the damage it has sustained on account of the putting into operation of the "provisional solution" by Czechoslovakia and its maintenance in service by Slovakia;

E. by thirteen votes to two, that the settlement of accounts for the construction and operation of the works must be effected in accordance with the relevant provisions of the Treaty of 16 September 1977 and related instruments, taking due account of such measures as will have been taken by the Parties in application of points 2B and 2C of the present operative paragraph.

The judgment of the ICJ indicates its usefulness as a tool for legal mediation in disputes over the nonnavigable use of international watercourses. Before the pronouncement of the Court, Margesson (1997) warned that a narrow legal ruling that failed to take into account broader issues of equitable utilization as they related to sustainable development would not satisfactorily address the long-term questions at stake between the parties. According to Sands (1998), the Court's ruling did take those issues into account and thus provided important implications both for the law on international watercourses and for international environmental law. The ruling confirmed the principle of equitable and reasonable use of international watercourses, "underscoring the importance of obtaining agreement between riparian states having an interest in the nonnavigable use of an international watercourse" (Sands, 1998). Furthermore, the Court confirmed (but with a conservative stance) the principle of ecological necessity by invoking the law of state responsibility, which requires a state to ensure that activities within its jurisdiction or control do not cause damage to the environments of other states. The Court thus underscored the importance of taking environmental concerns into consideration while limiting the legal basis for the politicization of environmental issues.

The court's ruling, however, left a lot of uncertainty and plenty of room for interpretation of the legality of possibly conflictual actions related to the environmental aspects of transboundary water management

decisions. While invoking the concept of sustainable development, for example, possibly implying that it has a legal component, the court failed to indicate what the concept meant in practical terms. In regard to the GNP case, the ICJ recognized the relevance of the newly developed norms of environmental law for the implementation of the 1977 Treaty and encouraged their incorporation through the application of several of its articles. The Court, however, chose not to rely on those norms for its judgment and failed to define standards to be applied in the recommended reexamination of the environmental implications of the GNP (Sands, 1998). Ultimately, the ICJ did not accept Hungary's environmental claims, which were supported by a memorandum submitted to the ICJ by a consortium of NGOs – a precedent in international environmental law – and suggested the preservation of the status quo.

While the ICJ judgment obliged the two parties to reach an agreement on resolving the GNP case within six months, i.e., by March 1998, they failed to reach not only a formal agreement about bilateral actions but even a joint interpretation of the Court's decision by the specified deadline. Thus, on 3 September 1998, Slovakia filed a request with the ICJ for an additional judgment regarding the modalities for executing the original judgment. According to Slovakia, the additional judgment was necessitated by Hungary's alleged postponement of and its unwillingness to approve a draft framework agreement for implementing the Court's judgment that had been delivered on 25 September 1997 (ICJ, 1998a). Hungary was to file a written statement of its positions on Slovakia's request for an additional judgment by 7 December 1998 (ICJ, 1998b). Meetings of the government delegations between the two countries were renewed in November 1998. Following an exchange between the delegations of the two countries of their viewpoints and of the environmental impact assessments prepared by their respective experts, an alleged discrepancy concerning the technical aspects of the debate led to the separation of the legal from the technical issues and the establishment of forums for joint discussion of the respective issues within the framework of the Joint Working Groups on Legal Matters and on Water Management, Ecology, Navigation, and Energy. These two working groups held their first meetings in October and November 2001, respectively (Plenipotentiary of the Slovak Republic, 2003). Joint discussions on the legal aspects of the GNP case, however, have been suspended since the summer of 2002 because of the dissolution of the Hungarian Government Delegation following the 2002 elections in the country.

Thus, while the ICJ judgment failed to provide a practical mechanism for resolving the GNP dispute, it confirmed the legal basis of the obligations of states to take into account the nonnavigable uses of water and, in particular, the environmental implications of water management deci-

sions in the context of international watercourses. The failure of countries to consider these issues during the long history of water regulations on the Danube River is a major reason for the current water problems in the international river basin and for the undertaking of the GNP itself. To understand the water management issues that Hungary and Slovakia are currently searching for a way to resolve, we next look at the history of water management in the Danube and the middle Danubian basin and at the genesis and the technical features of the GNP itself.

Physical setting

The Gabčíkovo-Nagymaros project for the management of the water resources of the middle section of the Danube is intimately intertwined with the water management history and practices in the broader Danubian basin. This connection is related to the incongruity between the political and the ecosystem borders, which forced the Hungarians and the Slovaks to respond to the physical changes in the middle Danube resulting from the unaccounted-for environmental impacts of earlier water regulation works and economic activities of the riparian states upstream and in the middle reaches of the river.

Water management in the Danube River basin

The Danube is one of the three major European rivers together draining a quarter of the continent. It constitutes a journey through the old and new states of post-Cold War Europe – a 2,778-kilometer trip through Germany, Austria, the Slovak Republic, Hungary, Croatia, Serbia, Romania, Bulgaria, and the Ukraine. Before emptying into the Black Sea, the river also drains the catchment areas of Switzerland, Italy, Poland, the Czech Republic, Slovenia, Bosnia-Herzegovina, Albania, Moldova, and Macedonia, thus forming the largest international river basin on the continent that covers an area of 817,000 square kilometers (fig. 1).

The natural topography along the river is as varied as the social and political characteristics of the river basin. The Danube passes through mountain gateways, agricultural plains, wetlands, and deltaic interlacings of inland and water near the river's terminus. From a hydrological perspective, it is characterized by a fluctuating volume and movement of gravel and fine sand, a deepening in sections of it, an increasing and meandering riverbed, sedimentation and erosion, and frequent floods.

The current physical characteristics of the river and its ecosystems have been largely shaped by the centuries of human intervention, guided by different political interests and priorities. For centuries, human settlers

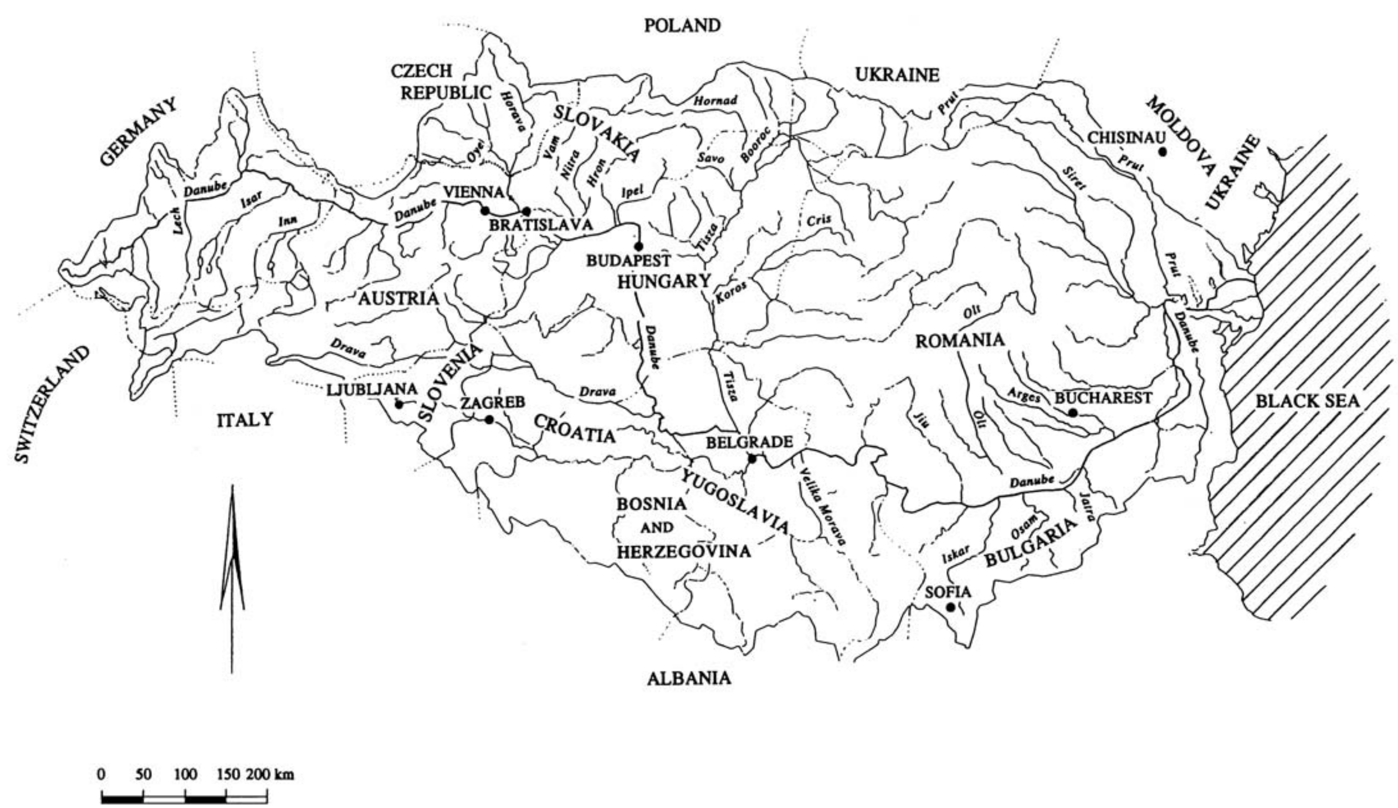

Figure 1 The Danube River Basin
[Source: EPDRB, 1993]

along its banks have used the river for fishing, navigation, drinking, an agricultural and industrial water supply, and the disposal of purified wastewater. Population growth, urbanization, industrialization, and the related felling of forests, draining of wetlands, construction of irrigation systems and river dikes, as well as the advent of modern agriculture based on chemicals and the development of transportation and communication systems, have inevitably affected the natural processes and characteristics of the Danube basin. At present the river basin, which hosts about 83 million inhabitants and 60 large cities, is growing at an estimated rate of 0.5%. Currently 67% of the basin constitutes cropland, 11% makes up developed land, 20% is covered by forests, whereas 18% of the basin is classified as eroded (Revenga, Murray, and Hammonds, 1998). The fact that at present forests in the basin constitute only 37% of the original forest cover (Revenga, Murray, and Hammonds, 1998) is in line with forest management trends in Europe, where, according to the "Global Forest Resources Assessment 2000" (FAO, 2001), only 5% of the forests, the smallest proportion in the world, are protected, and those are predominantly located on poor soils in inaccessible mountainous areas, as noted in a World Wildlife Fund report (Hakka and Lappalainen, 2001).

Waterworks, directly modifying the physical environment of the Danube, were initially carried out with the primary purpose of flood control. Later, flood control measures were combined with training of the river for the extension of navigation and for hydropower generation. The former has been carried out largely within the framework of the Danube Convention regulating the regime of navigation, which was signed by the Danubian states in Belgrade in 1948 and came into force in 1964. The earliest predecessor of the Convention was the 1856 Danube Convention, which established, in the aftermath of the Crimean War, the first international regime for safeguarding free navigation on the Danube. According to the 1948 Convention, the implementation of which has been supervised by the Danube Commission established for that purpose, the signatories "undertake to maintain their sections of the Danube in a navigable condition for river-going, and, on the appropriate sections, for sea-going vessels and to carry out the works necessary for the maintenance and improvement of navigation conditions and not to obstruct or hinder navigation on the navigable channels of the Danube" (Danube Commission, 2003). The Commission holds annual meetings and extraordinary sessions if necessary. Its tasks and activities, which are carried out in accordance with European Union regulations and in close cooperation with numerous international organizations, involve regular consultations with the member states on economic, technical, and legal issues (among others); coordination of hydrometeorological services and publication of hydrological forecasts for the Danube; establishment of uniform

systems of navigation regulations; and conducting relevant studies. The results of these activities are reflected in the rapid expansion of navigation on the Danube during the past fifty years.

Between 1950 and 1980, according to a report by the Secretariat of the United Nations Commission for Europe (1994), a total of 69 dams, with a total volume exceeding 7,300 million m^3 (IWAC, 2002), and a number of more complex waterworks were constructed on the Danube (fig. 2). The volume of goods carried on the Danube increased 13.3 times since 1950, reaching 91.8 million tons in 1987 (Danube Commission, 2003). Similarly, the volume of goods handled in ports on the Danube increased 11.2 times after 1950, reaching 152.8 million tons in 1986. Since the opening of the Rhine-Main-Danube waterway in 1992, the river has become an artery for the continent, connecting hundreds of inland ports from the North Sea to the Black Sea. The waterway, built over in the past thirty years, accommodates huge Euro-barges carrying up to 2,425 tons of bulk cargo, the equivalent of the amount of cargo in 78 truck trailers, and carries some 6 million passengers annually (Bryson, 1992). Traffic along the Danube, which is registered as an international corridor for transportation, was restricted only during the period of strong Nazi influence in the region between the 1930s and 1940s and at the beginning of the 1990s, because of the economic transformations in the central and eastern European countries and the UN Security Council sanctions against the Federal Republic of Yugoslavia.

In addition to navigation, the Danube has been intensively utilized for hydroelectric power generation. The hydroelectric capacity of the Danube was developed mainly during the second half of the twentieth century. According to Mucha (1999), between 1956 and 1997 some 28 hydroelectric power projects were completed in the German sector of the river and about 10 hydroelectric power plants with navigation locks were put into operation on the Austrian side.

The development of the water resources of the Danube inevitably resulted in changes in the hydromorphology and water quality of the river. According to a report by the International Water Assessment Center (IWAC, 2002), the construction of reservoirs on the Danube caused a drastic decrease in the riverbed and in the transportation of suspended bed-load sediment. Furthermore, the flow regime of the river drastically changed. From 1981 through 1995, mean annual discharges progressively and cumulatively decreased along the river, compared to those of the preceding period (1951–1980). Over the period 1982–1993, for example, stream flow volume in Bulgaria, one of the riparian states located lowest downstream, decreased by 19% to 42%, compared with the period 1935–1974.

In addition, serious deterioration of the river's water quality has been

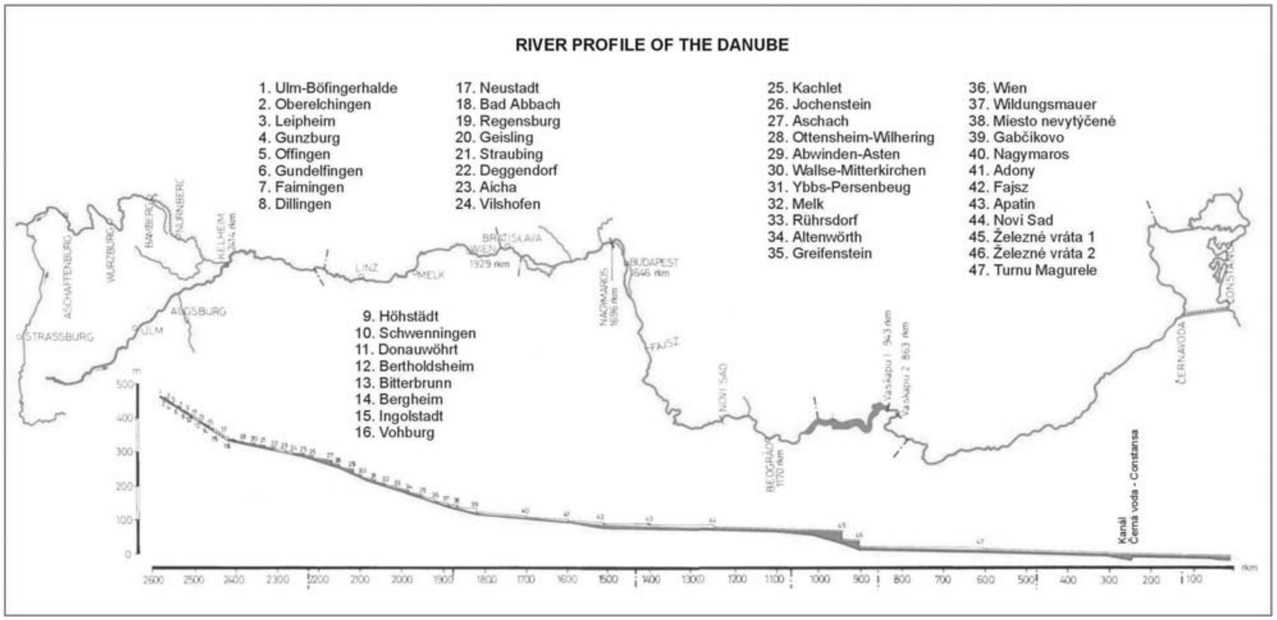

Figure 2 Danube river profile: Dams along the river
[Source: Plenipotentiary of the Slovak Republic for the Construction and Operation of the Gabčíkovo-Nagymaros Hydropower Scheme

recorded over the last twenty years. Monthly mean water temperature of the river has increased by 0.8 C as a result of human activities along its banks, thus affecting the chemical and biological characteristics of Danube water (IWAC, 2002). Reports and studies conducted by the United Nations Economic Commission for Europe (UNECE) (1994), the European Environment Agency (EEA) (Kristensen and Hansen, 1994), and the Environmental Programme for the Danube River Basin (EPDRB) (Somlyódy et al., 1997) point out the high levels of organic pollutants, bacteria, gamma-hexachlorocyclohexane, and cadmium as significant examples of the degraded water quality of Europe's largest international river. Rising nutrient and pesticide loads have resulted in increasing eutrophication (depletion of dissolved oxygen) in the Danube, as well as in the Black Sea into which it flows. The four- to five-fold increase of nitrates recorded over the past thirty years is also reported to have led to a serious contamination of groundwater, posing a threat to the drinking water supply in certain regions. In addition, pollutants in sediments trapped in reservoirs and in reaches downstream from industrial concentrations have been pointed out as causes for concern. Although the situation differs in different parts of the river, deteriorated water quality and lack of oxygen threaten the biodiversity of the Danube basin, which provides a habitat for more than 100 species of fish from the total of 227 found in Europe, as well as the biodiversity of the Black Sea, where the associated decline of the recreational value of the basin has resulted in the impoverishment of the coastal populace. Estimates of the economic costs of water quality degradation in central and eastern Europe (CEE) alone point to a reduction of 5% to 10% of the gross domestic product, according to a consultative report on water issues in CEE (GWP, 2000). The water quality problems of the Danube are attributed to governments' limited consideration of the complex interrelationships and developments among people, water, land, and the environment in the processes of planning and executing many water resource development projects on the international river (Jansky, 2001).

The increasing anthropogenic stress on the physical environment of the Danube River basin and the public pressure to deal with it resulted in the development of a growing number of projects and activities aiming at controlling and mitigating the human impact on the environment in the region (Regional Environmental Center for Central and Eastern Europe, 2003). Those activities have been recently integrated under the legal framework of the Danube River Protection Convention (DRPC), which was signed in June 1994 in Sofia by eleven of the thirteen riparian states and came into force in October 1998, following ratification by the majority of the signatories (ICPDR, 2003). The Convention, the history of which dates back to the 1985 Bucharest Declaration for the Protection of

the Danube River, is implemented by the International Commission for the Protection of the Danube River (ICPDR), which coordinates a set of related activities within its expert groups on River Basin Management, Emissions, Ecology, Monitoring, Laboratory, and Information Management. A large number of the activities were initiated under the framework of the Danube Pollution Reduction Programme (UNDP/GEF, 1999) and have been supported by relevant activities of the NATO Science Programme (Murphy, 1997), the Accident Emergency Prevention and Warning System for the automatic monitoring of transboundary water quality (Gilyén-Hofer and Pintér, 2002), and other regional and international initiatives. A "Joint Action Programme for the Danube River Basin: January 2001–December 2005" defines the goals and focus of ICPDR activities (ICPDR, 2000). Complementary to and integrated within them is the UNDP/GEF Danube Regional Project (DRP), an initiative with the aim of contributing to the long-term sustainable development of the Danube River basin and the Black Sea area by supporting a regional approach to the development of relevant national policies and the definition of priority actions.

At the same time, GEF, UNDP, and the World Bank have undertaken the cofunding of a Strategic Partnership for the Danube and the Black Sea Basin, which aims to help countries address top priorities, thus complementing actions funded by the European Union (GEF, 2002). The activities of the International Commission for the Protection of the Danube and of the related partnerships and initiatives are based on the principles of Integrated Water Resources Management (IWRM) and Integrated River Basin Management (IRBM) ("EU Water Framework Directive," 2000). IWRM refers to the coordinated development and sequencing of water-, land-, and other-related resource management activities that will optimize the social and economic well-being of all stakeholders in an equitable manner without compromising the sustainability of the ecosystem. IRBM recognizes the interdependence of human and natural factors within a catchment and requires that river basins be treated as units of analysis and management. These principles constitute the basis of the strategy for the "Vision to Action" plan for water resources management in central and eastern Europe in the twenty-first century, which was presented at the Second World Forum and the Ministerial Conference at The Hague in March 2000 (GWP, 2000). These strides towards the development of integrated management of the Danube basin coincide with the "EU Water Framework Directive" (2000), which aims at sustainable development within the European Union, and with the closely related initiatives for Pan-European biodiversity ("Pan-European Biological and Landscape Diversity and Strategy," 2002) and soil monitoring (Huber et al., 2001), as well as with more regional initiatives,

such as the ‘‘Multifunctional Integrated Study Danube: Corridor and Catchment,’’ which aims to assess the principal habitat parameters in the main channel of the river, in the floodplain waters, and in the Danube tributaries (Janauer, 2002, October).

However, developments toward a sustainable management of the Danube basin began only recently, in response to the negative impacts of earlier water management practices. The Gabčíkovo-Nagymaros system of locks on the Danube itself was initiated partly as a response to the environmental changes in the middle Danubian basin that had resulted from earlier water regulation works upstream and in the middle Danube. Signed in 1977, however (i.e., before the rise of the ideas for integrated and sustainable river basin management), the GNP itself was conceived and developed in line with earlier water regulation works for flood control and navigation improvement practices and hydroelectric power constructions along the river.

Physical characteristics of the middle Danube

The original Gabčíkovo-Nagymaros project covers the approximately two hundred kilometers of the Danube River that serve as a border between Hungary and Slovakia and that connect the capitals of the two countries, Budapest and Bratislava. The geographical scope and location of the project are related to the geological structure and characteristics of the region. The granite threshold connecting the Alps and the Carpathians in the area of Bratislava and the similar, predominantly andesite, hard-rock river threshold situated at Nagymaros (between the cities of Štúrovo-Estergom and Visegrád-Nagymaros), about 160 kilometers downstream from Bratislava, constitute the geological boundaries of the Danubian aquifer in the middle Danubian basin and serve as natural hydrological barriers damming the Danube bottom (see fig. 3). These characteristics have been pointed out as important for making decisions regarding water regulation works in the Gabčíkovo-Nagymaros section of the Danube.

Late Tertiary sediments (marine and lacustrine sand, fine sand, clay, sandstone, shale) and Quaternary sediments (Danube River sand and gravel settled in fluvial or lacustrine conditions), with a total depth of 8,000 meters, form a highly permeable gravel-and-sand aquifer that ranges from a few meters at Bratislava to more than 450 meters at Gabčíkovo, thinning to several meters downstream of Sap, in the direction of Komárno (Mucha, 1999). Beneath this aquifer is a system of substantially less permeable aquifers and aquitards.

Such threshold and aquifer structures are usually associated with meandering rivers and river arm systems, high water-flow velocities, and

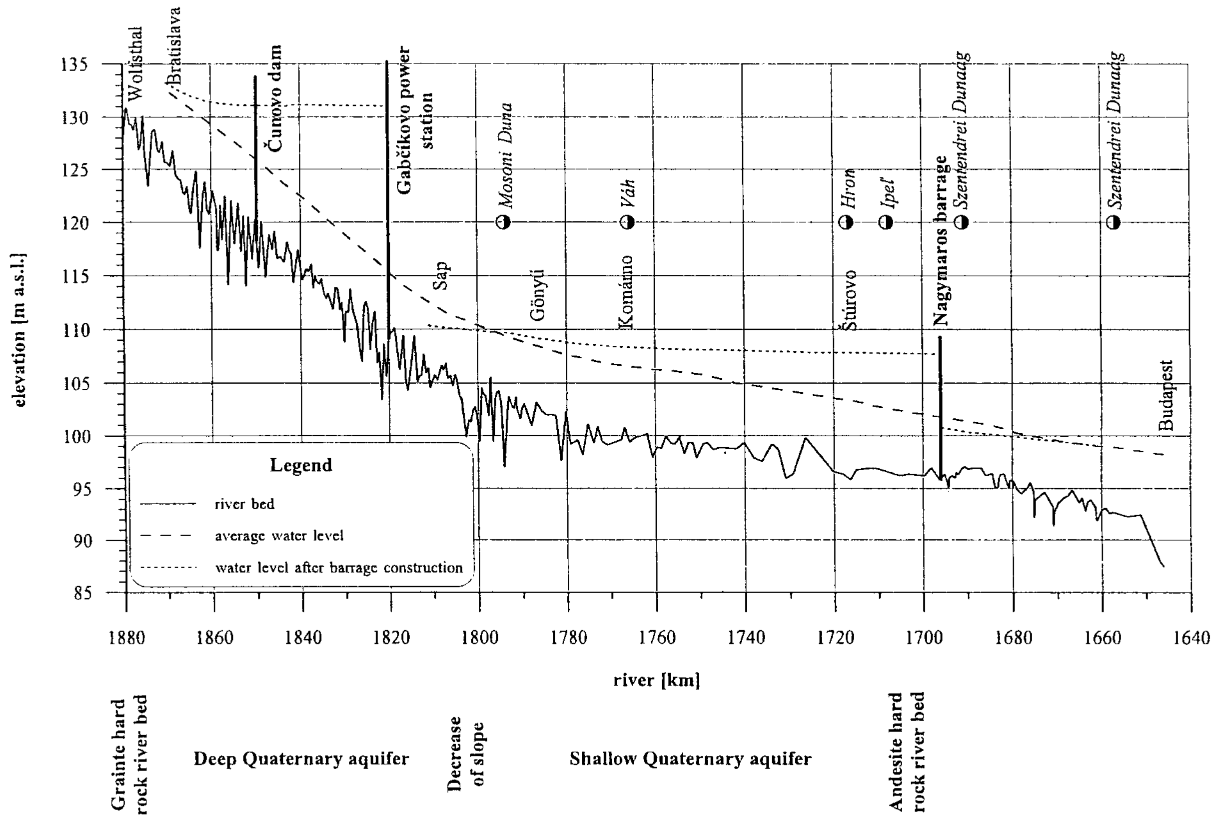

Figure 3 Longitudinal cross section of the middle Danube
[Source: GROUND WATER Consulting Ltd, Bratislava, Slovakia]

lower navigation water depth, as well as higher erosion downstream of the thresholds and serious flooding. Indeed, according to a report of the Nominated Monitoring Agent of the Slovak Republic (NMASR) (2001), before the eighteenth century, the two arms of the Danube into which the river splits downstream from Bratislava, the Malý Danube in Slovakia and the Mosoni Danube in Hungary, constituted meandering systems of shifting channels that created two similar large islands in the two countries, "Žitný ostrov" (Rye Island, in English atlases) and "Szigetköz," and a number of small ones, as a result of progressive sedimentation where the Danube entered into the plain. Downstream from Bratislava, the river was characterized by high-flow velocity and relative shallowness. In addition, seasonal variability was accompanied by serious floods, such as the ones recorded in 1445, 1501, 1721, 1787, 1876, and 1884. These characteristics of and events along the Gabčíkovo-Nagymaros section of the Danube gave rise to the need for flood control regulations and works for improving navigation in that section of the river during those earlier years.

History of regulation works in the middle reaches of the Danube

According to Fitzmaurice (1996), flood control in the middle section of the Danube dates back to the thirteenth century. The earliest dikes were constructed in 1426; systematic flood protection measures were instituted in the seventeenth century; and river controls, drainage channels, and pumping stations were added at an increasing rate after 1850.

Regulations for navigation and hydroelectric power generation in the middle reaches of the Danube started only in the nineteenth century, because they were technically, politically, and economically more demanding. Initial proposals for channeling the middle Danube date back to the reign of the Emperor Charlemagne, and the dream for the construction of a navigable waterway connecting the rivers Rhine, Main, the Danube, and thus the North Sea and the Black Sea, which was finally realized on 25 September 1992. Concrete construction and regulation plans were considered by the Austro-Hungarian monarchy as early as 1880 (Lejon, 1996). The earliest plans, elaborated by Pal Vasarhelyi, were modified by the Italian engineer Ennio Lafranconi, as the strategic importance of the Bratislava harbor for the Habsburg Empire increased. Construction works, undertaken by a Swiss firm and led by Dr. Fischer-Reinan, were completed in 1915. Lafranconi's works were primarily concerned with the training of the riverbed in order to improve the navigation conditions for big steamships in the Bratislava region.

Together with regulations for navigation, Lafranconi also proposed the construction of a hydroelectric power plant on the Danube. Proposals for

harnessing the middle section of the river for hydroelectric power were also made by Dr. Fischer-Reinan in 1915, by Dr. Holecek in 1921, and by others. In 1918 a Swiss firm acquired the rights to exploit the section of the river between Bratislava and Györ for electricity production. In 1919 the Hungarian Republic elaborated a plan for electrification, according to which one third of the production of electricity would have originated from hydroelectric power generation from the middle Danube. Political and economic turmoil, border and population shifts, and changing usage rights in the period during and between the two world wars hindered the further development and implementation of regulation projects in the middle Danube. However, increased flooding and the deterioration of navigation resulting from earlier regulation works on the river brought the issue back to the forefront following the political and economic stabilization in the region after World War II.

Physical impacts of early regulation works

The regulation works for improving navigation that started in the nineteenth century transformed the once meandering river system connecting Bratislava and Budapest into a straightened and heavily fortified channel characterized by rapid water level fluctuations, larger stream velocities, steeper and higher flood peaks, and shorter but more frequent floods. Dam constructions in the upper reaches of the river, preventing the movement of sand and gravel, resulted in increased flow velocity and erosion of the river bottom below Bratislava. The deepening of the water bed led to a sinking of the groundwater table and the drying up of wetlands. It also aggravated navigation conditions in the region, known for being almost as bad as those in the notorious Iron Gate section of the river.

The changed sedimentation because of dam construction upstream of the andesite hard-rock threshold at Nagymaros led to lowered permeability and aquifer thickness downstream from Gabčíkovo. As a result, the groundwater carried through the Danubian lowland by the alluvial fan or inland delta on the Slovakian side, which is characterized by coarse sediment accumulation, erosion, and changes in the riverbed gradient, began to flow back into the Danube through river arms, tributaries, and drainage canals in the lower parts of the river, which are characterized by a drastic decrease in slope.

In addition, the cutting off of the meanderings and numerous smaller side branches and tributaries because of the construction of a main canal resulted in a decline in the groundwater levels in the side-arm area and in the drying out of a part of the wetland woods behind the protective dikes. The large number of weirs and dams activated at higher discharges formed a cascade system at low discharges.

These changes gave rise to floods which were shorter in duration but

more frequent and devastating. Before the development of regulation works on the Danube, serious floods were recorded only once or twice a century. But their number more than doubled during the twentieth century, as indicated by historical records listing serious floods in 1929, 1947, 1954, 1963, and 1965. The 1954 and 1965 floods were particularly devastating. In 1954, the flood broke the dikes at four points on the Hungarian side in the Szigetköz region, and water completely or partially flooded an area of some 33,000 hectares. During the flood of 1965, the dikes broke on the Czechoslovakian side at two places, near the villages Patince and Čičov. Some 114,000 hectares were flooded completely, and at least 3,500 buildings were completely destroyed (Nominated Monitoring Agent of the Slovak Republic, 2001). About 65,000 people had to be evacuated from the affected areas. The flow at Bratislava during the flood reached 9,170 m^3/s (Lejon, 1996). While Slovakia was most seriously affected by the 1965 flood, parts of Austria, Hungary, and Yugoslavia also suffered heavy damages.

The response to the deteriorated navigation conditions and to the increase in floods in the middle section of the Danube was shaped by the parallel socioeconomic and political transformations taking place in Hungary and Czechoslovakia.

Geopolitical setting

The nature and timing of the response to the water management needs in the middle section of the Danube have been determined by the geopolitical location of the region and the politico-economic interests and priorities of its inhabitants.

Situated in the heart of Europe, along the borderlines of warring empires, political blocs, and ethnic groups, the middle Danubian basin has long been a battlefield of the geopolitical struggles for domination over the region. The centuries of Roman, Ottoman, Habsburg, and Soviet rule have shaped the conflicting national identities, political priorities, and economic interests of the Magyars (Hungarians), Slovaks, Germans, Czechs, Croats, and Serbs living there, but they have done so within the common geopolitical history of east-central Europe, which has led to the development of common traits and cultural bonds among them (Avenarius, 2000). Those contradictory interlinkages and levels of interaction among Hungarians, Slovaks, and Czechs determined the complexity of the Gabčíkovo-Nagymaros project for the management of the shared water resources of the middle Danube.

Hungarian national identity was formed in the struggle for independence from the Habsburgs that had subjugated the Kingdom of Hungary

and relegated it to the status of a colony from 1526 to 1867, when a dual Austro-Hungarian monarchy was formed. At the same time, Hungarian domination over Slovakia, among other Slav territories, since A.D. 907, gave rise to Slav nationalism, which ultimately sparked the flame of the First World War that engulfed the whole of Europe and led to the collapse of the Austro-Hungarian monarchy and the redrawing of the map of Central Europe.

The 1920 Treaty of Trianon, which endorsed the establishment of Czechoslovakia and Yugoslavia and the expansion of Romania and Ukraine at the expense of Hungary after the end of World War 1, gave rise to new sources of resentment and conflict within and among the Danubian states that have hindered the joint management of the shared water resources of the middle Danube. As a result of the treaty, Hungary lost two-thirds of its pre-1920 territory, two-thirds of its total population, one-third of its Hungarian population, and 94.5% of its hydroelectric potential (Fitzmaurice, 1996). Meanwhile, the political union between the Czechs and the Slovaks began an uneasy political partnership that affected the historical development of the Gabčíkovo-Nagymaros project.

Political turmoil in Europe in the first half of the twentieth century, particularly in the Central European Danubian basin, prevented the undertaking of joint water management projects. The transition period during and between the two world wars, involving frequent transfers of political control over the Danubian lands between Hungary and Czechoslovakia, brought about conflicting political claims on the shared water resources (Lipschutz, 2000). However, the political unification of the region under Socialist rule provided the political basis and the economic stimulus for joint water management between Hungary and Czechoslovakia, as well as the social impetus for cooperation facilitated by the long history of the coexistence of Hungarians and Slovaks under the Habsburg rulers and later the Austro-Hungarian monarchy.

Joint planning between the two countries for the modification of the middle reaches of the Danube began in the 1950s with a proposal by the Hungarian Academy of Sciences. It received the approval of the Council for Mutual Economic Cooperation (COMECON) among the Socialist states in the early 1960s. However, domestic developments in the two countries, namely, political turmoil followed by changing economic orientation and objectives in Hungary and internal struggles over the diverging interests of Czechs and Slovaks in Czechoslovakia, did not allow for reaching on agreement on the project until 1977 (Fitzmaurice, 1996). The change of the domestic leadership in the two countries, combined with external factors, such as the devastating floods mentioned above and the sharp increase in world oil prices in the 1970s, brought about the consensus necessary for finalizing the planning stage of the project.

Technical characteristics

The 1977 Treaty (see Appendix No. 1) sets the general framework and the key elements of the project, leaving a number of issues and details to be determined by joint agreements and jointly agreed operating procedures coordinated by government delegates. It postulates joint financing of the investment, joint ownership of the project, and equal benefits from the generated energy.

The Gabčíkovo-Nagymaros part, as originally designed, was to utilize a 205-kilometer stretch of the Danube between river kilometers 1860 and 1655. The Gabčíkovo part was to make use of a declivity of 21 meters for 69 kilometers, while the Nagymaros part was supposed to take up a 7-meter declivity for 136 kilometers.

The main structures of the Gabčíkovo-Nagymaros system of locks agreed on in the Treaty include the following (see fig. 4):

Gabčíkovo part *(upper part of the system – fig. 5)*

Main Reservoir (Hrušov-Dunakiliti)

Total volume: 243 million m^3

Useful volume: 60 million m^3

Dunakiliti Weir *(for damming the Danube River at the rkm 1842 in the territory of Hungary; constructed but not in operation)*

Width: 7 × 24 m; with one weir serving as navigation lock (24 × 125 m)

Water discharge into old Danube – 200 m^3/s in summer; 50 m^3/s in winter

Diversion Canal (continuation of the reservoir to the power plant)

Length: 17 km; width: variable 267–737 m; depth: 17.8 m

Hydroelectric Power Station

Installed capacity: 720 MW (8 vertical Kaplan turbines, max. 90 MW)

Navigation Locks

Two twin locks: length: 275 m, width: 34 m

Outlet Canal

Length: 8.2 km; width: 185 m; depth: 12.8 m

Nagymaros part *(lower part of the system as originally designed)*

Reservoir

Total volume: 170 million m^3

Useful volume: 25 million m^3

Weir

Width: 7 × 24 m

Hydroelectric Power Station

Installed capacity: 157.8 MW (6 bulb turbines)

Navigation Locks

Two twin locks: length: 275 m, width: 34 m

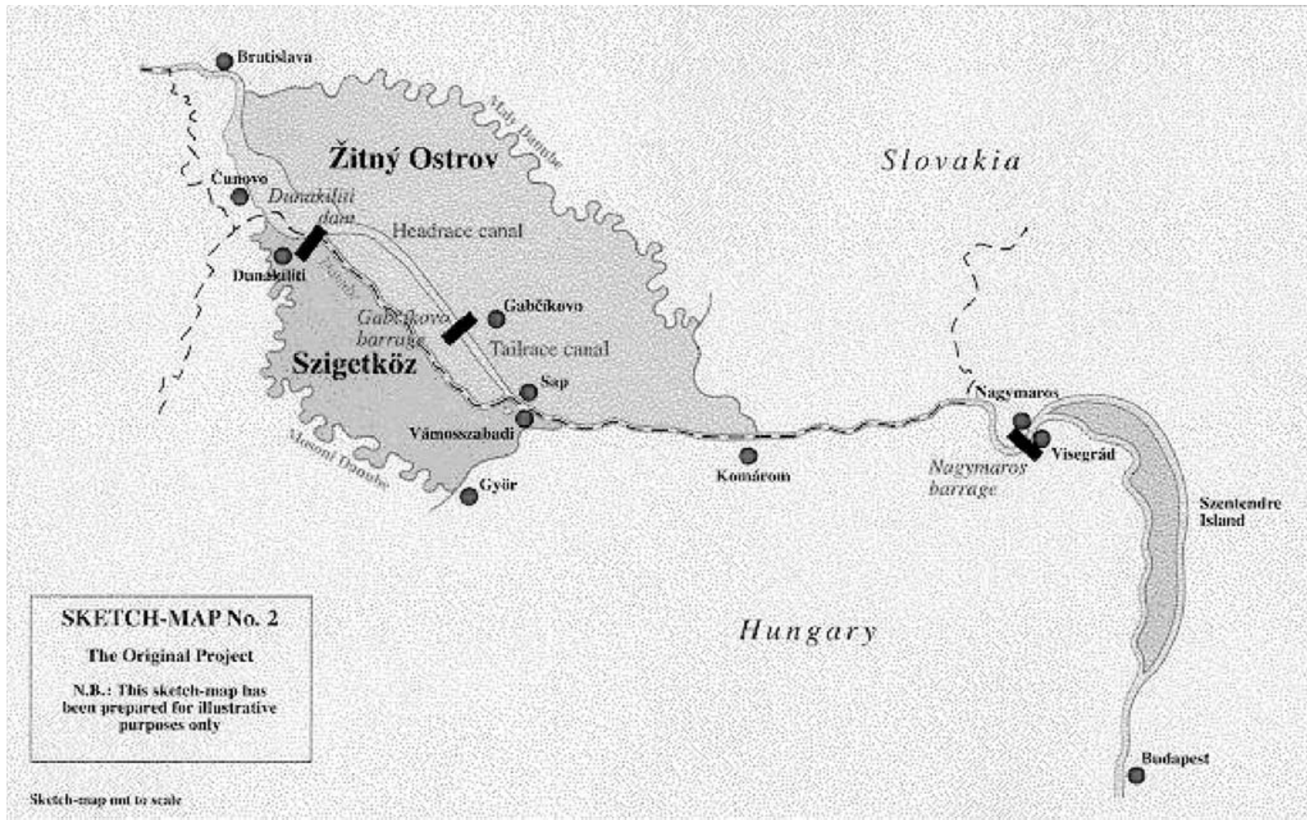

Figure 4 The Gabčíkovo-Nagymaros system of locks as originally designed
[Source: ICJ]

The original project also involved a number of other river regulation and protective measures, including reconstruction of existing flood control dikes, sealing aprons, seepage canals, drains, and pumping stations.

According to the Treaty, the upper part of the project, Gabčíkovo (including the weir and reservoir at Dunakiliti, the power canal, and the hydropower station) was originally to be completed by 1986, and the Nagymaros part by the end of 1989. Construction started in 1978 and continued at a slower rate on the Hungarian side than on the Slovakian side because of mounting environmental concerns and financial constraints in the context of growing pressure for political and economic transformations in the country. These concerns and constraints led to the postponement of the completion date of the Nagymaros part of the project and ultimately to the cancellation of the project and the dismantling of construction works on the Hungarian side. Hungary officially abandoned the project in 1989 and unilaterally denounced the 1977 Treaty in 1992. The latter action was a response to the Slovak Republic's unilateral development and subsequent construction and putting into operation of a alternative water regulation measures known as Variant C. Variant C involved the damming of the Danube, which was completed between 24 and 27 October 1992, and the construction of a central weir, auxiliary navigation locks, and a hydropower plant at Čunovo on the territory of the Slovak Republic – constructions which were completed subsequently (Abaffy, Lukáč, and Liška, 1995). Variant C was designed as a temporary measure to allow the operation of the Gabčíkovo part of the project in the absence of the Dunakiliti weir, which, though constructed, had not been put into operation because of Hungary's abandonment of the GNP. The parameters of the Variant C structures are given below:

"Variant C" at Čunovo, rkm 1851.75
(a temporary measure on the territory of Slovakia)

Dividing Dam along the Left Danube Bank
Length: 10.85 km, crest width: 6 m
Bypass Weir
Number of gates: 4; crest length: 85 m; width: 8.5 m
Capacity at flood event: 1,200 m^3/s
Maximum discharge at nonfilled channel: 1,600 m^3/s
Damming of the Danube Channel
Length: 380 m; crest width: 46 m
Central Weir
Length: 120 m; gate width: 24 m
Auxiliary Navigation Lock
Length: 50–125 m, depth: 23 m
Discharge capacity: 3,300 m^3/s

Hydropower Plant (4 turbogenerators)
Installed capacity: 24.2 MW
Inundation Weir (with 20 gates)
Length: 580 m; crest width: 7 m; gate width: 24 m
Weir capacity: 6,000 m^3/s
Outlet Structures into the Mosoni Danube:
Installed hydropower plant capacity (2 turbines): 1 MW
Capacity (at full reservoir): 25.6 m^3/s

Environmental Impacts of GNP: Conflicting claims

The claims regarding the environmental implications of the project, which were used as a justification by Hungary for denouncing the 1977 Treaty for the joint construction and operation of the system of locks on the Danube, encompass a large range of actual and potential problems. The environmental debate over the GNP has been presented as one between growth-oriented modernism and conservation-minded post-modernism. Arguments range from broad, philosophical, and subjective claims regarding human interference in nature, as well as the cultural role of the Danube, to more specific claims, open to objective verification, about matters related to surface water and groundwater quantity and quality, agriculture, fisheries in the area of the construction, and the safety of the construction itself.

Opponents of the project, such as the Danube Circle in Hungary (which originally raised the issue of the environmental impacts of the project), the World Wildlife Fund, and other NGOs, IOs, and governmental institutions, emphasized, as major arguments in the environmental debate, the reduction of water levels in the side arms and the drying out of the wetlands along the GNP-affected section of the Danube – wetlands imbued with cultural and biodiversity value. In addition, it was argued that the construction of the system of locks posed a threat to the surface water and groundwater levels and quality in and around the main channel and thus to drinking water supplies for Budapest. The potential threat of the slower water flow to the oxygen regime of the river and, in particular, the danger of eutrophication and thus the destruction of the river's biological filtration capacity were also raised as concerns. Finally, some critics questioned the safety of the project, claiming it could bring floods to Budapest.

On the other hand, proponents of the project argued that it was in fact environmentally friendly, since it was expected to reduce the pollution caused by the use of 3.9 million tonnes of brown coal or 1.4 million tonnes of oil, annually (Fitzmaurice, 1996). They pointed out that minor

technical solutions in the Danube's old riverbed could easily resolve the problems of maintaining the inland Danube delta with its forests and wetlands, if the solutions were accepted by the parties (Lejon, 1996). Furthermore, they argued that the impounding of water would stop the erosion of the bed and thus prevent the decline of the groundwater. They also pointed out that impoundment would feed the deeper aquifers and secure a steady supply of water to the Mosoni Danube. They admitted the threat of pollutants entering the water supply but dismissed it as theoretical and easily resolvable with the help of the advanced purification technologies available in both countries. They pointed out that the possible transfer of traffic from more polluting sources to river transportation was environmentally beneficial as well.

According to Fitzmaurice (1996), over 400 studies of the potential environmental impacts of the project were carried out before the signing of the Treaty and many more after that. Some of those were developed and elaborated within the framework of the Bioproject, initiated in 1976 and supplemented in 1982 and 1986 (Kocinger, 1998). On the basis of those studies, the 1977 Treaty included three paragraphs dealing with the protection of the quality and quantity of surface water and groundwater, the protection of the environment, and the protection of fish (Kocinger, 1998). Different interpretations of those paragraphs, however, allowed for the escalation and politicization of the dispute over the environmental impacts of the GNP.

While the judgment of the International Court of Justice settled the legal aspects of the debate, it left the technical questions for the two countries to agree upon. A basis for the ongoing negotiations on the issue has been the accumulated data from the joint monitoring of the environmental impact of the Gabčíkovo part of the GNP. The monitoring was established by the two countries in 1995 as an obligation under an Agreement (Appendix No. 3) signed by the governments of the republics of Hungary and Slovakia. The agreement concerns certain technical measures aimed at addressing the most critical negative impacts of the damming of the river on the environment in the middle Danubian plain. The somewhat paradoxical political agreement laying the basis for cooperation between relevant scientific communities of the two countries could be seen as motivated by the need for Hungary and Slovakia to find a peaceful solution to the GNP dispute in view of their EU membership aspirations and the favorable changes in the domestic balance of power in the two countries at the time. A preexisting technical basis, as well as a history of cooperation between the two countries in monitoring different elements of the environment in the affected areas of the Danubian basin, facilitated the establishment of the joint monitoring. Nevertheless, it has proved a demanding task.

4

Environmental monitoring of an international river

Environmental monitoring is a term applied to a range of disparate activities aiming at obtaining and providing information about the state of the environment. The UN Inter-Agency Working Group on Monitoring, which led to the development of the UN Global Environmental Monitoring System (GEMS) in 1974, defined monitoring broadly as "a system of continued observation, measurement and evaluation for defined purposes" (Munn, 1973). Later definitions have narrowed the scope of the term to a type of intermittent (regular or irregular) surveillance of either one or more environmental indicators carried out for the purpose of ascertaining the extent of compliance with a predetermined standard or the degree of deviation from an expected norm, according to prearranged schedules in space and time, and using comparable methodologies for environmental sensing and data collection (Goldsmith, 1991; Munn, 1973).

Principles of environmental monitoring

Environmental monitoring is an integral component of resource management. Therefore, it should be seen as a process, starting with a definition of policy-relevant information needs, which are then used to design a monitoring strategy and develop a network. The next step in the process is data collection and processing, followed by data analysis and reporting (Helmer, 1997). Since information needs evolve with time and socioeconomic developments, periodic adjustments of monitoring programmes are essential for their optimization.

The objectives of monitoring programmes are broadly classified as follows (Goldsmith, 1991):

- detecting incipient change (early warning);
- assessing the effectiveness of policy or legislation;
- testing compliance with regulatory measures.

A properly designed and implemented monitoring programme can result in the identification of harmful trends, the correction of unanticipated impacts, and/or the resolution of controversies over resource management through the provision of data useful for mediation between interested parties (Glasson, Therivel, and Chadwick, 1999).

Research on environmental monitoring shows that, it has been most widely utilized as a tool for conflict resolution in a national context. A study conducted in Australia by Beckley in 1991 found that environmental monitoring data and testable predictions were available for only 3% of the 1,000 environmental impact statements examined and that those 3% were mainly related to ‘‘large complex projects, which had often been the subject of public controversy, and whose monitoring was aimed primarily at testing compliance with standards rather than with impact predictions’’ (Glasson, Therivel, and Chadwick, 1999).

From an issue-specific perspective, environmental monitoring covers a range of topics. According to a research study conducted at Oxford Brookes University, which examined a sample of 700 environmental-impact statements, water quality (16%) seems to be the problem most commonly addressed by monitoring programmes, followed by air emissions and aqueous emissions (Glasson, Therivel, and Chadwick, 1999).

The particular focus on the monitoring of international water quality during the past two decades, as exemplified by the monitoring networks on the Rhine (in Europe), la Plata (in South America), and the Mekong (in Southeast Asia), is in line with the above-mentioned trends, although the level of complexity and accuracy of the different monitoring networks varies. The large percentage of the world’s population (40%) dependent for their water security on effective international water management, the high potential for and the significant costs associated with political conflicts over transboundary river water quantity and quality (especially for downstream countries in arid and semiarid areas), and catastrophic accidents on transboundary rivers (e.g., the Sandoz accident on the Rhine) have served as justifiable stimuli for undertaking the establishment of complex and, under normal circumstances, costly environmental monitoring programmes (Ministry of Foreign Affairs of Sweden, 2001; Helmer, 1997).

The design and the implementation of transboundary and international water monitoring programmes follow the above-mentioned general monitoring cycle. Unlike national programmes, however, international monitoring schemes need to be undertaken in ‘‘a highly integrated manner,

based on commonly agreed objectives, criteria and standards related to different types of water uses as well as ecological requirements'' (Helmer, 1997). Transboundary water monitoring strategies also correspond to the three major types of monitoring objectives mentioned above. Helmer (1997) summarizes them as follows:

- ambient river water quality monitoring to observe the status and trend of aspects such as the flow regime, sediment transport, ecological habitats, natural water constituents, and finally, any anthropogenic influences and pollutants;
- early warning systems in rivers which are potentially threatened by industrial accidents or unintentional release of toxic effluents which may cause the closure of downstream waters' intakers (as happened in the Rhine river); and
- effluent monitoring of wastewater discharges which have been authorized under certain conditions in a permit or license issued by the national regulatory agency.

Important points to be considered in the design of the monitoring network and the sampling method are the location of the monitoring stations and the sampling frequency and intensity. In view of the regulatory function of monitoring, stations should be located at or near the border crossings and at major point sources and tributaries. In order for the samples to be representative, the temporal and spatial variability of water quality in the river system and the particular objectives of the monitoring programme should be taken into account (Goldsmith, 1991).

The selection of the concrete variables to be monitored should be based upon the specific information needs of the programme, the intended water uses, the river functions, the existing and potential water quality issues and threats, as well as the financial, technological, scientific, and human-resource limitations of the individual programmes. Examples of water quality and quantity problems as related to different river functions and a list of indicators related to specific water quality issues are given in Tables 1 and 2 in Helmer (1997).

The comparability of data collection and processing procedures needs to be ensured through regular inter- and intralaboratory comparison studies and analytical quality control. Data have to be verified and transformed into policy-relevant information through the use of comparable statistical analysis and reporting of annual and monthly averages, peaks and lows, pollution load calculations, and flux estimates. For reliable trend analysis, one must consider the autocorrelation and the separation of the three main features contributing to the value of each observation, namely, the effects of trends, the effects of cycles, and the residual variation (Goldsmith, 1991). Evaluation of the results should be based on commonly agreed and preselected baselines and criteria, taking into account the long-term and cyclical processes in the environment (Goldsmith, 1991; Nakayama, 1998b).

Given the changing nature of water pollutants (from biodegradable

Table 1 Functions of rivers and related water quantity and quality problems (Helmer 1997 × UNECE 1996)

Functions/Issues	Safety	Ecosystem	Recreation	Drinking water	Irrigation	Industrial use	Hydro-power	Fishery	Navigation
Flooding	x	x	x						x
Scarcity		x	x	x	x	x	x	x	x
Sedimentation/ Erosion	x	x		x			x		x
Quantitative management (1)	x	x	x	x	x	x	x	x	x
Salinisation		x		x	x	x		x	
Acidification (2)		x		x				x	
Organic pollution (3)		x	x	x				x	
Eutrophication		x	x	x	x	x		x	
Pollution with hazardous substances (4)		x	x	x	x			x	

x – main potential pressure on function.
1 – Includes impacts of the management of water resources, a.o. in case of water diversion or improper construction and/or operation of hydropower dams.
2 – Dry/wet deposition, eventually followed by leaching to groundwaters or run-off to surface water.
3 – Organic matter and bacteriological pollution by waste discharge.
4 – Specific substances, e.g., radio-nuclides, heavy metals, pesticides, etc.

Table 2 Indicative variables related to water quality issues (Helmer 1997 × UNECE 1996)

ISSUES	INDICATIVE VARIABLES Phase 1: core set of indicative variables	Phase 2: additions for extended set
Sanitation	Dissolved oxygen, BOD, faecal coliform, faecal streptococcus	COD, TOC, viruses, salmonella
Salinisation	Conductivity	Major ions, Cl
Acidification	Acidity (pH)	Alkalinity
Eutrophication	Dissolved oxygen, nutrients (total nitrogen, total phosphorus), chlorophyll-a	Ammonium, Kjeldahl-nitrogen nitrate, or/ho-phosphate
Pollution with hazardous substances	Floating oil, heavy metals (cadmium, mercury), radioactivity (total a-activity, residual, B-activity, tritium), organochlorine pesticides (EOX, AOX), chlorinated hydrocarbons (VOX), acethylcholinesterase inhibition	Characteristics of oil, other heavy metals of relevance, y-nuclides (Cs-137), Sr-90, Po-210, endosulphan, y-HCH, organo-P-esters atrazine, benzene, pentachlorophenol, organotin, characteristics of sediments: PAHs (Bornef 6) in sediment and/or biota, PCB (indicator 6) in sediment and/or biota

organic wastes to highly sophisticated, synthetic organic compounds), the expanding knowledge about their importance, and the capacity to measure them in view of technical and scientific developments and human- and financial-capital availability, monitoring programmes need to be periodically reviewed, adjusted, and optimized. Such reviews should aim at coping with the major challenges to transboundary water-monitoring programmes, namely (Helmer, 1997):

- limited amount of management-relevant information derived from large data sets;
- high costs of sampling and analysis;
- inadequate comparability of national data with transboundary river basins.

While these challenges are common for environmental monitoring programmes in general, international river monitoring seems to be particularly vulnerable to them because of the complexity associated with the scale of the programmes; cross-border cooperation and coordination, difficulties arising from the often competing interests of the parties involved; the justifiability of higher expenditures in cases of conflicts and in

situations involving international pressure and support for improving water quality; and the larger institutional vested interests favoring the maintenance of the programme after its establishment.

The environmental monitoring of the areas affected by the Gabčíkovo-Nagymaros project presented below illustrates the benefits and complexities associated with the establishment of such programmes.

Joint environmental monitoring of areas affected by the Gabčíkovo Part of the Gabčíkovo-Nagymaros Project

Legal and institutional framework and objectives

The joint environmental monitoring of areas affected by the Gabčíkovo part of the project was established as an obligation under the "Agreement between the Government of the Slovak Republic and the Government of Hungary about Certain Temporary Technical Measures and Discharges in the Danube and Mosoni Branch of the Danube," signed on 19 April 1995 (Appendix No. 3). The Agreement, aiming at addressing some of the negative environmental impacts of the construction and operation of the Gabčíkovo part of the project, had a temporary character. Initially, it was contingent upon the judgment of the International Court of Justice in the case concerning the Gabčíkovo-Nagymaros Project. On 23 October 1997, the Slovak Republic informed the Republic of Hungary of its willingness to prolong the validity of the Agreement from 19 April 1995 to a date when an agreement on the implementation of the ICJ judgment, declared on 25 September 1997, was reached. The Republic of Hungary accepted this proposal by governmental resolution on 17 December 1997 (Joint Annual Report, 2001). Discussions on the issue are currently being carried out by the Working Group on Legal Matters, which is comprised of delegates from the Government of the Slovak Republic and the Government of Hungary and which held its first meeting in Bratislava on 29 October 2001. Although a draft of an agreement to effect the judgment of the International Court of Justice of 25 September 1997 was prepared as early as March 1998 (ICJ, 1998a), negotiations are still continuing according to the minutes of the Working Group, which held its fourth meeting in April 2002, in Budapest (Plenipotentiary of the Slovak Republic, 2003). Input to the negotiations is being provided by the ongoing joint monitoring of the environmental impact of the technical measures implemented in 1995.

The technical measures and the monitoring obligations specified in the 1995 Agreement, include the following (Appendix 3):

- The Slovak Party will increase the discharge of water through the intake structure at Čunovo into the Mosoni branch of the Danube to 43 m^3/s subject to hydrological and technical conditions specified in Annex 1 to this Agreement.
- The discharge into the main riverbed of the Danube below the Čunovo weir will be increased to an annual average of 400 m^3/s, in accordance with the rules of operation contained in Annex 2 to this Agreement.
- There will be a weir partly overflowed by water and constructed by the Hungarian Party in the main riverbed of the Danube, at rkm 1843.... A maximum quantity of 150 m^3/s will be discharged into the right side branch system on the Hungarian side.
- The Parties undertake to exchange those data of their environmental monitoring systems operating in the area that are necessary to assess the impacts of the measures envisaged in Articles 1–3. Collected data will be regularly exchanged and jointly and periodically evaluated with a view to making recommendations to the Parties. The observation sites, parameters observed, periodicity of data exchange, the methodology and periodicity or joint assessment are contained in Annex 5 to this Agreement.

The explicit goals of the joint monitoring as formulated in the Joint Annual Reports (1996–2001) constitute a combination of the general goals of monitoring programmes discussed earlier and the specific political aspects of the GNP case. Thus they can be classified as follows:

- Regulatory – to establish compliance with the technical measures set by the 1995 Agreement;
- Evaluatory – "to observe, record and jointly evaluate quantitative and qualitative changes of surface and groundwater bodies and the water-related natural environment in connection to the realized measure and applied water supply," thus allowing for detection of incipient changes in the environment and evaluation of the environmental impact of the agreed policies;
- Advisory – "to submit joint evaluation of monitoring results and joint recommendations for monitoring improvement and environment protection activities to the respective governments."

The elements included in the joint monitoring of the environment in areas around the Danube influenced by the Gabčíkovo part of the project (fig. 5) are divided into the following groups:

- Surface water and groundwater hydrological regime
- Surface water and groundwater quality
- Soil moisture monitoring
- Biological monitoring
- Forest monitoring

Basic guidelines for the design of the monitoring programme, including determination of the scope of the affected areas, the sampling and measurement points, the monitored parameters, measurement frequencies, and frequency of data exchange are described in the Annexes to the

Agreement. The activities connected with the implementation of the environmental monitoring in the influenced areas follow the Statute on the Activities of the Nominated Monitoring Agents, envisaged in the Agreement and signed in May 1995.

The monitoring on the Slovak side is financed by the state and is based on data collected by the Slovak Hydrometeorological Institute, the Faculty of Natural Sciences of Comenius University, the Slovak Academy of Sciences, the Forest Research Institute, the Soil Science and Conservation Research Institute, West Slovakia's Waterworks and Sewage Enterprise, Waterworks and Sewage Enterprise (Bratislava), the Slovak Water Management Authority, the Water Research Institute, and GROUND WATER Consulting, Ltd. The data exchange and the evaluation of the monitoring under the framework of the joint monitoring are coordinated by the Plenipotentiary of the Government of the Slovak Republic for the Construction and Operation of the Gabčíkovo-Nagymaros Project.

The Ministry of Environmental Protection is financing the monitoring at the Hungarian side. The monitoring and the evaluation are conducted by the North-Trans-Danubian Water Authority, the North-Trans-Danubian Inspectorate for Environment Protection, the Forest Research Institute, Pannon Agricultural University, the Museum of Natural Sciences, the Hungarian Academy of Sciences, and Eötvös Loránd Science University. The data exchange and evaluation are coordinated by the Ministry.

Incorporated in the design of the joint monitoring programme is a mechanism for continuous review and optimization through regular meetings and discussions of relevant issues among specialists in different areas from the two countries. The effectiveness of that mechanism is obvious from the Joint Annual Reports, which, in addition to results from the monitoring, include information on the joint activities related to the optimization of the monitoring programme carried out during the respective year in response to the recommendations from the previous one. In 2002, for example, field trips including experts from both sides were carried out to observe the forest monitoring areas on the Hungarian side and to prepare a new list of observation sites as suggested by the joint report from the preceding year. In 2001 several meetings of biological monitoring experts from the two countries were held, and three different groups of biological communities – phytocoenology, fishes, and phyto- and zooplankton – were chosen for elaboration of joint methodology for long-term evaluation. Some progress with regard to phytocoenology was made; however, agreement on the ecological values of the respective plant species is still to be reached through joint consultations (Joint Annual Report, 2001). In 1999 joint surface water discharge measurements

on selected profiles and joint visits to biological monitoring areas were carried out (Joint Annual Report, 1999).

The outcome of these activities is reflected in the continuous modification of the monitoring network, including replacement, exclusion, and inclusion of new monitoring areas and observation sites aimed at improving the evaluation of the environmental changes on the jointly monitored areas. In 2001, for example, field documentation of new groundwater level observation objects carried out on both the Slovak and the Hungarian sides resulted in the replacement of monitoring points left out from the regular observation network (Joint Annual Report, 2001). In addition, the Hungarian side proposed the inclusion of additional surface water quality monitoring sites in the framework of the joint monitoring programme. Similarly, in 2000, two new monitoring objects for soil moisture observation and two for surface water quality measurement in the old Danube riverbed on the Slovak side became part of the joint evaluation (Joint Annual Report, 2000).

Policy issues related to the elaboration of technical solutions for the implementation of the ICJ judgment based on results from the monitoring are being discussed along with the joint monitoring activities in a Joint Working Group for Water Management, Ecology, Navigation, and Energy, which is comprised of specialists in the respective areas from the two countries. The first meeting of the Working Group was held on 19 November 2001, in Bratislava. The mandate of the Working Group, accepted at the sixth meeting, which was held in Budapest on 23 April 2002, includes the following (Plenipotentiary of the Slovak Republic, 2003):

1) undertaking a dialogue and detailed discussions on water management, ecology, river transport, and energy issues pertaining to the ICJ judgment concerning the GNP project on 25 September 1997;
2) discussing the possibilities of alternative, mainly technical, solutions enabling the implementation of the ICJ judgment, including the following:
   - fulfillment of the main targets of the original 1977 Treaty between Czechoslovakia and Hungary (see Appendix No. 1) to the extent possible in view of the new conditions;
   - incorporation of the factual situation developed since 1989 into the context of the agreement (or contractual relations) for an optimal fulfillment of the purpose of the Treaty from 1977;
   - renewal of the joint regime according to the Treaty of 1977;
   - incorporation of Variant C into the contractual agreement;
   - harmonization of the joint system with international standards for environmental protection and sustainable development through joint examination of the environmental impacts and identification of

a satisfactory solution concerning the water discharge into the old Danube River and the arms on both sides of the river;
- harmonization of the joint management of the Bratislava-Budapest section of the Danube with the requirements of international river legislation and the 1977 Treaty through the identification of technical solutions based on equality of the parties involved and on the optimal use of joint energy resources;

3) preparing a methodology for the joint consideration of individual proposals/solutions in terms of Environmental Impact Assessment (EIA);
4) formulating joint statements for submission to the governmental delegations;
5) identifying the differences in the opinions of the parties in case they fail to reach consensus on a certain issue;
6) ensuring compliance of the discussed solutions with the agreed priority of the part of the Danube between Bratislava and Sap over the part between Sap and Budapest.

Some specific issues related to the management of the Bratislava-Sap section of the Danube include the identification and development of the following:

1) requirements related to flood control and ice flow;
2) targeting environmental conditions and requirements;
3) navigation requirements;
4) energy requirements;
5) joint methodology and implementation of EIA;
6) temporary measures necessary for the period until the implementation of a solution based on EIA results;
7) solutions in response to issues related to the Čunovo and Dunakiliti dams.

The first five points apply to the management of the Sap-Budapest section of the river as well.

The mandate of the Working Group is not a substitute for either the Treaty of 1977 or the ICJ judgment. The suggestions of the Working Group become valid if jointly authorized by both governmental delegations. The decisions of the delegations are informed by the results from the joint environmental monitoring on the GNP–affected areas which united the previously separate decision-support information bases in the two countries.

Technical and scientific information bases for assessment of the environmental impacts of the GNP

A basis for the joint monitoring of the GNP-affected areas was provided by the preexisting monitoring experience in the two states. That included

the measuring of hydrological elements along the Danube initiated for navigation and meteorological purposes, as well as the monitoring of environmental changes on the areas affected by the Gabčíkovo part of the project – monitoring undertaken independently by both Hungary and Slovakia in the late 1980s and early 1990s in response to the escalation of the dispute over the environmental impacts of the GNP.

The development of hydrological monitoring on Hungarian and Slovak territories can be traced back to the eighteenth century, when they were part of a common political unity under the Habsburgs, and to the obligations for hydrological observations of the Danube under the Danube Convention. Tracking the development of the monitoring of environmental elements in the areas affected by the GNP is more complicated.

A predecessor of the joint environmental monitoring on the areas affected by the Gabčíkovo part of the GNP in Slovakia is an environmental monitoring project carried out by the Slovak Academy of Sciences and the Faculty of the Natural Sciences of Commenius University. The groundwater monitoring element of the project was based on earlier research on groundwater on the territory of the Danubian Lowland by the Faculty of Natural Sciences. Building on that research, in 1990 an independent group, GROUND WATER Consulting, was established as an advisory group for the Plenipotentiary of the Government of Slovakia for the Gabčíkovo-Nagymaros Hydropower Scheme (Mucha, 1995). The biota monitoring was initiated by the Slovak Academy of Sciences but was later coordinated by the Comenius University Faculty of Sciences. The monitoring was established in the belief that the escalating dispute over the environmental impacts of the GNP could be resolved only by limiting discussions on the topic to the scientific sphere, which could provide a common language and a verifiable basis for rational argumentation (Mucha, 1995). The monitoring specified parameters reflecting the project's direct operation and its potential impact on both the ecological-production area (agriculture, forestry) and the ecological-environmental area (the impact on natural ecosystems and the conservation of the geographic environment). The monitored components were similar to those currently included in the joint monitoring, namely, hydrological regime and quality of surface water and groundwater, soil moisture, and forest and biota monitoring. In addition, attention was paid to the influence of the project on water in the zone of aeration and on climate changes.

As part of the process of the development and the improvement of the pre-1995 environmental monitoring on the GNP-affected areas in Slovakia, suggestions for optimization have been made by Matečný et al. (1995b) and Molnár (1995). They include the following:

- better coordination of special groups aimed at interaction of individual subsystems;
- a unified digitized database;
- unified appliances and their regular standardized calibrations for comparability of measurements;
- unified evaluation of quantitative and qualitative analysis;
- authenticated methods for monitoring of chosen indicators;
- compatible nets of monitoring territories and locations, ensuring an extrapolation in space of individual subsystems and the whole ecosystem;
- optimizing of the nets based on the dominating influence of the hydrosphere;
- simultaneous terms of monitoring of similar phenomena, assuring the synchronization of the monitoring of the chosen indicators in time;
- the use of appropriate mathematical models for the water balance of the monitored ecosystems;
- the use of methods of long-distance surveying of the earth for space synthesis of the ecosystem;
- the application of a functional geographic information system for the total concerned area under the influence of the Gabčíkovo part of the project.

Some of these suggestions have been taken into account in the design and optimization of the joint monitoring programme as well.

In Hungary environmental monitoring on the areas affected by the construction and operation of the Gabčíkovo part of the GNP, which covered the so-called Little Hungarian Plain in northwestern Hungary and, in particular, the Sigetköz region neighboring the Danube riverbed, was developed, based on a preexisting project carried out by the Geological Institute of Hungary. In its work on the geological mapping of lowland areas and on the relationship between the effects of human activities and the geological settings of the given region, the institute had been collecting data on the state of the physical environment in the area since the mid-1960s (Láng, Banczerowski, and Berczik, 1997). The compiled series of maps, including geological, hydrological, geomorphological, engineering-geological, archaeological, environmental-ecological, and geophysical maps, facilitated the identification of the geological properties of superficial formations, their vulnerability to pollution, and their features concerning the biological environment. The monitoring network in the Sigetköz region, established within the framework of the above-mentioned project during the period 1982–1987, was used as a basis for the policy-oriented ecological research on the area commissioned by the Hungarian Parliament in 1992 in relation to the GNP. The purpose of the research was to develop a concept for the rehabilitation

and development of Sigetköz, with special regard for environmental protection, landscape preservation, and regional development. As Láng, Banczerowski, and Berczik (1997) point out, the findings of the environmental monitoring, along with the conclusions drawn from them, were also to be used in support of the Hungarian position taken during the proceedings at the Hague International Court of Justice.

Coordination of the related geological research, synthesis of the results, and formulation of ecological requirements for the region with the involvement of the regional bodies concerned was assigned by the Ministry for Environment and Regional Policy to the Hungarian Academy of Sciences. Data collection was based on a network of 45 sites evaluated according to the following criteria (Láng, Banczerowski, and Berczik, 1997):

- topographic positioning;
- assessment of land use and land resources management on the basis of infrared aerial images;
- geomorphologic setting of the microregion;
- description of the geological environment, including profiles;
- position and quality of groundwater;
- type of soil profile;
- engineering-geological features;
- assessment of the geological setting in terms of nature conservation.

Geological data processing was computerized. By 1994 a regional, spatial GIS database of the Sigetköz region was set up as a component of the complex geological database of the Little Hungarian Plain, making the collected information available to environmental protection experts in a uniform format. Closely associated with the Environmental Geological Information System of the Little Hungarian Plain was the launching of a project for the integration and presentation in a uniform format of the geological, hydrological, and environmental-geological information accumulated by the Geological Institutes of Hungary, Austria, and Slovakia. Thus, the accumulated data on Sigetköz, according to Láng, Banczerowski, and Berczik (1997), could be regarded as reliable basis for evaluating changes in the state of the environment in the region as a result of putting into operation the Gabčíkovo part of the GNP.

While independently established, certain elements of the environmental monitoring programmes, developed in Hungary and Slovakia in response to the escalating environmental dispute over the GNP, seem to have been integrated or harmonized between the two countries long before the official establishment of a joint monitoring system under the 1995 Agreement. In addition to the above-mentioned integration of geological data between Hungary, Austria, and Slovakia, a Slovak-Hungarian Transboundary Water Commission agreed on the establish-

ment of an extended joint water quality monitoring at its meeting in 1989 (Makovinská et al., 2001). The purpose of the programme was to study the effect of the GNP on surface water quality in the Bratislava-Budapest section of the Danube. The programme was motivated by concerns for the safety of drinking water in the region, which depends on the Danube as its primary source. Involved in the monitoring and analysis were the laboratories ÉDUKF (Györ), KÖDUKF (Budapest), VITUKI (Budapest), and WRI (Bratislava). Results were systematized jointly by the expert group of the Slovak-Hungarian Transboundary Commission and have been included in the Trans-National Monitoring Network, which is the main framework for transnational monitoring along the river organized and coordinated by the International Commission for the Protection of the Danube River (ICPDR) as part of its activities related to integrated Monitoring and Laboratory and Information Management in the river basin.

The establishment of these environmental monitoring systems marked a change unparalleled in nature and scope toward a more qualitative approach to erecting engineering works in the two countries and in the region. This change was instrumental for the initiation and realization of the joint environmental monitoring system under the 1995 Agreement. While initially established as tools for the legitimization of conflicting environmental and political claims, the environmental monitoring programmes on both sides of the river came to be seen as a promising bridge between diverging views. The preexisting technical, institutional, and human capacities provided the basis necessary for using science as a common language for settling the international water management dispute. The common origin of the scientific language and instruments used in the two countries – associated with their common historical roots and sociopolitical development routes – facilitated the harmonization of the existing independent monitoring practices. The interplay of these factors allowed for streamlining the monitoring efforts of the two countries toward the establishment of a joint environmental monitoring system on the Danube in 1995. The information accumulated during the pre-1995 independent monitoring of the state of the environment and the short- and long-term relationships among different environmental components in the areas affected by the GNP provided the scientific knowledge and the baseline necessary for measurement, evaluation, and interpretation of the environmental changes observed in the area following the introduction of the joint technical water regulation measures in 1995. The historical background of the establishment of the monitoring of each major environmental component and the accumulated results from the independent monitoring conducted in Slovakia and Hungary before 1995 are examined in detail below.

Hydrological regime of surface water

As an obligation under the Danube Convention for navigation purposes (Danube Commission, 2003), monitoring hydrological profiles along the Danube River has been carried out in both countries as part of their hydrometeorological monitoring of water and air (Slovak Hydrometeorological Institute, 2003). On Hungarian territory, measurement of some hydrometeorological elements began as early as 1780, of water levels and discharges in 1817 and 1825, respectively, and of sediments and water quality in 1867 (Starosolszky, 1998). Systematic hydrological monitoring of water levels of the Danube in Slovakia has been regularly recorded since 1823, discharges since 1871, and continuing data sets of both kinds of monitoring are available, beginning in 1901 (Minárik, 2003). The collection of hydrological data in more recent years has been coordinated by the Danube Commission, which is in charge of managing activities related to hydrometeorological services on the international river and the publication of long-term hydrological forecasts. The regular consultations and exchange of hydrological information among the Danubian states within the framework of the activities of the Commission, the relevant professional linkages established during the Socialist period, and the existing physical infrastructure and qualified human capital for hydrological monitoring provided a useful basis, for coordinating the monitoring of the hydrological regime of surface water in the areas affected by the Gabčíkovo part of the GNP between Hungary and the Slovak Republic.

According to long-term hydrological data, the annual average, minimum, and maximum fifty-year discharges in Bratislava are 2,025,570 and 10,400 m^3/s, and in Nagymaros, 2,421,590 and 8,180 m^3/s, respectively. Predictable 100-, 1,000- and 10,000-year floods in the former will discharge 10,600, 13,000, 15,000 m^3/sm and in the latter, 8,700, 10,000, 11,100 m^3/s (Hlavatý et al., 1999). The differences in peak discharges between Bratislava and Nagymaros reflect the retention function of the floodplain area between them. The long-term trend of discharge fluctuations has remained relatively constant over the years. However, a continual lowering of the water level had been observed at Bratislava, and thus into the Malý Danube and Mosoni Danube, over the three decades before the construction and putting into operation of the Gabčíkovo part of the GNP project. This trend is related to the geomorphological characteristics of the middle section of the Danube as well as the anthropogenic impacts on the river upstream.

The water level in the Danube is a function of its discharge and of the depth and shape of the riverbed, including the floodplain area, which has been restricted to the space between the flood protection dikes during

the past century. The gradient of the Danube river declines in the reaches downstream of Bratislava from about 0.04% to approximately 0.01% at Komárno (Kl'učovská and Topol'ská, 1995). The Danube changes its character from a mountainous to a lowland river just below the Gabčíkovo part of the project – at the village of Sap (fig. 3). Extensive aggradation has taken place in the areas where the slope reduction and the river created an inland delta with a number of meandering branches. River regulation works, carried out on the Danube since the early eighteenth century, gradually reduced the natural river development processes to a strip several kilometers wide. Erosion of the riverbed, because of the increased velocity related to the barring of sediment transportation upstream, led to a lowering of the water level in the main stream and a partial disconnection between the side arms of the inland delta and the main river during the low-flow periods of the year.

According to Hlavatý et al. (1999), the construction and operation of the Gabčíkovo part of the project did not have an impact on discharges (fig. 6) but reversed the declining trend in water level in the main stream at Bratislava. The damming of the river, however, threatened the old Danube riverbed below Bratislava and the river branch system on both sides. Results from hydrological monitoring in the area of Sigetköz indicate that the rate of flow of the river's main channel was subject to the most profound changes. According to Liebe (1997), who compares hydrological conditions during the years 1993–1994 with the water levels and discharges expected under normal conditions based on data accumulated during the preceding years, only 10–20% of the flow that could be expected without the diversion of the river was carried by the main channel, and water levels dropped by three meters on average. He also points out that, without diversion, the floodplain on Hungarian territory would have been inundated for a period of 32–36 days annually, while no water levels causing inundation occurred after the diversion of the river. Similarly, the side river arms of the floodplain would have been supplied with water from the main channel for 63–70 days under ordinary conditions rather than for 2–4 days, as was the case during the two years after 1992. The lowering of the water surface in the main stream and in the side arms led to the drying of the upper parts of the sides of the main riverbed and of the river arms and then to the overgrowth of vegetation on the land in those areas. Decreased flow velocities led to the deposition of much finer sediment than before in the area upstream of the confluence of the tailrace canal. According to Liebe (1997), the accumulated sediment, half a meter on average and up to two meters at certain locations, severely damaged the drinking water production potential from the bank-filtered resources for a span of about ten kilometers along the river.

Since changes in hydrological conditions determine changes in other environmental elements, in order to prevent the negative impact of the construction and operation of the Gabčíkovo part of the project on surface water levels and discharges, temporary measures ensuring the provision of additional water supply in the old Danube riverbed, the Mosoni Danube, and the Hungarian floodplain were taken under the joint Agreement Hungary and Slovakia signed in 1995, which required the two countries to jointly monitor the environmental impact of those measures on the affected areas.

The hydrological regime of surface water is one of the core elements of the joint monitoring programme. The joint surface water quantity monitoring network in 2001 included 28 jointly agreed gauging stations (15 in Slovakia and 13 in Hungary). The names and locations of the originally agreed gauging stations included in the joint monitoring are presented in table 3 and figure 7. Particular attention is paid to measuring the discharges into the Danube downstream of the Čunovo weir and into the Mosoni Danube, as well as their distribution over Hungarian territory, as regulated by the 1995 Agreement. The jointly agreed time series data from the conducted measurements create the basis for evaluating the measures implemented, according to Articles 1–3 of the 1995 Agreement.

Surface water quality

Surface water quality in rivers is a function of anthropogenic impacts. The way human activities affect water quality, however, depends on a number of river-specific factors such as flow speed, scouring, stream temperature, nutrients, chemistry, sediment load, and size (Perry and Vanderklein, 1996). At the same time, the definition of water quality depends on the intended use of the water resources. These factors, combined with the need for coordinating monitoring practices across the political border, have determined the complexity of establishing a joint surface water quality monitoring system in the areas affected by the Gabčíkovo part of the project. Nevertheless, the importance of surface water quality in the Bratislava-Budapest section of the Danube for drinking water supply in the region, as well as concerns regarding the safety of drinking water related to the construction and operation of the GNP, made surface water quality one of the first jointly monitored elements in the areas affected by the project.

As mentioned earlier, an extended joint surface water quality monitoring in the Bratislava-Budapest section was established as early as April 1989 under the coordination of the Slovak-Hungarian Transboundary Water Commission (Makovinská et al., 2001), supported by the preexisting surface water quality measurement practices in the two

Table 3 List of stations for surface water level and discharge monitoring [Source: Groundwater Consulting]

	Country	Station No.	Location and station name
1	Slovakia	1250	Danube, Bratislava-Devín
2	Slovakia	2545	Danube, Hamuliakovo
3	Slovakia	2558	Danube, Dobrohošt'
4	Slovakia	1251	Danube, Gabčíkovo
5	Slovakia	1252	Danube, Medved'ov
6	Slovakia	1600	Danube, Komárno
7	Slovakia	2848	reservoir, Čunovo-bypass weir
8	Slovakia	2552	Danube, Čunovo-downstream the Čunovo weir
9	Slovakia	2851	Mosoni Branch of the Danube, intake at Čunovo
10	Slovakia	3126	left-side river arm system, intake at Dobrohošt'
11	Slovakia	2849	power canal, Gabčíkovo Power station
12	Slovakia	2850	tailrace canal, Gabčíkovo Power Station
13	Slovakia	3124	seepage canal – upper water level, Čunovo
14	Slovakia	3125	seepage canal – lower water level, Čunovo
15	Slovakia	1653	Malý Danube, Malé Pálenisko
1	Hungary	0001	Danube, Rajka
2	Hungary	0236	Danube, Doborgaz
3	Hungary	0002	Danube, Dunaremete
4	Hungary	0005	Danube, Komárom
5	Hungary	0011	Mosoni Danube, Mecsér
6	Hungary	0018	Mosoni Danube, Bácsa
7	Hungary	0043	Danube, underwater weir
8	Hungary	0237	right-side river arm system, Helena
9	Hungary	0082	seepage canal, lock No. I.
10	Hungary	0084	seepage canal, lock No. II.
11	Hungary	0090	seepage canal, lock No. V.
12	Hungary	0103	seepage canal, lock No. VI.
13	Hungary	0106	Zátonyi Danube, Dunakiliti, Gyümölcsös út

countries. Joint evaluations carried out annually and based on jointly agreed data from eighteen sampling sites on the Danube have served as a basis for modifying proposals that reflect the changing environment since the Gabčíkovo structures were put into operation.

The monitoring included the following groups of parameters: physical-chemical parameters, the levels of nutrients, organic and inorganic micropollutants, indicators of radioactivity, and microbiological and hydrobiological parameters. For most of the parameters, over the period from April 1989 to December 1997, measurements were carried out regularly in two-week intervals, except for 1991 when measurements were conducted from January to April only. Some special parameters were monitored quarterly and in a reduced number of sampling sites. The limit values of the water quality classes correspond to the six-class water qual-

ity classification scale of the former COMECON and to the proposals of the European Economic Committee (Makovinská, 1999).

In addition to the joint surface water quality monitoring, after the diversion of the Danube's main arm as a result of the construction and putting into operation of the Gabčíkovo part of the GNP, the system for environmental monitoring on the affected Hungarian side was expanded with a monitoring programme geared to record resulting changes in surface water quality (Horváth, 1997). Within the framework of that programme, water quality examinations at forty sampling sites along the Danube and the Mosoni Danube, as well as in the wet areas between the flood walls (in the floodplain) and outside the flood walls (on the protected side) in the territory of Hungary, were performed biweekly.

Results from the extended joint monitoring summarized by Makovinská (1999) indicate that water quality in the Danube in the section between Bratislava and Visegrád was characterized by increasing water temperature, reflecting the climate change trend in the region and the impact of human activities upstream; low transparency due to the high content of suspended solids constraining photosynthetic activities; and high levels of nitrates and nitrogen and of bacteria (associated with a high content of biodegradable organic matter). Those characteristics of water quality in the middle Danube are in line with the general trends for the Danube reported by the river-wide water quality reviews of IWAC (2002) and UNECE (1994). The report from a consultation on water quality issues in central and eastern Europe (GWP, 2000), which points out the high level of nutrients as a problem in the middle reaches of the Danube, also confirms the monitoring results. According to Makovinská (1999), results from the extended joint monitoring also reflect a trend of decreasing organic load and ammonium and phosphorus levels and a relatively good oxygen condition in the Bratislava-Visegrád section, results which she ascribes to waste water treatment in the upper part of the Danube and in Hungary and Slovakia. The monitoring results also reflected an increasing abundance of zooplankton, indicating changes in the river flow characteristics, while chlorophyll-a levels implied a decreasing trend in phytoplankton biomass.

On the Hungarian side of the river, from the end of the 1950s to the end of the 1970s, the increased retention capacity of the Austrian river barrages resulted in a 50% decrease of the amount of suspended matter and an increase of transparency by 100–200% in some places (Berczik, 1997). As a result, between 1970 and 1980 the algae count (or the chlorophyll-a content) increased 8–10 times, indicating a significant rise in tropism. Long-term monitoring of organic pollutants over the period 1976–1994 indicated a decreasing trend of chemical oxygen demand

(COD) but an increasing trend of NO_3 in the main riverbed and of chlorophyll-a concentrations along the Sigetköz stretch of the river (Horváth, 1997). The quality of surface water in the Sigetköz region in the period after the damming was determined by that of water in the Dunacsúny reservoir. Results from the monitoring of those areas suggest that, during the first two years after the putting into operation of the Gabčíkovo part of the project, the dissolved oxygen content of the water released to the main channel, to the Mosoni Danube, and to the side river arms outside the levee was sometimes lower than before the diversion of the river, in areas where water stagnated and the transfer of water slowed down. Suspended soil content was also somewhat reduced (Liebe, 1997). In the main riverbed following the damming, an extreme increase in chlorophyll-a concentrations was also observed, while parameters indicating plant nutrients and organic matter did not show significant changes. For the side arm system on Hungarian territory, while no significant difference in water quality following the damming could be noticed, fluctuations of pH values increased, and average values for organic material and NO_3 declined. No significant changes in water quality in the protected side of the Upper-Sigetköz branch were observed.

Surface water quality measurement as part of the joint monitoring established under the obligation of the 1995 Agreement is based on the preexisting joint monitoring networks in Hungary and Slovakia. Currently it includes 15 profiles on Slovak territory and 8 on Hungarian. The originally agreed profiles and their locations are presented in table 4 and figure 8. According to the Joint Annual Report (2001), the methods of sampling and analysis were mainly based, with slight differences, on methods agreed by the Subcommission for Water Quality Protection of the Slovak-Hungarian Transboundary Water Commission. The report also points out that evaluation in 2001 was based on long-term surface water quality developments, suggesting reliance on results from the pre-1995 water quality monitoring in the region. Evaluation was based on limit values for surface water quality parameters agreed by the Slovak-Hungarian Transboundary Water Commission and following the general six-group classification used in the pre-1995 joint monitoring (table 5).

Hydrological regime of groundwater

The hydrological regime of groundwater, defined as water that exists below the earth's surface and completely fills pore spaces in the rock strata (Thornton, Lerner, and Davidson, 2002), is one of the most complex and extensively studied elements of the joint monitoring of the areas affected by the Gabčíkovo part of the project. The complexity of groundwater

Table 4 List of stations for surface water quality monitoring [Source: Groundwater Consulting]

	Country	Station No.	Location and station name
1	Slovakia	109	Danube, Bratislava – middle
2	Slovakia	111	Danube, Dobrohošt' – left side
3	Slovakia	112	Danube, Medved'ov – middle
4	Slovakia	1205	Danube, Komárno – middle
5	Slovakia	307	reservoir, Kalinkovo – navigation line
6	Slovakia	308	reservoir, Kalinkovo – left side
7	Slovakia	309	reservoir, Šamorín – right side
8	Slovakia	311	reservoir, Šamorín – left side
9	Slovakia	3530	Danube, Sap – left side
10	Slovakia	3529	Mosoni Danube, Čunovo – middle
11	Slovakia	3531	right side seepage canal, Čunovo – middle
12	Slovakia	317	left side seepage canal, Hamuliakovo – middle
13	Slovakia	3376	left side river arm system – Dobrohošt'
1	Hungary	1848	Danube, Rajka
2	Hungary	1806	Danube, Medve
3	Hungary	0012	Mosoni Danube, Vének
4	Hungary	0001	right side seepage canal, Lock No. I.
5	Hungary	0002	right side seepage canal, Lock No. II.
6	Hungary	1112	right side river arm system, Helena
7	Hungary	0042	right side river arm system, Szigeti arm, 42.2 km
8	Hungary	0023	right side river arm system, Ásványráró, 23.9 km

monitoring is related to the need for the monitoring system to reflect the mutual relationship and hydraulic interconnection of the Danube River and the other surface waters in the region with the groundwater.

These interconnections are related to the type and structure of aquifers, where groundwater is contained. Aquifers can be broadly classified as unconfined and confined. An unconfined aquifer is situated in porous rock exposed at the surface and in a position where the water table lies at a depth in the unsaturated zone that corresponds to atmospheric pressure. The form and the slope of the water table in unconfined aquifers can vary, depending on areas of recharge and discharge, pumpage from wells, and permeability. Recharge of unconfined aquifers takes place by vertical seepage of rainfall through the unsaturated zone, lateral groundwater flow, and upward seepage from underlying strata. Changes in the volume of the groundwater stored in aquifers, corresponding to the vertical movements in the water table, depend on pumping and seasonal variations in recharge.

Groundwater flow depends on the cross-sectional area of the aquifer through which flow occurs, the hydraulic gradient, and the hydraulic

Table 5 Jointly agreed limits for surface water quality classification [Source: Groundwater Consulting]

Parameter	Unit	I.	II.	III.	IV.	V.	VI.
temperature	°C	<20	25	25	30	30	>30
pH	–	6.5–8	6.5–8.5	6.5–8.6	6–8.5	6–8.5	6–9
conductivity	$mS.m^{-1}$	<40	70	110	130	160	>160
O_2	$mg.l^{-1}$	>8	6	5	4	2	<2
Na^+	$mg.l^{-1}$	–	–	–	–	–	–
K^+	$mg.l^{-1}$	–	–	–	–	–	–
Ca^{2+}	$mg.l^{-1}$	–	–	–	–	–	–
Mg^{2+}	$mg.l^{-1}$	–	–	–	–	–	–
$NH_4{}^+$	$mg.l^{-1}$	<0.1288	0.2576	0.644	2.576	6.44	>6.44
$HCO_3{}^-$	$mg.l^{-1}$	>200	200–100	100–20	20–10	<10	–
Cl^-	$mg.l^{-1}$	<50	150	200	300	500	>500
$SO_4{}^{2-}$	$mg.l^{-1}$	<50	150	200	300	400	>400
$NO_3{}^-$	$mg.l^{-1}$	<4.43	13.28	22.13	44.27	88.53	>88.53
$NO_2{}^-$	$mg.l^{-1}$	<0.0066	0.0164	0.066	0.164	0.33	>0.33
$PO_4{}^{3-}$	$mg.l^{-1}$	<0.0245	0.199	0.491	1.01	1.99	>1.99
total P	$mg.l^{-1}$	0.016	0.13	0.33	0.65	0.98	>0.98
total N	$mg.l^{-1}$	<0.3	0.75	1.5	2.5	>2.5	–
Mn	$mg.l^{-1}$	<0.005	0.1	0.3	0.8	1.5	>1.5
Fe	$mg.l^{-1}$	<0.5	1	2	5	10	>10
Zn	$mg.l^{-1}$	<0.2	1	2	5	10	>10
Hg	$\mu g.1^{-1}$	<0.1	0.2	0.5	1	5	>5
As	$\mu g.1^{-1}$	<10	20	50	100	200	>200
Cu	$\mu g.1^{-1}$	<20	50	100	200	500	>500
Cr	$\mu g.1^{-1}$	<20	50	100	200	500	>500
Cd	$\mu g.1^{-1}$	<3	5	10	20	30	>30
Ni	$\mu g.1^{-1}$	<20	50	100	200	500	>500
COD_{Mn}	$mg.l^{-1}$	<5	10	20	30	40	>40
BOD_5	$mg.l^{-1}$	<2	4	8	15	25	>25
suspended solids	$mg.l^{-1}$	<20	30	50	100	200	>200
saprobic index	–	1	1.5	2.5	3.5	4	>4
chlorophyll-a	$mg.m^{-3}$	<10	35	75	180	250	>250
coliform bacteria	$CFU.ml^{-1}$	0.1	1	10	100	1000	>1000
faecal coliform bacteria	$CFU.ml^{-1}$	<0.1	0.1–0.3	0.3–1	1–10	>10	–
faecal streptococci	$CFU.ml^{-1}$	<0.1	0.3	1	10	>10	
TOC	$mg.l^{-1}$	<3	5	8	12	20	>20
NEL-UV	$mg.l^{-1}$	0	<0.05	0.1	0.30	1	>1
dissolved solids	$mg.l^{-1}$	<300	500	800	1000	1200	>1000
total number of algae	$cells.ml^{-1}$	–	–	–	–	–	–
zooplankton	$In.ml^{-1}$	–	–	–	–	–	–
macrobenthos	$In.ml^{-1}$	–	–	–	–	–	–

conductivity, which indicates the rate at which water flows. Hydraulic conductivity is determined by the fluid and rock properties and in particular by the interconnectivity of the rock pore spaces of the particular aquifer, and it can be measured through slug, pumping, or tracer tests. The porosity of the aquifer, which represents the volume of water stored in an aquifer, can be estimated through geophysical logging of boreholes and analysis of the aquifer rock core.

Despite the complexity associated with groundwater monitoring, regular measurements and observations of the groundwater levels and regime on both Slovak and Hungarian territory had been carried out for decades. Research and intensive studies in those areas have been prompted by the importance of groundwater as the primary source of drinking water, in addition to its use for industrial production and agriculture, in both Hungary and Slovakia. A country's reliance on groundwater, which is usually considered as a cheaper and more easily exploitable drinking water supply source, reflects largely the geographical distribution of suitable aquifers, i.e., rocks that are sufficiently porous to store water and that are permeable enough to yield groundwater in economic quantities, as well as the availability of surface water supplies. While all rocks can contain water, sedimentary rocks usually form the majority of important aquifers.

Thus in the Slovak Republic 56% of the country's utilizable groundwater resources are located in the quarternary sediments of the Danubian lowland and in the alluviums of the Ván River and its tributaries. That percentage has effected the considerable attention and progress made in the research and monitoring of groundwater in the Danubian lowland (Slovak Environmental Agency, 2003), including the development of mathematical modelling of groundwater flow and floodplain hydrology (Refsgaard and Soerensen, 1997). Currently groundwater levels are measured at more than 600 observation wells in the region of Bratislava-Komárno. The groundwater level monitoring network was established by the Slovak Hydrometeorological Institute (SHMÚ) (Banský and Mažáriová, 1995). Manual weekly measurements and continuous automatic monitoring with the help of limnigraphs have provided a long-term database of groundwater levels in the region. The locations and density of the observation wells are shown in figure 9.

Like Slovakia, Hungary relies heavily on groundwater for its drinking water supply (78%–90%) and has therefore put special efforts into groundwater research (Havas-Szilágyi, 1998). The fact that close to 40% of its 1,600 drinking water well fields, supplying more than two-thirds of its drinking water, are considered vulnerable, i.e., not hydrologically protected from pollution coming from the surface, has created additional pressure for the continuous study and monitoring of such elements as

groundwater levels, flow systems, and recharge conditions in the country. Measurements of groundwater levels on Hungarian territory began in 1866 and of springs and groundwater intakes in 1910. Since 1991 the drinking water supply has been the responsibility of municipalities, which have been granted ownership of waterworks as part of the decentralization initiated in the country along with other transition reforms. However, the groundwater monitoring and protection system in the country has been developed on a nationwide basis within the framework of the national groundwater protection programme, the first phase of which started in 1996. Financed by the central budget and executed with the assistance of the regional authorities, the countrywide groundwater monitoring network includes 3,640 abstraction wells in 643 well fields different in type, depth of the aquifer, number of wells, capacity, hydrogeology, and number and types of pollution sources. The long history of groundwater monitoring in both the Slovak Republic and Hungary have provided a basis for evaluating the impact of the GNP on the hydrological regime of groundwater from a long-term perspective. Results from monitoring on the Slovak territory for the period 1962–1992 (fig. 10), for example, indicate the considerable lowering of groundwater levels in the area affected by the GNP, in particular the upper part of the Danubian basin downstream from Bratislava, during the three decades before the construction and putting into operation of the Gabčíkovo part of the project. According to Banský and Mažáriová (1995), the causes of those changes vary in different places. While some changes are the results of the sinking of the riverbed, others have been caused by water pumping for industrial purposes, agricultural melioration, changes in irrigation and drainage canal systems, irrigation patterns, exploitation of groundwater for municipal water supplies, and other changes driven by increasing urbanization in the region.

The impact of putting into operation the Gabčíkovo part of the project on groundwater levels on Slovak territory is illustrated in figure 11, which shows the differences in groundwater levels in the affected region between 1992 and 1995. The figure shows a general increase of groundwater levels, reversing the declining trend from the preceding decades in the upper part of Žitný ostrov as well as on the right side of the Danube in Slovak territory. At the same time, however, a lowering of the groundwater level close to the Gabčíkovo tailrace canal was recorded. A decline in the groundwater level was also noted in the area close to the Danube floodplain, which, according to Banský and Mažáriová (1995), was the result of the drainage of the old riverbed and which could be ameliorated by the construction of underwater weirs in the old Danube. Banský and Mažáriová (1995) also suggested regulating seepage canals and water supply, as well as flooding the inundation area, as technical measures for

reducing the environmental impact of the construction and operation of the Gabčíkovo structures.

On Hungarian territory, the impact of the construction and operation of the Gabčíkovo part of the project on groundwater levels over the same period (1992–1995) is also illustrated in figure 11. According to Liebe (1997), during the period 1993–1994, groundwater levels in the area between Rajka and Ásványráró near the Danube declined by three meters on average compared to expected water levels in undistributed channel flow conditions. Groundwater levels in the area between the Danube and the Mosoni Danube had been considerably low in the middle part of that region and failed to reach the upper fine-particled topsoil in the upper part of the Szigetköz area before the diversion. As a result of the damming, however, the areas with no groundwater supply reaching the topsoil expanded to include the middle part of Szigetköz as well. According to Palkovits (1997), within about 4,200 hectares (19% of the middle part of Szigetköz), the drop in the groundwater level led to its disappearance from the topsoil after the diversion of the Danube. Measures for additional water supply were taken in response to the situation.

According to Liebe (1997), however, the diversion of the Danube also resulted in a change in the direction of the groundwater flow in the region – from the south-southwest, toward the Mosoni Danube, to the east, toward the main channel of the Danube. As a result, most of the infiltrating water provided by the supplementary flow to the floodplain seeped back into the main channel. Further away from the Danube riverbed, the likely source of recharging the groundwater became the reservoir. The extent to which the additional water supply provided in the area as a result of technical measures agreed and introduced in 1995 has changed the situation is currently being monitored jointly.

The joint monitoring network in 2001 included 257 observation wells situated in the area of Žitný ostrov in Slovakia and in Szigetköz in Hungary (Joint Annual Report, 2001). The originally agreed observation wells are presented in figure 12. In order to account for the impact of seasonal and other variations in surface water levels and discharges, precipitation, evapotranspiration, irrigation, abstraction, and other relevant processes related to the input and output of water in the aquifer, the joint groundwater monitoring in the areas affected by the Gabčíkovo part of the project selected three different discharge conditions in the Danube at Bratislava, namely, 1,000, 2,000, and 3,000 m^3/s, for studying groundwater level differences in comparable hydrological situations at different times. For selected periods, maps of equipotential lines are jointly constructed. In the wells where the water level is measured once a week, the groundwater level for the selected periods is obtained through linear interpolation.

Groundwater quality

Closely related to the monitoring of the groundwater regime in the area has been that of groundwater quality, which is critical in view of the use of groundwater for drinking water supply. Groundwater quality depends on the natural composition of groundwater and on the impact of anthropogenic factors. The major constituents of groundwater in its natural state are dissolved gases (e.g., oxygen, carbon dioxide, methane), inorganic ions (e.g., Ca, Mg, Na, K, Cl, NO_3, SO_4, HCO_3), organic compounds (e.g., humic, fulvic, and amino acids), and a wide range of other inorganic species present at trace levels. Differences in the levels of chemicals contained in groundwater in its natural state depend on the mineralogy of the aquifer rock. At the same time, a combination of physical processes (advection, dispersion, dilution), biological processes (biodegradation), and chemical reactions (sorption, precipitation, hydrolysis, oxidation-reduction), which reduce or eliminate contaminant concentration, controls the geometry, the composition, the extent of the downstream transport of pollution, and thus the risk to receptors. Therefore, the choice of a groundwater monitoring strategy, as Thornton, Lerner, and Davidson (2002) point out, needs to take into account the mineralogy of the aquifer and the behavior of expected contaminant plumes through time and space.

The design of the network should reflect the objectives of monitoring (e.g., to determine the water quality or chemistry of a specific water supply or well field, to identify the extent of contamination of a known source, or to monitor a potential source of contamination) but also on the properties of the contaminants under consideration in view of differences in the position of their accumulation in geological structures and aquifer layers. To avoid bias in sampling, the well's diameter, the casing length, the method of installation, as well as the chemical compatibility of the material used with the groundwater contaminants under investigation, need to be taken into account in designing groundwater quality monitoring networks.

Evaluation of the results should reflect the desired use of groundwater. The suitability of groundwater for human or other use is determined by a standard set of constituents, such as pH, total dissolved solids, specific conductance, and inorganic salts. According to Thornton, Lerner, and Davidson (2002), ensuring that natural processes in situ are in accordance with the particular water use targets can be a legitimate end point of monitoring.

In the GNP case, the groundwater quality monitoring system in the affected areas, like the monitoring of the hydrological regime of the groundwater, was based on the preexisting waterworks in the vicinity of

the project. On the Slovak side, the system of municipal water wells near the previously existing river arms, near the reservoir, behind the seepage canals, and opposite the downstream part of the Čunovo reservoir required regular observation of groundwater quality long before the start of the GNP. The waterworks, in operation since 1972 and 1975 respectively, were established as a major source of drinking water for Bratislava because of polluted groundwater at the original source that supplied the capital. Systematic measurement and monitoring of groundwater quality in the region have been carried out within the framework of the basic and special-purpose monitoring networks of the Slovak Hydrometeorological Institute (SHMÚ). These networks include monofilter shallow wells, spread regularly between the Danube and Little Danube rivers, and a system of deep, multilevel observation wells constructed parallel with the water supply wells. The existing monitoring system in the region is currently being used for monitoring the development of the impact of Gabčíkovo structures on the groundwater level and the groundwater quality (Vavrová, 1995). Because of a decline in water demand during the past decade, some of the existing wells have been kept in operation solely for monitoring the impact of the operation of the Gabčíkovo part of the GNP on groundwater quality in the region. In addition to the original monitoring system, new methods of observation have been established between the reservoir and the waterworks' walls under the project "Ground Water Model for the Danubian Lowland," funded by the European Union.

The hydrochemical profile of the municipal water supply waterworks has been determined based on a 3-D model of the groundwater flow. The presupposed course of geochemical processes in the infiltrating groundwater has been used to define the distance of individual wells from the Danube and the depth of their filter parts. Horizontal and vertical distribution of filters allows for following the development of the groundwater quality along the flow lines at various depths. The collected data are employed for hydro-geochemical analysis of migration processes in the aquifer of the Danube River side zone and for the study of oxidation of organic matter, the oxidation-reduction state, the process of recharge of the gravel aquifer with Danube water, and other processes and states (Rodák and Mucha, 1995).

The peculiarities of the aquifer and the groundwater flow in the region have also been taken into account in designing the monitoring system. The relevant characteristics of the geological structure of the region, as described by Rodák and Mucha (1995), include a layer of loam 1–2 meters thick, overlaying highly permeable and poorly graded sandy gravel with an irregular lens of sand. The thickness of the sandy-gravel aquifer increases further from the Danube, and the underlying aquitard is com-

posed of less permeable, fine- to medium-grained sand, sandstone, and clays of the Neogene epoch. Upstream from the municipal waterworks, water from the Danube recharges the groundwater of Žitný ostrov.

As in Slovakia, groundwater quality monitoring in Hungary has been developed within the framework of hydrological monitoring in the country. In more recent years, groundwater quality monitoring has been the focus of the above-mentioned National Groundwater Protection Program, which was implemented in 1997. However, groundwater quality monitoring in the areas affected by the Gabčíkovo part of the GNP was established before the official obligation for joint monitoring was agreed upon in 1995. According to László (1997), the pre-1995 groundwater quality monitoring network in the areas consisted of a set of 70 observation wells divided into 11 groups and situated along the banks of the side arms and canals.

Results from the pre-1995 groundwater quality monitoring in the areas affected by the Gabčíkovo part of the GNP in Slovakia indicate that no significant changes in groundwater quality have been detected as a result of the construction and operation of the waterworks. In fact, according to Hlavatý et al. (1999), a positive change in groundwater quality, linked with an increased proportion of water infiltrated from the Danube, was observed on the right side of the Danube after the Gabčíkovo part of the GNP was put into operation. According to results from long-term monitoring in Slovak territory, iron and manganese are typical components of groundwater in the area because of the geological composition of the aquifer. The high content of dissolved iron and manganese near the municipal water wells close to the river branches, a condition observed as early as the 1970s, led to the exclusion of one of the wells from operation. The occurrence of iron and manganese dissolved in the groundwater depends on the content of oxygen and nitrate in the groundwater and on the content of organic carbon in the groundwater and the aquifer. Thus the decrease in the content of nitrates observed since 1992 could lead to a further increase in the content of manganese and iron. Such problems, however, can be resolved (and have been resolved) in the region by aeration of water in the waterworks or by in situ treatment in the aquifer (Hlavatý et al., 1999). Other groundwater quality changes in Slovak territory, such as the decrease of total dissolved solids, chlorides, and sulphates at the wells, which had been affected by water from urbanized territory during pre-dam conditions, have been noted as positive changes as a result of the construction and operation of the Gabčíkovo part of the GNP.

Pre-1995 monitoring on Hungarian territory also indicates that no substantial changes in groundwater quality were observed during the two years after the diversion of the Danube, although recharge patterns in

the region were modified as a result of the damming (Liebe, 1997). According to László (1997), during pre-dam conditions, groundwater in Szigetköz was recharged primarily by the gravel bed of the main Danube channel, and the quality of the bank-filtered water was suitable for drinking water supply. As a result of the diversion of water from the main Danube riverbed, the bed lost its dominant recharge function along some of the river sections, and the reservoir and the side arm system became important recharge areas for the alluvial aquifer. Nevertheless the groundwater quality changes observed in the area after the diversion are similar to those on Slovak territory, namely, a decrease of nitrate and ammonium concentrations accompanied by an increase of dissolved iron and manganese.

The joint groundwater quality monitoring in the region introduced in 1995 was conducted in 2001 through a network consisting of 40 wells, 22 on the Hungarian side and 18 in Slovakia. The originally agreed joint monitoring sites are given in table 6 and figure 13. Of the wells on the Hungarian side, 16 are groundwater quality observation wells, situated in the upper layers of the gravel sediments, and 6 are used for the observation of the drinking water supply. The evaluation of the results of the joint water quality monitoring is based on jointly agreed drinking water quality limits for groundwater (table 7) and is being carried out from a long-term perspective in both countries.

Soil monitoring

Changes in the surface water and groundwater regime and quality are carried on to the living environment through changes in the moisture and quality of soil, i.e., the weathered material mainly composed of disintegrated rock and of organic matter that sustains plant growth (Gallegos, Brandstetter, and MacQueen, 1999). Soil moisture, one of the crucial characteristics of soil and the most relevant one regarding the environmental impact of the GNP, is a function of the availability of precipitation (in the form of rain, melting snow, and irrigation) and of water transported from the ground via capillary rise. Soil moisture affects plant transpiration, soil aeration and temperatures, the vertical transport of nutrients, chemicals, and pollutants, as well as the long-term development of soils and soil structures (Hlavatý et al., 1999). The character of sediments or the type of soil, the sediments' thickness, the groundwater level, and its fluctuation determine the capillary rise. In gravel deposits, for example, the capillary transport is poor – nearly null. It is good in finer sediments, such as fine sand silt, loam, and agricultural soils, and it is best in loess (eolian sediments). The lack of water content but also the

Table 6 List of stations for groundwater quality monitoring [Source: Groundwater Consulting]

	Country	Station No.	Location
1	Slovakia	899	Rusovce, right side of the reservoir
2	Slovakia	888	Rusovce, right side of the reservoir
3	Slovakia	872	Čunovo, right side of the reservoir
4	Slovakia	329	Šamorín, left side of the reservoir
5	Slovakia	170	Dobrohošt'
6	Slovakia	234	Rohovce
7	Slovakia	262	Sap
8	Slovakia	265	Kl'účovec
9	Slovakia	102	Rusovce, drinking water source
10	Slovakia	2559	Čunovo, drinking water source
11	Slovakia	116	Kalinkovo, drinking water source
12	Slovakia	105	Šamorín, drinking water source
13	Slovakia	467	Dobrohošt', drinking water source
14	Slovakia	485	Bodíky, drinking water source
15	Slovakia	103	Gabčíkovo, drinking water source
16	Slovakia	906	Bratislava-Petržalka, drinking water source
1	Hungary	9310	Rajka
2	Hungary	9327	Dunakiliti
3	Hungary	9331	Dunakiliti
4	Hungary	9368	Rajka
5	Hungary	9379	Rajka
6	Hungary	9413	Sérfenyősziget
7	Hungary	9418	Mosonmagyaróvár
8	Hungary	9430	Kisbodak
9	Hungary	9435	Arak
10	Hungary	9456	Ásványráró
11	Hungary	9457	Ásványráró
12	Hungary	9458	Ásványráró
13	Hungary	9475	Győrzámoly
14	Hungary	9480	Győrzámoly
15	Hungary	9484	Vámosszabadi
16	Hungary	9536	Püski
17	Hungary	DU-I	Dunakiliti, drinking water source
18	Hungary	T-II	Mosonmagyáróvár, drinking water source
19	Hungary	DA-I	Darnózseli, drinking water source
20	Hungary	K-5	Győr – Révfalu, drinking water source
21	Hungary	6-E	Győr – Sződgye, drinking water source
22	Hungary	25-E	Győr – Sződgye, drinking water source

Table 7 Groundwater quality limits for drinking water [Source: Groundwater Consulting]

Parameter	Unit	Limit value	Highest limit	Note
temperature	°C	12	25	EU
pH	–	6.5–8.5	–	EU
conductivity	$mS.m^{-1}$	40	–	EU
O_2	$mg.l^{-1}$	–	–	–
Na^+	$mg.l^{-1}$	20	175	EU
K^+	$mg.l^{-1}$	10	12	EU
Ca^{2+}	$mg.l^{-1}$	100	–	EU
Mg^{2+}	$mg.l^{-1}$	30	50	EU
Mn	$mg.l^{-1}$	0.1 (SK)	0.5 (H)	–
Fe	$mg.l^{-1}$	0.3 (SK)	1.0 (H)	–
NH_4^+	$mg.l^{-1}$	0.05	0.5	EU
HCO_3^-	$mg.l^{-1}$	–	–	–
Cl^-	$mg.l^{-1}$	25 (EU)	100 (H)	–
SO_4^{2-}	$mg.l^{-1}$	25	250	EU
NO_3^-	$mg.l^{-1}$	25	50	EU
NO_2^-	$mg.l^{-1}$	–	0.1	EU
PO_4^{3-}	$mg.l^{-1}$	–	–	–
COD_{Mn}	$mg.l^{-1}$	2.5 (H)	3.5 (H)	–

EU-European standard, SK-Slovak standard, H-Hungarian standard

surplus of it considerably influence humus conditions in the soil, leading to humus mineralization or a slowing of nutrient circulation, respectively. At the same time, humus influences the physical properties of soil, such as structure, consistency, regime of temperature, soil moisture, speed of infiltration, and water content (Bublinec and Kukla, 1999). Changes in organic carbon content can be used as indicators of changes of humus in the soil and of changes of carbonates in the water regime, which are also indicated by decarbonisation and/or salination processes.

According to Hlavatý et al. (1999), since soil moisture is determined by the sediment and soil horizons in which the groundwater fluctuates or by the depth and course of groundwater level fluctuations and the extent to which groundwater comes into contact with sediments with good capillary transport ability, the interaction of the groundwater with the soil in the areas of Szigetköz and Žitný ostrov depends on the depth of the boundary between the gravel strata and the overlying finer sediments or soils. From the point of view of agricultural production, an optimal groundwater level is one that stays permanently in the finer sediments overlying the gravel during the growing season. At the same time, however, Bublinec and Kukla (1999) note that different combinations of local conditions, such as fluctuation of groundwater level, velocity of capillary elevation from groundwater, spatial changes in humus, particle size dis-

tribution, soil moisture distribution, porosity, penetrability for water, and soil aeration may result in the same soil water regime, thus making the identification of the causes of changes and the management of the soil water regime a complicated task.

Information about the particular dynamics of soil moisture and the hydrological surface water and groundwater regimes, as well as data about the limiting values of the factors determining phytocenoses, could facilitate decision making on water management in the framework of ecosystem analysis. Soil research and monitoring carried out in both agricultural and forest areas affected by the Gabčíkovo part of the GNP in Hungary and Slovakia during the past decade have provided a solid basis for such decision making concerning the areas of Žitný ostrov and Szigetköz.

Soil monitoring in agricultural areas on Slovak territory affected by the Gabčíkovo part of the GNP started in 1989, although a wide set of the basic physical and chemical soil parameters, the pedogenetic processes, the chemical compositions of the soil and the groundwater, and the crop production of the agricultural cooperatives in the region had been monitored since 1984. The 20 monitored observation plots included pedological observation wells, soil moisture measuring wells, hydrogeological wells, and precipitation and irrigation gauging instruments, allowing for the monitoring of the different characteristics of soil, such as soil moisture, humus extent and quality, soil salinity, and other parameters (Fulajtár, 1995a; Fulajtár et al., 1998). Monitoring objects were situated in areas where changes both in the groundwater levels after the construction of the Gabčíkovo structures and in the concentration of salts in the groundwater had been forecast. Some of the factors considered in the selection of the monitoring plots included the morphogenetic-stratigraphic structure of the soil profile, the depth of the gravel base, the groundwater level and fluctuation, and the content of salts in the groundwater and in the soil.

The soil in forest areas affected by the construction and operation of the Gabčíkovo part of the GNP had also been monitored for more than a decade, starting in 1990. Monitoring was conducted on 24 permanent plots representing a variety of original (i.e., anthropologically unaffected) soil profile structures (Bublinec and Kukla, 1999). The objective of soil monitoring was to observe changes in the soil as an acceptor, a source, and a medium reflecting changes in the ecosystem (Cambel, 1995). In order to quantify the potential impact of the Gabčíkovo structures on forest areas, changes in the humidity of the soil were measured in ten-centimeter intervals to a point below the groundwater level. Monitoring was carried out at approximately ten-day intervals, using neutron logging.

On Hungarian territory, soil monitoring in areas affected by the con-

struction and operation of the Gabčíkovo part of the GNP also started before it became an obligation under the 1995 Agreement. According to Palkovits (1997), the water content of soil at 48 agricultural and 6 forest observation points has been continually observed since 1989 by the Mosonmagyaróvár Department of Production-Development of the Pannon University of Agricultural Sciences. Annually, 12–13 measurements, adjusted to weather conditions and the development phases of plants, were performed between the end of March and the beginning of November. Phenological surveys were carried out on 47 agricultural fields, and the growth, the development, and the health of stands were examined in the main development phases of plants in production conditions based on 4–6 observations. The effects of the production methods on the sizes of the yields were taken into account in the evaluation of the field level data.

Soil studies of areas in Hungary affected by the construction and operation of the Gabčíkovo part of the GNP before 1995 were also carried out as part of a larger study of the hydrogeological and soil-mechanical problems in the area in 1993 and 1994 – a study commissioned by the Hungarian Ministry for Environmental and Regional Policy in response to reports of house-cracking damages in settlements in Szigetköz after the diversion of the Danube in 1992 (Nemesi and Pattantyús-Ábrahám, 1997). The study was carried out by the Eötvös Loránd Geophysical Institute in cooperation with the Hungarian Geological Institute and with the Geotechnical Department of the Budapest Technical University, which was responsible for soil sampling and analysis. Depth, soil type, and the mechanical properties of the different soil types in view of their water saturation were taken into account in selecting the samples. From the stations along the integrated geophysical profile measured in one of the affected settlements, soil samples were taken from three depths in order to reflect each of the characteristic layers below and above the water table. A total of 20 samples were analyzed for grain size frequency distribution and compressibility.

According to the findings of soil research and monitoring in the affected areas on Slovak territory, shallow soils prevail upstream, while deep soil horizons are typical downstream (Hlavatý et al., 1999). Waterlogging of soils takes place only if the groundwater level is shallow, i.e., usually close to the surface – 0–0.5 meters deep. A shallow groundwater level in the floodplain supports a typical floodplain biotope and is naturally regulated by the river branches. The optimal depth of groundwater in agricultural areas with shallow groundwater levels is ensured by drainage systems, as in the eastern (lower) part of Žitný ostrov.

A comparison of the groundwater level with the gravel and finer-structured sediments having good capillary transport ability in agricultural areas on Slovak territory affected by the Gabčíkovo project in 1962,

1992, and shortly thereafter indicates that no waterlogging was observed in the region except in the inundation area, where conditions improved after 1992. According to Hlavatý et al. (1999), no additional waterlogging of agricultural soils was observed after the project was put into operation.

Based on results from the research and monitoring in the affected forests in Slovakia, the soil in those areas belongs to the class of eutric and calcaric fluvisols with a different water-air regime and is built of sediments with an admixture of carbonates, in particular $CaCo_3$ (Bublinec and Kukla, 1999). The hygroscopic quality of the observed soils has been found to correspond to that of light and middle-heavy soils. Basic minerals (quartz, feldspar, mica) were found to prevail in fractions of sand and silt and in fractions of clay (a secondary mineral) in the humus-clay complex.

In the areas near the old Danube riverbed where groundwater level declined, a decrease in the humus content of the soil surface layers was noted, reaching levels about 22% and 41% lower than the humus content observed on average and in the flooded areas, respectively. Humus content and quality determine the available phosphorus for plants, which is essential for their health. In certain areas a decrease in potassium was also observed. Insufficiency of potassium, a basic plant nutrient, causes decomposition of proteins, increases the number of free amino acids, contributes to the accumulation of toxic substances, increases respiration, and decreases phosphorus content, resulting in the seed germination capacity of the root system of plants. However, as Bublinec and Kukla (1999) point out, the limited time span of the pre-1995 observations did not allow for drawing conclusions about the permanence of those changes.

According to soil monitoring in the affected agricultural areas in Hungary, the periodical or constant presence of groundwater in the cover layer in Szigetköz determined the limited impact of weather extremities on soil moisture in the area (Palkovits, 1997). However, the decline of groundwater levels below the soil layer in 19% of the territory as a result of the diversion of the Danube in 1992 led to an increase in the vulnerability of agricultural production to weather conditions. This was demonstrated by the lower-than-average yields from the region in 1993 and 1994 because of the prolonged drought and limited precipitation during those years, especially 1993.

Studies of soil in forests indicate that changes in the fluctuation pattern and chemical composition of surface water and groundwater in the region affected the direction and intensity of soil formation processes (Hahn et al., 1997). Analysis based on soil sampling data indicates that, as a result of the diversion of the Danube, some abrupt changes were noted in the natural trend of a gradual increase of fine sediment and a decrease of gravel as one moves away from the open water toward the former

riverbank. Those changes have been pointed out as causes of changes in the natural vegetation in the region.

However, results from soil analysis also indicate that changes in water saturation affected different soil types differently. While they had little impact on coarse-grained soils, they considerably affected the formation processes in the uppermost thick layer in areas characterized by clayey soils. According to Nemesi and Pattantyús-Ábrahám (1997), a permanent drop in the water level could cause a sinking of the clay layers by several centimeters as a consequence of compression and a loss of 5%–20% of their volume as they dry up. They note that the sinking of the relief associated with similar changes in the period after the diversion of the Danube could have been the reason for house cracking in some of the affected areas in Hungary.

The impact of the changes in the hydrological regime and quality of surface water and groundwater on soil and, in particular, on soil moisture on Slovak and Hungarian territories as a result of the construction and putting into operation of the Gabčíkovo part of the project is currently being monitored jointly. In the hydrological year 2001, soil moisture measurements within the framework of the joint monitoring programme were carried out at 34 observation sites. Measurements on the Slovak side were performed on 12 forest, 5 biological, and 3 agricultural monitoring areas, and on the Hungarian side, on 9 forest and 5 agricultural areas. The originally agreed joint observation points are shown in figure 14 and table 8. The measurement method used in the Slovak Republic is a neutron probe that reaches a prescribed depth of the groundwater level. In Hungary, the method used is a capacity probe that reaches down to the underlying gravel layer. To allow for comparability, both sides use the same method to present the measurement results. Soil moisture in both Hungary and Slovakia is shown by the total soil moisture content in volume percentage recorded in ten-centimeter depth intervals for each measurement during the year. An example of the time record of soil moisture changes in Dunajská Lužná is presented in figure 15.

Forest monitoring

The impact of the construction and operation of the GNP on forests, which are defined by FAO as land with an area greater than 0.5 hectares and with tree crown density (or equivalent stocking level) exceeding 10% (ECPP, 1999), has been one of the major environmental concerns of the project. Particularly controversial has been the impact of the decreased water supply in the old Danube riverbed and the arm system on floodplain forests, which are characterized by much higher water needs for transpiration than can be supplied through precipitation.

Table 8 List of stations for soil moisture monitoring [Source: Groundwater Consulting]

	Country	Station No.	Location and station name
1	Slovakia	2703	Dobrohošt', inundation
2	Slovakia	2704	Bodíky, inundation
3	Slovakia	2705	Bodíky, inundation
4	Slovakia	2706	Gabčíkovo, inundation
5	Slovakia	2707	Kl'účovec, inundation
6	Slovakia	2716	Rohovec, agricultural area
7	Slovakia	2717	Horný Bar – Šul'any, agricultural area
8	Slovakia	2718	Horný Bar, agricultural area
9	Slovakia	2755	Sap, inundation
10	Slovakia	2756	Gabčíkovo, inundation
11	Slovakia	2757	Baka, inundation
12	Slovakia	2758	Trstená na Ostrove, inundation
13	Slovakia	2759	Horný Bar – Bodíky, inundation
14	Slovakia	2760	Horný Bar – Šul'any, inundation
15	Slovakia	2761	Horný Bar – Bodíky, inundation
16	Slovakia	2762	Vojka nad Dunajom, inundation
17	Slovakia	2763	Vojka nad Dunajom, inundation
18	Slovakia	2764	Dobrohošt', inundation
1	Hungary	9355	inundation
2	Hungary	9452	agricultural area
3	Hungary	9498	inundation
4	Hungary	9972	inundation
5	Hungary	9994	inundation
6	Hungary	9995	inundation
7	Hungary	9996	inundation
8	Hungary	9997	inundation
9	Hungary	9998	inundation
10	Hungary	2605	agricultural area
11	Hungary	2630	agricultural area
12	Hungary	2653	agricultural area
13	Hungary	7920	agricultural area
14	Hungary	9443	agricultural area

Kerner von Marilaun, an Austrian botanist, wrote in his *Das Pflanzenleben der Donauländer,* published in 1863, that every form of phytocenosis develops and disappears. So do floodplain forests. The spread and the general character of forest communities are determined mainly by the amount of available water and the influence of other growth factors (sunlight energy, nutrient accessibility, intensity of erosion accumulation processes, etc.), which differ for different tree species and kinds of vegetation cover. The availability of water and other growth factors depend on the regimes of flow and transmission of solid material along the riverbed (the traction load). Changes in these regimes are determined by

the climate and the anthropogenic activities in the riverbed and in the catchment basin (Valtýni, 1993; 1994).

Floodplain forests in the middle reaches of the Danube on both Slovak and Hungarian territories have been subjected to similar climate conditions and anthropogenic factors related to the common water and forest resource management practices on both sides of the river. Those commonalities have determined the similarities in the types of floodplain forests in the region, in their development through time, and in their current condition.

In the territory of Slovakia, for example, four phytocenologically different vegetation groups, classified as economic sets of forest types, exist in the Danube floodplain (Valtýni 1993; 1994). Arranged according to water needs in descending order, these groups include the following:

1) Willow-poplar woods (soft floodplain woods), represented by the group *Saliceto-Alnetum* (willow-alder);
2) Oak-ash woods (intermediate floodplain woods), represented by the groups *Querceto fraxinetum* (oak-ash) and *Ulmeto-fraxineto populeum* (elm-ash with poplar), which are typical of the river arm system;
3) Hornbeam-ash woods (hard floodplain woods), represented by the group *Ulmeto-Fraxinetum carpineum* (elm-hornbeam with ash);
4) Extremely limestone oak woods, represented by the group *Corneto-Quercetum* (cornel-oak).

Forest vegetation on the floodplain in Hungary is characterized by similar forest types. According to Fodor and Pál-Fám (2001) and László and Pál-Fám (2001), the most common forest types in Szigetköz include:

1) Willow and poplar woods represented by *Salix purpurea, Populus nigra, and Alnus glutinosa* in the wettest areas (Hahn et al., 1997);
2) Ash-elm-oak (*Pimpinello majoris-Ulmetum*) gallery forests which are typical of the higher region of the floodplain area;
3) Oak-hornbeam forests (*Majanthemo-Carpinetum*) found in more arid areas;
4) Oak forests (*Piptathero virescentis-Quercetum roboris*) found in the driest, semiarid habitats.

Floodplain forest development, the result of which is today's forests around the middle reaches of the Danube River, began in the Subatlantic era, 2,800–1,400 years ago, when an increase in humidity and a decrease in temperature intensified erosion/accumulation processes in the Danube bed and created conditions for the disappearance of boreal forests and the formation of forest communities capable of existing in extreme local conditions. Later, changes in the river flow and the traction load regimes mainly because of anthropic activities, such as antiflood measures and a shortening of the watercourse in connection with an increase in the lon-

gitudinal watercourse slope, resulted in changes in the development and spread of the Danubian riparian forests, changes which are obvious in the differences between Lichtenstern's and Mikovíni's maps from 1794 and 1730, respectively (Valtýni, 1993; 1994).

The construction of antiflood dikes, which began in 1885, influenced the flow regime in the area between the dikes, the extent and duration of floods, as well as the water level in the flooded area, increasing average water depth, deposition of fertile silt, and thus the supply of nutrients to tree species between the dikes. As a result, hardwood broad-leaved tree species were replaced by willow-poplar forests (Šomšák, 1999). Later, anthropogenic influences upstream, namely, the construction of several dams on the territories of Germany and Austria, led to a decrease of detritus in the lower parts of the stream. The decrease intensified riverbed erosion, which, combined with gravel excavation from the Danube bottom and other measures taken to improve navigation, as well as with drainage for agricultural purposes, resulted in a drop in the water level not only in the Danube watercourse but also in the soils of the adjacent flood plains, especially during the vegetation period. As a result of the repeated shortage of water in the poplar vegetation root zone, vegetation started to dry in some localities (namely, Rusovce and others), and marsh habitats disappeared.

Floodplain changes affected the distribution of individual tree species as well. In the Danubian lowland along the Danube and its tributaries, for example, willows belonging to the *Salix* genus originally prevailed. In some places, willows were an admixture in alder woods (*Alnetum glutinosse-salicetosum*) or poplar-willowwoods (*Saliceto-populeum*). Poplars, predominantly domestic black poplar, created a vegetation cover of a simple structure which was well lit throughout. Elms and other accompanying species gradually entered this vegetation cover, thus forming a second floor. As a result of the drying of the alluvial upper parts, at elevated places poplars ceased to reproduce naturally and grew only sporadically during periods of huge floods or rich atmospheric precipitation. Elms gradually took over, forming elm woods which included species such as alder, buckthorn, blackthorn, maple, etc. Further developments led to the spread of oaks and the formation of elm-oak woods (*Ulmeto-Quercetum*) or other mixed deciduous vegetation covers. The poplar species, *Populus nigra pannonica*, as well as its *genuina* and *pyramidalis* variants, which were originally spread in the neighborhood of the Danube River, were mixed with white poplar, ash, elm, European alder, gray alder, which grew from seeds conveyed by the river from Alpine regions which then settled in the inland delta (Valtýni, 1993; 1994).

At the same time artificial afforestation was taking place in the dried-

out areas. In Slovakia, starting from around 1850 and intensifying after World War II, the planting of utility poplar monocultures, characterized by up to ten times higher annual incremental growth than the average in the country, added to changes in the vegetation cover in the area along the Danube, including the area between the weirs near Gabčíkovo. According to Šomšák (1999), approximately 80% of the natural floodplain forests were replaced by allochtonous monocultures. Similarly, in Hungary, artificial afforestation led to the introduction of poplar hybrids in the floodplain area (Varga, 1997). Those changes are in line with forest management practices on the rest of the territory of the two countries. According to a European Commission's Phare Programme Report, "Conservation and Sustainable Management of Forests in Central and Eastern European Countries" (ECPP, 1999), in Hungary there are currently no virgin forests, and in Slovakia forests undisturbed by man account for 1% of the forests in the country.

Like previous water regulation activities, the GNP was expected to affect forest ecosystems in the Danube floodplain as well. In order to evaluate the impacts, a number of studies, as well as regular monitoring of selected plots, were undertaken in the two countries. They drew on earlier research on floodplain forests in the Danube and their relation to soil conditions and changes of groundwater levels, vegetation of stagnant waters and dead arms, phytocenoses of bank biotopes, synecological conditions, and primary productivity of floodplain forests.

In Slovakia, monitoring of forest trends was established within the framework of the biota monitoring initiated by the Slovak Academy of Sciences in 1990. The monitoring included a set of plots representative of the variety of forest ecosystems found in the area, e.g., ecosystems with original wood plant composition, cultivated poplar monocultures, monolayer forests and forests with a developed shrub layer, forests with disintegrated structure, and compact stands with high stocking and canopy density. The monitoring aimed to evaluate the conditions and possible changes in the structure of the tree and shrub layer and in the leaf area index. The evaluation was based on features and parameters such as species composition, thickness, height and biosocial structure of the main stand, Kraft-classified tree inventory, crown architecture, and canopy cover (Oszlányi, 1995).

Repeated phytocenological (semiquantitative) and population-ecological (quantitative) observations and analysis were carried out in certain areas, each measuring one hectare. Dendronometric and tree diameter measurements were performed in 15 permanent sampling plots (Šmelko, 1999). For monitoring the dependence of increment on changes in the water regime, younger stands (of up to 10 years in age) of cultivar poplars were observed since older trees were assumed to have an internal

physiological disposition to an incremental decrease in thickness (Šomšák et al., 1995). For the monitoring process, the age of a poplar was determined by counting annual rings based on radial borings at a 130-centimeter height from the soil and by following the same direction of borings in order to ensure comparability of long-term data. Results were evaluated in relation to groundwater level developments and precipitation, annually and during the vegetation period, and were integrated with a computer-based Dendrochronological Analysis System, allowing for observation of the whole course of growth in a tree's diameter retrospectively and for distinguishing a tree's natural growth from deviations caused by environmental factors, while taking into account the natural incremental growth pattern as related to the age of a tree. Dendrochronological analysis of a tree's lifelong growth was performed on 30 sample trees to verify the reliability of short-term results (Šmelko, 1999).

In addition the leaf area index, indicating the size of one side of a leaf as related to one hectare of stand area, was monitored during an interval of two to three years and evaluated with the help of planimetric analysis. Leaves, taken together as an assimilating apparatus, quickly and intensively react to changes in growth conditions within one growth season as well as over a longer period. Therefore they were used as indicators of the production capacity of a plant cover, as well as the cover's vitality and health as related to the hydropedological regime in a locality (Oszlányi, 1999).

The monitored sites were located according to the expected impact of the GNP on floodplain affected forests in Slovak territory. Altogether, the forests were expected to come up to about 4,014 hectares and include an area of 1,092 hectares around the Hrušov reservoir and an area of about 2,922 hectares in the river arm system where floodplain forests grow inside the inundation area (containing 2,289 hectares) and outside the inundation area (containing 633 hectares). Several variants of anticipated development had been worked out, especially for the forests in the arm system, based on the difference between the average flow rate in the old riverbed and the amount of water in the arm system conveyed by the diversion canal via the intake structure at Dobrohošt'. In the area around the Hrušov reservoir, the putting into operation of the GNP was expected to lead to an improvement in the supply of the existing vegetation. However, redirecting the stream of the Danube was expected to change habitat conditions along the old riverbed from those suitable to floodplain softwoods to those more favorable to floodplain hardwoods, in proportion to changes in the average water level in the old bed. Even the most skeptical prognoses, did not envision the disappearance of floodplain forests. They did predict, however, a replacement of the prevailing cultivated poplars with tree species capable of existing in drier locations,

such as oaks, ashes, and other autochtons considered more natural for the region but characterized by a substantially lower accumulation of wood.

In Hungary, forest monitoring in the areas expected to be affected by the construction and operation of the GNP began in 1986 in response to rising public concern about the environmental impact of the project. This concern also led to the establishment in 1987 of the Szigetköz Land Conservation District, which covered areas along the bank of the Mosoni Danube, the old Danube floodplain, and areas between the two branches, 65% of which constitute forests (Koltai, 1997). Concern focused on wetland forests, i.e., willow carr forests, softwood and hardwood riparian forests, and riparian alder groves. As defined in the "European Wetland Inventory Review" (Wetlands International 2002, October 30), wetlands are water bodies with an area-related mean water depth below two meters at mean water level, parts of deeper waters covered or fringed by macrophytes on at least one-third of their extent, as well as areas with hydromorphic soils, the upper layers of which are continuously or seasonally waterlogged and therefore support characteristic vegetation. In order to monitor the impact of the GNP on floodplain forests in Szigetköz, different institutes calculated production, growth, leaf area, and other indexes, which were used as indicators for forest health and trends. The forest monitoring performed by the Forest Research Institute within the framework of the general environmental monitoring in the country had the following objectives (Csóka-Szabados, Halupa, and Somogyi, 1997):

- to identify the main abiotic site factors and observe their changes;
- to study the impact of the measurable abiotic factors on the growth and development of trees and stands in the region;
- to study how tree growth reflects changes in the environment;
- to observe health conditions of trees and stands;
- to make economic predictions for forestry enterprises;
- to study forests as essential biological entities from a conservationist point of view.

In order to account for forest development changes in response to abiotic factors, the study examined the major environmental factors considered important in determining the spatial distribution, development, and productivity of terrestrial plants. These factors are climate, soil, and hydrological conditions. Csóka-Szabados, Halupa, and Somogyi (1997) classify the macroclimate of Szigetköz as that of a forest steppe, unfavorable for forests and stands of higher-than-marginal productivity in the absence of accessible groundwater or inundation. However, high evaporation because of the large open water of the river and its branches pro-

duces a mesoclimate slightly more favorable for the floodplain trees classified as sessile oak-turkey oak. Pure alluvial soils, characterized by azonal formation because of repeated depositions from the river and by sandy and muddy-sandy physical structures, combined with humic alluvial soils in higher elevations, define the soil profile of the region. Below the nutrient-rich and regularly deposited alluvial layers, ranging from 50 to 150 centimeters in depth, a thick gravel layer mixed with coarse sand exists. The hydrological conditions are defined in terms of the elevations of the soil surfaces above the water level. High elevations, according to Csóka-Szabados, Halupa, and Somogyi (1997), account for only 2% of the floodplain, and middle-high and middle-low elevations under a constant supply of water for 1–2 months annually account for 20% and 71% of the floodplain, respectively.

Productivity was measured on 30 plots, each measuring 0.1–0.25 hectares, in predominantly hybrid-poplar stands (80%), which are considered most sensitive to environmental changes. Hybrid-poplar stands constitute 65% of all floodplain forests. Stand volume and increment were determined by measurements of tree height and of tree diameter (at breast level) carried out annually after the vegetation season. The changes in the measured parameters and their variations according to the differences in tree species, age, and silvicultural treatment (thinnings), as well as differences in weather conditions, were analyzed. Also, from 1–2 weeks before the vegetation period to 1–2 weeks after it, girth growth measurements of single trees in 10 of the 30 plots were conducted weekly. Changes in growth rhythm, points of local maximum, and the length of the vegetation period were taken into account as indicators of changes in the environment. Because of difficulties in investigating individual influences, however, studies focused on factors at minimum values, i.e., limiting factors at the local positive or negative peaks of the growth curves (Csóka-Szabados, Halupa, and Somogyi, 1997).

In addition, the health of forests in Szigetköz was monitored as an indicator of long-term trends in the region. The University of Forestry and Wood Science in Sopron, together with the Scientific Institute of Forestry, conducted measurements twice a year at sample plots, each containing 100 trees. They recorded changes in the following parameters: lack of foliage, quantity of dry branches in the crown, top dryness, trunk damage, stump and root decay (Varga, 1997). Insect light traps were used for recording changes in the whole community. Soil quality, based on soil profiles in the sample plots, was also reported in order to help identify the causes of changes in the health of the forests.

As in the Slovak Republic, changes in leaf area have been monitored both in localities on Szigetköz which have been influenced by the diver-

sion of the Danube and on areas which have not been affected, for the sake of comparison. Starting in 1989, the Department of Plant Taxonomy and Ecology at Eötvös Loránd University conducted annual measurements based on samples of 200 leaves collected in autumn, after leaf fall (Szabó et al., 1997).

Results from the above-mentioned monitoring activities indicate that, as expected, the putting into operation of the Gabčíkovo part of the project did not have a uniform impact on floodplain forests in Slovakia. About 2,500 hectares of floodplain forests and other flora communities disappeared. Disintegration of forest communities in the area between the Čunovo reservoir and the main trailrace channel – a process which had started about two decades earlier – continued at an accelerated pace. However, the increase of groundwater levels at the reservoir stimulated a regeneration of the humid floodplain forest in previously destroyed habitats (Šomšák, 1999). Results from dendrometric and tree diameter measurements during the periods before and after the damming roughly corresponded to the model-based forecasts of intensified growth in the areas where groundwater levels increased, i.e., in the parts of the territory downstream, and were confirmed by dendrochronological analysis (Šmelko, 1999). The changes in the leaf area index also reflected the negative impact of the decrease of groundwater level above the intake structure at Dobrohošt' and in the narrow belt along the old Danube main channel on floodplain forests, as well as the positive effect of the rise of groundwater levels associated with the construction of the Čunovo reservoir. Small or insignificant groundwater level changes (both positive and negative) in most of the monitored sites were not reflected in the leaf index changes (Oszlányi, 1999).

On Hungarian territory, the most adverse impact of the diversion of the Danube on floodplain forests was registered in the middle part of Szigetköz, where groundwater levels fell below the topsoil layer. The resulting conditions were characterized as favorable for species with a wide range of tolerance for changes in the environment, in particular a high degree of tolerance for drought (Szabó et al., 1997). The new conditions were found to be most unfavorable for willow stands, according to the results of growth monitoring (Csóka-Szabados, Halupa, and Somogyi, 1997), and to have, on hardwoods, both a limited impact, since they are less dependent on water availability, and an impact more difficult to detect, since they grow at a slower rate. At the same time, however, Hahn et al. (1997) point out that changes in the hydrological conditions led to the formation of new habitats for terrestrial plants, such as the exposed riverbed where a new willow thicket belt was formed in the years immediately after the diversion of the Danube. Csóka-Szabados, Halupa, and Somogyi (1997) report that the deteriorating health of the monitored

forests was reflected in an abnormally early shedding of leaves, the way a tree reacts to drier conditions in order to avoid damage to itself. Top dryness, observed by Varga (1997) in the area of Rajka-Dunakiliti, seems to support those findings. However, Csóka-Szabados, Halupa, and Somogyi (1997) note that in some cases the exact causes of the observed changes are difficult to determine and the period of observation was not long enough to draw reliable conclusions.

The results of the floodplain forest monitoring carried out in the two countries in the years before and immediately after the Gabčíkovo part of the GNP was put into operation were used as a basis for elaborating technical measures needed to provide additional water supplies in the most adversely affected areas. Some of these measures were jointly agreed in 1995 and implemented shortly afterward. Their impact is currently being observed within the framework of the joint monitoring programme in the affected areas. In 2001 the joint forest monitoring network included 15 observation plots on Slovak territory and 12 on Hungarian. Most of the monitored forests in the two countries are poplar stands. Two willow stands are monitored in Slovakia, and one alder and one oak stand in Hungary. The forest observation sites as other components of the joint monitoring network are being continually reviewed and modified. The locations of the original joint monitoring sites are presented in figure 16 and table 9. The two countries are measuring the weekly girth growth and examining the health of their observed forests using comparable methodologies. To evaluate the forests' health, they are using, or planning to use, aerial photographs. In addition, they are evaluating data concerning annual wood yield (Joint Annual Report, 2001).

Biota monitoring

The monitoring of individual species or groups of fauna and flora has a long tradition (Böcker et al., 1991; Duvigneaud, 1988) that can be traced back to the earliest efforts to study life forms on earth. In more recent years, the development of biological monitoring has been closely related to ecosystem ecology as a new "integrative science," pioneered by Odum (1971). Taking a broad view of the environment, Odum urged integration of the individual pieces of the puzzle in the context of the complex interrelationship between the living and the nonliving environment.

Advances in the knowledge of biological organisms and their reactions to changes in the physical environment, combined with progress in microelectronic and information technology, led to the employment of biological indicators for monitoring the state of the environment and the impact of anthropogenic factors. For example, continual biological monitoring of water quality in the major international rivers in Europe has

Table 9 List of stations for forest monitoring [Source: Groundwater Consulting]

	Country	Station No.	Location and tree species	Age
1	Slovakia	2681	Sap, willow	26
2	Slovakia	2682	Gabčíkovo, cultivated poplar – Robusta	22
3	Slovakia	2683	Baka, cultivated poplar – I-214	22
4	Slovakia	2684	Trstená na Ostrove, cultivated poplar – Robusta	22
5	Slovakia	2685	Horný bar – Bodíky, cultivated poplar – Robusta	28
6	Slovakia	2686	Horný Bar – Šul'any, cultivated poplar – Robusta	18
7	Slovakia	2687	Horný bar – Bodíky, cultivated poplar – I-214	28
8	Slovakia	2688	Vojka nad Dunajom, cultivated poplar – I-214	18
9	Slovakia	2689	Vojka nad Dunajom, cultivated poplar – Robusta	37
10	Slovakia	2690	Dobrohošt', cultivated poplar – I-214	24
1	Hungary	9600	Dunakiliti 6B, cultivated poplar – Robusta	23
2	Hungary	9992	Dunakiliti 13B, cultivated poplar – OP-229	17
3	Hungary	9991	Dunakiliti 14C, cultivated poplar – I-214	16
4	Hungary	9496	Dunasziget 5E, cultivated poplar – Robusta	27
5	Hungary	9498	Dunasziget 11D, cultivated poplar – I-214	17
6	Hungary	9994	Dunasziget 21B1, oak	41
7	Hungary	9495	Dunasziget 34A, cultivated poplar – I-214	24
8	Hungary	9452	Hédervár 11B1, alder	52
9	Hungary	9995	Lipór 4A, cultivated poplar – Pannonia	11
10	Hungary	9980	Lipót 4A, cultivated poplar – I-214	11
11	Hungary	9979	Lipót 27D, cultivated poplar – Pannonia	14
12	Hungary	2690	Ásványráró 6G, cultivated poplar – I-214	28

Age specification is related to the monitoring performed in 1997.

been carried out since the 1970s, when the idea of using biological early warning systems, specifically, automated biological sensor systems for water quality management, was first proposed and elaborated (Gunatilaka and Diehl, 2000). Based on the principle of monitoring a certain function of physiology or behavior in a test organism, which changes as a result of exposure to a toxic substance at a sufficient concentration, biological monitoring initially employed fish, and later, algae, mussels, photobacteria, and other organisms. Some of the commonly monitored functions include swimming behavior, decline of luminescence, delayed fluorescence, and oxygen production, as well as the opening and closing of valves. Dynamic alarm thresholds, comparisons of activity patterns and of samples versus controls, and former data or fading curves are some of the basic evaluation methods employed. Biomonitoring is still considered to be in its infancy, since over the past three decades advances in its methodology, despite large strides in biochemistry, molecular biology, and genetics, have remained confined to the laboratory stage (Gunatilaka and Diehl, 2000). Yet biological monitoring is a widely recognized and an increasingly employed element of environmental monitoring.

In addition to the kind of biological monitoring used for early warning, another type of biological monitoring, called biodiversity monitoring or biota monitoring and used for conservation purposes, has expanded over the past decade. Preserving biological diversity, which refers to the varieties of life on earth at the genus, species, and ecosystem levels, was internationally recognized as a global concern through the Convention on Biological Diversity (CBD), which was adopted at the United Nations Conference on Environment and Development (UNCED) in 1992 in Rio de Janeiro. The international commitment to ensuring the preservation of biological diversity was confirmed at the 2002 World Summit on Sustainable Development in Johannesburg, which led to the development of ‘‘A Framework for Action on Biodiversity and Ecosystem Management’’ (WEHAB Working Group, 2002). Biological monitoring is a basic tool for achieving this international goal as indicated by Article 7 of the CBD which requires each party to:

a) identify components of biological diversity important for its conservation and sustainable use according to the indicative list of categories set down in Annex I;
b) monitor, through sampling and other techniques, the components of biological diversity identified pursuant to subparagraph (a) above, paying particular attention to those requiring urgent conservation measures and those which offer the greatest potential for sustainable use;
c) identify processes and categories of activities which have or are likely to have significant adverse impacts on conservation and sustainable use of biological diversity, and monitor their effects through sampling and other techniques; and
d) maintain and organize, by any mechanism, data derived from identification and monitoring activities pursuant to subparagraphs (a), (b), and (c) above.

In Europe, biodiversity has been part of the reports made to the ministerial conferences within the ‘‘Environment for Europe’’ process of the UNECE. In addition, Pan-European intergovernmental conferences on ‘‘Biodiversity in Europe,’’ held in Riga in 2000 and in Budapest in 2002, have taken up the issue of the establishment and integration of biodiversity monitoring on the continent. The latter was elaborated in a proposal for a European Biodiversity Monitoring and Indicator Framework developed in 2001 by the European Center for Nature Conservation and the European Environment Agency (EEA) in consultation with key stakeholders in Europe (Delbaere, 2002). As indicated by the title of the framework, a major problem in the establishment of biodiversity monitoring is the identification of appropriate indicators to capture the ongoing biological processes.

Biota monitoring, or the monitoring of biocenoses and biotopes, aims to study the accumulated long-term environmental trends reflected in changes in flora and fauna populations. That study is possible because plant and animal species constitute vehicles of certain indicative charac-

teristics and ecological functions in the ecosystem. However, the selection of appropriate indicators, as well as the method of quantification thereof must take into account the different organizational levels of biota – individual, population, ecosystem (Odum, 1971; Duvigneaud, 1988) – characterized by different resolution scales and time steps. Indeed, as mentioned above, an indicative list of suggested categories was developed as an annex to CBD, and the process of developing national indicators is guided by a work programme endorsed at the third meeting of the Subsidiary Body on Scientific, Technical, and Technological Advice and other CBD follow-up activities (Delbaere, 2002). Because of the differences in the ecological conditions in different areas, however, the set of recommended groups can not be readily applied to concrete cases.

In addition to the selection of appropriate indicators, data collection and interpretation pose significant challenges related to the fluctuations obscuring the detection of long-term underlying trends. Such fluctuations may be related to natural population dynamics associated with births, deaths, immigration, emigration, weather effects, etc., as well as to methodological deficiencies and constraints (USGS Patuxent Wildlife Research Center, 1999). Thus, while biological monitoring is not necessarily a capital-intensive activity requiring the use of sophisticated technology, it does require highly qualified experts (''Ecological Monitoring,'' 1995).

In the GNP case, the necessary expertise for biological monitoring was developed in the course of the biota monitoring on the GNP-affected area, which was established in Hungary and the Slovak Republic in the late 1980s and early 1990s. Although, compared to other components of the environmental monitoring, biota monitoring in the two countries has a relatively short history, the accumulated data provide the baseline necessary for evaluating the ongoing biological processes in the area.

The appeal of biological monitoring is that, unlike traditional indicators, biological ones allow for directly measuring the state of the living environment and its dynamic changes and responses to external factors, such as the construction and putting into operation of the GNP. In the Slovak Republic the biological monitoring in the areas affected by the GNP established in 1989 (fig. 20) was defined as a monitoring aimed at evaluating the impact of a particular stress factor on the living environment (Lisický et al., 1991; Rovný et al., 1992; Matečný et al., 1993; 1994; 1995a; 1996a; 1997). That type of monitoring was differentiated from what came to be known as basic monitoring under the two-level biota monitoring network, which was established as one of the twelve sectional monitoring systems that the Ministry of the Environment of the Slovak Republic developed in the framework of the Information System on the Slovak Republic's Environment. The two levels are currently defined as follows (Cambel and Rovný, 1991):

– a first (higher) level consisting of the so-called complex monitoring areas which are only few in number in each natural unit and display a wide range of monitored elements with the highest frequency of monitoring;
– a second (lower) level consisting of so-called complementary monitoring areas with a reduced range of monitored elements and a lower frequency of monitoring. These complement the complex areas. The second level is aimed at working toward characterizing the state of and changes in the entire natural unit.

The network is currently made up of 120 basic and 316 complementary monitoring areas by geomorphologic units.

The concept of biota underlying those monitoring projects was defined on the basis of discussions among specialists from different branches (zoology, botany, forestry, geography) and of works by Cambel, Matečný, and Rovný (1992) and by Cambel and Rovný (1991). A basis for the design and implementation of the biota monitoring was provided by the knowledge accumulated through earlier observations of individual protected animal species, short-term studies under the basic research on tracts of fauna or flora, early forest monitoring cognate to biota, especially in a floristic respect (Zapletal and Dudík, 1991), as well as the monitoring carried out over the last two decades of some areas of bioindicative groups like mosses, stricken by polluting emissions and demonstrating the concentrations of fluorine.

The main principles used as a basis for the design of the biota monitoring systems in the Slovak Republic and for the selection of the appropriate indicators are permanence, integrity, and comprehensiveness. Permanence is to be read as a time regularity and boundlessness of the monitoring process. Integrity resides in a uniform method of selecting the monitored areas of the observation network and in identical methods of observing, processing, and evaluating monitoring elements. Comprehensiveness refers to the need for monitoring ecosystems in the context of the internal and external relationships they entail. In practice, that means monitoring not only the subject of the monitoring system – flora and fauna – but also those elements and relations that determine their state. These imply the need for the observation of relevant parameters from the atmosphere, hydrosphere, and pedosphere as well. Comprehensiveness, however, does not mean that the biota is poised to be monitored across its species variety. The selected monitored elements, especially in the case of fauna, have to be indicative of important groups – not necessarily of the so-called taxocenoses but of the groups considered important in view of the objectives of the specific programme.

The principles of biota monitoring in the areas affected by the Gabčíkovo part of the GNP were developed along with the broader conceptualization of the terms discussed above. The original idea was a network

of 44 monitoring sites (Matečný et al., 1995b). Following the cancellation of the Nagymaros part of the project, the network was reduced to 24 sites that were selected based on surface projections of the stress factor being examined. In particular, the relation of the locale to an envisaged regime of underground waters was used to select a set of observation points covering biotope areas representative for the region of anticipated water level increases and decreases, as well as so-called control zones in the areas where no change was anticipated and relatively intact natural ecosystems was preserved (Lisický et al., 1991; Matečný et al., 1995a). The goal of the monitoring were to identify the principal trends in the development of biota. Thus the focus of the monitoring was flora and fauna. In addition, and in accordance with the principle of comprehensiveness discussed above, soil, water, and microclimate were also observed.

Individual methodologies were developed for each individual monitored indicator, both in light of sampling and measurement and processing and evaluating procedures (Matečný et al., 1993; 1994; 1995a; 1996a; 1997; Cambel, Matečný, and Rovný, 1992; Koreň et al., 1992). Individual procedures were based on the standards accepted for the particular methods in the respective disciplines (Braun-Blanquet, 1964; Hajdúk, 1989; Zapletal and Dudík, 1991; Ložek, 1956; Maglocký, 1983; Kováč, 1994; Pilous and Duda, 1960; Pišút, 1985; Škapec, 1992; Baruš and Oliva, 1992; Dostál, 1990).

The monitoring of phytocenoses was subdivided into observation of micro- and mesostructures of vegetation. At the micro level, the quantification method used was based on the principle of counting individuals inside a precisely delimited observation site; the count was carried out once or twice annually during the optimum vegetation development period. Special attention was paid to dominant species and ones with indicative values, such as nitratophilles and neophytes. Balance indexes, in addition to density and frequency indicators, were calculated. Ecological value indexes reflecting light, temperature, and humidity requirements were also estimated. In forest ecosystems, including hardwood, softwood, and passable meadow groves, as well as Danubian hawthorn and poplar grafts, dendrological components were observed through measurements of basic dendrometric quantities, health, and leaf loss. In some cases, leaf area index vegetation cover indicators were also calculated (Matečný et al., 1995b). At the mesostructure level, geobotanical semiquantitative photographs of vegetative communities were taken once or twice a year within a period of optimum vegetation development and were evaluated based on a seven-point scale of abundance and dominance, with the covering of individual tree, shrub, and herb layers or floors determined as a percentage.

Fauna monitoring was subdivided into terrestrial and aquatic fauna,

including 12 and 19 species groups, respectively. Terrestrial fauna was monitored on 5 key observation areas and 9 supplementary ones (Štepanovičová, 1995). Data collection methods and frequencies varied in accordance with the peculiarities of the wide spectrum of monitored species (Matečný et al., 1995a).

Soil observation within the framework of biota monitoring focused on two main parameters, namely, monitoring of soil moisture and chemical properties of soil. Measurements were performed at 7 and 11 of the 24 biota monitoring locations, using methodology similar to that used for the soil monitoring conducted independently from the biota monitoring. For example, soil humidity was measured with a neutron probe with a measurement step of 0.1 meter. The chemical properties of soil were evaluated based on analysis of nine parameters, including humus content and sorption properties, in addition to a number of chemical indicators.

Groundwater measurements were carried out at 5 monitoring sites twice or three times per month and at 3 observation sites daily. Nineteen physical and chemical parameters were measured, using instruments of the Slovak Hydrometeorological Institute.

In addition to the above-mentioned components, microclimatic characteristics, focusing on air temperature, relative aerial humidity, soil temperature, and velocity of wind, were measured at 3 localities in 1990. Because of the extraordinary requirements for such measurements and the difficulties associated with the interpretation of the collected data, monitoring of those elements was discontinued with the intention of soliciting support from relevant monitoring agencies (Matečný et al., 1995b).

In Hungary a national biodiversity strategy proposing the monitoring of 290 plant species, 106 plant communities, 245 animal species, and 9 animal assemblages was developed in response to the obligation of the country as a party to the Convention of Biological Diversity signed in Rio de Janeiro in 1992 (Török and Fodor, 2003). The programme, aiming at ensuring long-term biodiversity, was launched by the Authority for Nature Conservation of the Ministry of the Environment in 1995, and monitoring began in 1998 with the support of Phare funding. A ten-volume series of monitoring manuals describing the general fundamentals of monitoring and giving a short description of the objects selected for monitoring and the sampling methods was published, and the proposed methods were tested in the Tisza River floodplain in 1995 (Lisický, 2000). The goals of the monitoring have been defined as follows: to provide data on the state of the biota; to estimate the direction of changes (to distinguish trends from "noise"); to test hypotheses on the effects of different environmental changes and impacts; to support decision making related to nature conservation; and to establish a biological

information system. The main principles of guiding the monitoring are as follows (Török and Fodor, 2003):

- The monitoring programme must follow the hierarchy of biological organization: landscape, community, population levels;
- at each level, a strict selection of entities is needed;
- priorities during the selection of objects: endangered, protected values, elements characteristic of Hungary, effects of environmental or human impacts;
- priorities during the selection of methods: simple, easily repeated, widely used (accepted) methods, partly to facilitate the participation of nonspecialists; nondestructive sampling of endangered species;
- priorities during the selection of localities: value of habitats, regional environmental constraints, representation of different landscapes, availability of historical data, easy access.

Currently a biodiversity monitoring system consisting of 124 monitoring sites for habitats (5 by 5 kilometers each), classified according to the European Habitat Classification System (EUNISHAB), and of 130 quadrates for plant communities (100–2500 m^2 each) exists. The system includes degraded habitat types, as well as cultivated land and man-made habitats. The monitoring is implemented by the National Biodiversity Monitoring Service, supported by the National Advisory Board, with the Institute of Ecology and Botany of the Hungarian Academy of Sciences and the Hungarian National History Museum as the leading institutions, as well as by other external specialists and NGOs (Lisický, 2000; Czirák, 2003; Török and Fodor, 2003).

Biota monitoring on Szigetköz is the oldest of the ten monitoring projects within the Hungarian Biodiversity Monitoring System. It was set up in 1986, and monitoring was carried out by the Department of Plant Taxonomy and Ecology at Eötvös Loránd University in Budapest (Szabó et al., 1997). Zoological monitoring in the region was established before the diversion of the Danube in 1992 and has been carried out by the Zoological Department of the Hungarian National History Museum in Budapest in cooperation with the Limited Company of Agricultural and Food-Industrial Managers in Györ (Mészáros and Bertalan, 1997).

The goal of the botanical monitoring system was the regular collection and analysis of plant populations, communities, and the regional flora as indicators of environmental changes. The design of the monitoring programme was based on earlier studies and tested methodologies that used changes in certain vegetation characteristics to assess habitat properties – studies and methodologies such as those of Clements in 1920, Juhász-Nagy in 1970, and Weaver in 1924, among others (Szabó et al., 1997). A measurement of vegetation changes at the community level included the recording of species composition and abundance based on annual surveys of permanent quadrates. For the analysis of the collected data, species

group spectra were computed from cenological tables; the proportion of species groups was formulated according to a moisture preference index; and the nature conservation ranks of the species were estimated. Population indicators, capable of reflecting habitat changes more rapidly and sensitively, allowed for the study of morphology, ecophysiology, and phytomass production. Changes in leaf surface area and shoot height of several indicator species were also monitored. The flora status and vitality of the populations of the protected and endangered rare plant species were evaluated. In the evaluation of vegetation changes, particular attention was paid to the dynamics of abundant changes of species in the natural phase of succession, the speed of plant colonization on the newly exposed substrate, and the changes in the substrate itself due to the vegetation cover (Hahn et al., 1997).

Monitoring of the fauna on Szigetköz was motivated by the high biodiversity value of the region, characterized by species richness, special associations of species, and a high degree of special mosaicity, as well as by the expected damage or loss of value as a result of the construction and operation of the GNP (Mészáros and Bertalan, 1997). Evaluation was based on the belief that the sustenance of biodiversity, which is a characteristic parameter of nature and thus of the preservation of every specimen, species, population, and association of the biota on earth, is critical for the maintenance of life. A particular focus was placed on the conservation value of zoodiversity. This reflected in the wide spectrum of fauna included in the Landscape Conservation Area in Szigetköz established in 1987 and covering 375 km^2 of land situated between the old Danube and the Mosoni Danube branch (Koltai, 1997). The fauna of the conservation area consists of approximately 40 mammal species, 170–200 species of birds, 67 fish species (constituting about 75% of the fish fauna in Hungary), most of the amphibians living in the country, and several reptile species (Bolla and Kárpáti, 1997).

The pre-1995 biota monitoring in the areas affected by the construction and operation of the Gabčíkovo part of the GNP in the territories of both the Slovak Republic and Hungary provides the basis for studying the impact of the project on the living environment in the area. While the nature of biological processes and the limited time span of the monitoring make it difficult to draw conclusions regarding long-term trends, the accumulated data provide not only snapshot pictures of the state of biota before and after the construction and putting into operation of the project but also an indication of the immediate, short-term impact of the project on some of the elements of biota that were directly affected by the water regulations. Aquatic fauna and flora indicators for example clearly reflected the changes in the hydrological regime of surface water in the years immediately after the damming of the Danube. At the same

time, changes in terrestrial organisms corresponding to the modifications of the groundwater regime, and thus of soil moisture, were manifested at a slower rate. It should be noted, however, that the dependence of the surface water and groundwater regime and quality, which are accepted as the limiting factors for the development of biota in the area during the examined period, on other natural and anthropogenic factors unrelated to the water regulation works requires additional caution and adds to the uncertainty in interpreting the observed biota changes.

According to biota monitoring in the affected areas in the Slovak Republic, the damming of the Danube had a most notable impact on aquatic fauna, which were affected by the two main changes in the hydrological regime of surface water after the putting of the Gabčíkovo part of the project into operation – namely, the decrease of the discharge in the old main channel and the fluctuations of water levels in the adjacent side arms. Krno et al. (1999) point out, however, that changes in the hydrological regime affected differently the different parts of the river and thus the respective biological processes taking place there. In the upper part of the original riverbed, for example, the formerly mobile bottom partially stabilized; modified abiotic factors allowed excessive development of algae on the gravel bottom; and the metabolism of the river shifted from heterotrophy to autotrophy. The increased amount of food selection resulted in a significant increase of the abundance and biomass of zoobenthos. At the same time, in the lower section of the Danube, upstream from the confluence with the tailrace canal, the change of the character of the substrate and hydrological regime resulted in the almost complete destruction of the original community of benthos.

In the side arms a strong development of submersed macroscopic plants in formerly open water and/or on the gravel bottom was observed. The accumulation of silt and sandy sediments above the formerly gravel sediments resulted in a decrease of the diversity of benthos, along with the transformation of the biota of those ecosystems from aquatic to terrestrial.

According to the results from the monitoring of zooplankton, the transformation of the Danube arm system and in particular the periods of stagnant water flow led to a considerable decrease of the arm system's average abundance and biomass. That change was particularly notable for planktonic crustaceans in the previously parapotamon side arms downstream from the water supply structure at Dobrohošt'. The average proportion of euplanktonic crustaceans among the potamoplankton also declined in the section of the Danube between Čunovo and Gabčíkovo. Conditions for the development of euplanktonic crustaceans, however, remained suitable in the former parapotamon arms in the area between Gabčíkovo and Sap (Vranovský and Illyová, 1999).

The change of the character of some of the river branches from lotic, i.e., characterized by running water, to lentic, i.e., characterized by still water, and the associated changes in their physical and chemical characteristics also proved the determining factor for phytoplankton development in the period after the damming of the river (Makovinská and Hindák, 1999). While the recorded diversity of phytoplankton, including 263 genera, 1,063 species, and 106 varieties and forms, remained relatively high, chlorophyll-a, an indicator of phytoplankton biomass, showed a decreasing tendency in some of the monitored locations. Net primary production of phytoplankton was characterized by seasonal fluctuations corresponding to changes in the hydrological surface water regime.

Changes in zooplankton and phytoplankton – the main food of juveniles – constituted a part of the interrupted natural processes, which also affected the development of ichthyofauna after the damming of the Danube. Apart from the interruption of existing food chains the cutting off of some of the branches and the change of their character from lotic to lentic hindered migration possibilities for fish, while the decrease in the water level and the rise of the littoral in the original riverbed resulted in the disappearance of a number of natural shelters and thus in decreased fish abundance and species diversity in the littoral of the former main stream. The absence of floods and the extinction of the inland delta of the Danube led to a decrease in the number of habitats suitable as spawning grounds, pastures, and wintering grounds, which caused secondary changes in the structure of the ichthyocenoses and a decline in their productivity (Černý, 1995). According to Holčik (1995), following the damming of the river, total catch decreased by about 84% compared to the long-term average, and the decline corresponds to the prognosis of the development of ichthyofauna and fishery as a result of the GNP – a prognosis published in 1981. However, while largely a result of the ecological changes in the environment, a part of that decline, according to Černý (1995), should be attributed to other causes, such as illegal fishing. At the same time, while the impact of the diversion of the Danube on itchyofauna and fisheries, especially in the side arms, has been largely classified as negative, the reservoir has been found to play an important role during extremely high discharges as a large refuge for fish that have drifted from the very long upper stretch of the river, and the reservoir's ichthyofauna has been documented as diversified and valuable both from a zoological and economical point of view (Kirka, 1995).

Parallel to the changes in aquatic biota as a result of the changes in the hydrological regime of surface water, transformations of terrestrial flora and fauna because of the modification of the hydrological regime of groundwater in the region were also recorded. Those changes, however, were slower and somewhat more balanced. That was due to the indirect

impact of surface water changes and to the reciprocal changes of groundwater levels, leading to the destruction of biotopes characterized by high levels of biodiversity in certain areas but at the same time giving rise to conditions favorable for the creation of similar biotypes in other areas (Šomšák and Kubíček, 1995). As a result, the two years of terrestrial biota monitoring following the damming of the Danube provided no evidence for an overall decrease in the biotypes in the affected areas in Slovak territory.

Studies of vegetation and ecosystem changes in the region from a long-term perspective, based on evidence provided by earlier human interventions in the river basin environment, indicated the adaptability of ecosystems to different conditions. The development of terrestrial fauna in the affected areas in Slovakia during the examination period was also evaluated on the basis of the accumulated knowledge of the dynamic changes of original biotopes and of the changes in zoocenoses associated with them, elaborated in 1,979 items of zoological research on the region of the Danubian lowland published until 1985 by 729 domestic and foreign authors (Štepanovičová, 1995).

According to results from the terrestrial biota monitoring, the decrease of soil humidity in the floodplain forests between the bypass canal and the old Danube close to the riverbed which was manifested in 1992 after the diversion of the Danube, and the increase of soil moisture in the upper part of the area at the reservoir after 1993, i.e., after the start of the operation of the Gabčíkovo structures, had a very pronounced effect on invertebrates inhabiting the upper layers of the soil and leaf litter of floodplain forests. For example, as a result of the decrease in the groundwater level on the northern margin of the inner Danube delta, close to the beginning of the bypass canal, there was a decline in the population density of typical hygrophilous species and an increase in less water-demanding mesohygrophilous species. This change reflects a modification in the character of the softwood floodplain forest fauna communities. The impact of the changes of the hydrological regime on the floodplain forest in the region of the bypass canal was exacerbated by the high average daily temperatures, a long-lasting drought, and an absence of floods during the first years following the diversion of the Danube (Štepanovičová, 1995).

Unlike the partial aridization of floodplain forests in the region of the bypass canal in Slovakia there was the increase in soil moisture in the upstream part of this area, influenced by the Čunovo reservoir. Changes in terrestrial invertebrates in forest communities in this area were most clearly manifested in transformations of the structure of molluscan species, which react to changes in soil moisture very sensitively. The increase of the groundwater level resulted in the creation of conditions for the

appearance of typical hygrophilous species, which had not been observed there in previous years. Corresponding changes in the population densities of dominant species and species spectrums were also recorded (Štepanovičová, 1995).

Worth noting are also the results of bird monitoring in the area, which indicated a shifting of some of the water fowl from the old Danube riverbed and branch system to the reservoir and a considerable growth in the number of individuals, including species not typical of the Danubian area and species rare in the country. According to Kovačovský and Rychlík (1995), such a change was the result of the establishment of suitable conditions for hibernation, resting, food search, and nesting provided by the new, stabilized water surface which became an important gathering place for migrating and hibernating birds, as well as a consequence of the considerable ongoing construction in the immediate surroundings of the Danube River during the examined period. Áč (1995) suggests that some of the observed changes may have been due to population trends and some were most likely associated with the changes in the hydrological regime of the Danubian floodplain on Hungarian territory, as indicated by recorded bird dynamics related to earlier regulation works in the area.

This hypothesis, however, is difficult to test, since biota monitoring in the territory of Hungary before 1995 was carried out independently and was based often on similar, but not necessarily identical, indicators and methodologies. However, as in the Slovak Republic, biota monitoring in Hungary was designed to study the impact of the changes in the hydrological regimes of surface water and groundwater on aquatic and terrestrial biota in the region, respectively (Meszáros and Bertalan, 1997). Since the surface water and groundwater hydrological regimes changed in a similar way, their impact on both aquatic and terrestrial fauna in the region was similar, though the degree of the changes and thus their impact on biological processes differed. The decrease of water discharges and water levels in the Danube old riverbed and in the branch system in Szigetköz as a result of the diversion of the Danube directly affected aquatic biota. According to results from the monitoring of aquatic and semiaquatic fauna, aquatic molluscan species became extinct in temporary ponds, channels, and ditches, where water disappeared completely following the diversion of the Danube. The decline of surface water levels also damaged or led to the disappearance of an estimated 50% of the Szigetköz fish nurseries (Meszáros and Bertalan, 1997). The deterioration of spawning sites in the big branches near the main branch in upper and middle Szigetköz resulted in a decline of the production of fish. In 1993, for example, 20% less fish were caught from water bodies in Szigetköz than in 1992. An estimated 50% of the bigger mussels completely vanished, and about 70–80% of the smaller ones perished (Meszáros and

Bertalan, 1997). Changes in the water regime were also detected through the population structure changes of frogs in certain areas. They corresponded with the general trend of a decrease in the number of aquatic and semiaquatic species and of an increase in the number of drought-tolerating or xerophilous species. Changes in habitat conditions, manifested in an abnormal migration pattern of some of the least mobile wetland-meadows species, which were found outside their natural habitats in the middle of the summer (Meszáros and Bertalan, 1997), also reflected the transformations of aquatic and terrestrial flora.

Results from the monitoring of cryptogams, i.e., flora species such as algae, moss, and fern characterized by their small size and short life span, which make them more sensitive to changes in the environment, indicated a trend of disappearance of aquatic and riparian species and their replacement by forest ones (Buczkó et al., 1997). The decline of sediment transported from the Danube created conditions for the development in the Szigetköz branch system of phytoplankton species, which are typical for the Danube main branch but which had not been previously observed in the region (Buczkó et al., 1997). The constant low water level in the branch system, however, promoted the uniform spread of algal patches, leading to a gradual disappearance of the mosaiclike character of the previously existing habitat. At the same time, the decline of the water level and the associated increase of water plants emerging from the water accelerated the natural ageing process of the aquatic environment, which typically takes place through the accumulation of sediments. This was manifested in the years following the diversion of the Danube, in the significant benthonic eutrophication witnessed in 1994 (Buczkó et al., 1997).

It should be noted, however, that these biological processes were not observed throughout the Szigetköz area. In the Mosoni Danube, specifically in the channels outside the dikes and in the water bodies affected by them, for example, no aquatic and semiaquatic fauna changes were detected, and in some places populations were strengthened (Meszáros and Bertalan, 1997). At the same time, while terrestrial flora habitat degradation was observed in some places, as indicated by the decrease in the proportion of water-demanding species and by the more frequent occurrence of weedy- or disturbance-tolerant ones (Szabó et al., 1997), the exposed riverbed created conditions favorable for the formation of new willow thicket belts in certain areas (Hahn et al., 1997).

However, while results from the monitoring of biota in the years before and immediately after the putting into operation of the Gabčíkovo part of the GNP give some indication of the state of the living environment at the time, their interpretation is subject to the relative values placed on different plant and animal species. Furthermore, Hungarian

and Slovak specialists reporting on the pre-1995 results of the biota monitoring point out the uncertainties associated with the results and the inadequate basis they provide for a prognosis of long-term changes in different hydrological conditions. The joint biota monitoring in the areas affected by the additional supply of water in the old Danube and side arm system agreed in 1995 constitutes a step forward in overcoming those challenges. The joint monitoring network currently consists of 6 complex monitoring areas on Slovak territory and 31 monitoring sites in Hungary. The originally agreed observation sites included in the joint monitoring are presented in figure 17. Biological monitoring in the two countries currently includes phytocoenological, terrestrial mollusks, macrophytes, aquatic mollusks, dragonflies, crustaceans, caddis flies, may flies, and fish. Despite ongoing consultations and attempts to integrate the monitoring and evaluation methods, some differences still exist.

Other monitored components

In addition to the components discussed above, which were initially monitored independently and later as part of the joint monitoring in the areas affected by the construction and operation of the Gabčíkovo part of the GNP, regular observation of a number of other elements of the environment began in the two countries in the late 1980s and early 1990s, coinciding with the escalation of the debate over the environmental impacts of the project. The dynamics of water in the zone of aeration, climatic trends, and the socioeconomic impacts of the GNP-related changes in the hydrological surface water and groundwater regimes were also examined by either or both of the countries in order to provide additional information about the dynamic interaction between the anthropogenic impacts and the environment in the region.

Zone of aeration (Slovakia)

The zone of aeration, i.e., the area between the ground surface and the groundwater level consisting of pores filled partially by water and partially by air, transfers changes in the surface water and groundwater regimes to the biosphere through changes in the soil moisture regime. Water dynamics in the zone of aeration are affected by precipitation and evaporation at the surface level, by the exchange of water between the groundwater and the zone of aeration at the bottom layer, and by the extraction of moisture by plants directly in the zone of aeration (Hlavatý and Cambel, 1995). In other words, the volume of water in the zone of aeration can be defined as the biosphere's water resources, and changes in the retained quantity can serve as an indicator of the impact of water regulation works on the living environment (Matečný et al., 1995b).

Given the above, the zone of aeration was included as a basic component in the monitoring system in the areas affected by the construction and operation of the Gabčíkovo part of the GNP and was established in Slovakia at the beginning of the 1990s. Given the dependence of the water transmission processes in the zone of aeration on soil cracks, composition of the soil horizon, and other characteristics of the individual environment, the goal of the monitoring in the zone of aeration was to obtain data on the retention and dynamic changes of individual characteristics defining the water regime and water chemistry in the aeration zone, in the areas affected by the water regulation works.

In view of the peculiar function of the zone of aeration and its linkages with the other monitored components of the environment, dynamic changes in the zone of aeration were examined by four expert groups, namely, one group monitoring water in the aeration zone, one soil, one forestry, and one biota. Monitoring of the water reserves, in particular of the course of cumulative water content and its quarterly averages in the zone of aeration, began in 1990 (Šútor, 1995). In addition, quantification of the participation of individual soil stratum in the cumulative water content in the aeration zone during given time intervals for selected typical monitored locations was performed. The analysis of water content in the individual layers was based on the irregular emptying of individual levels of the aeration zone. Changes in the water content in the different layers reflected the structure of the porous medium of the soils and were documented in changes in the distribution of the root systems of the vegetation cover.

Evaluation of the results of the monitoring of the zone of aeration during the period 1990–1994 was made in regard to the humidity retention line, which refers to the availability and accessibility of the existing water resources in the zone of aeration and the point of field water capacity, the point of lowered accessibility for vegetation, and the point of withering. In addition, discharge in the Danube (at Bratislava and Gabčíkovo), precipitation, and temperature at the different times of measurement were taken into account to ensure comparability of the results and control for the influence of nontarget factors. Based on the results, the correspondence of seasonal variations of dynamics in the zone of aeration with the hydrological regimes of surface water and groundwater was identified. However, regarding the impact of the waterworks, according to Hlavatý and Cambel (1995), the only certain conclusion that could be drawn was that an increase of the groundwater level as a result of water regulation works may lead to an increase of humidity in the aeration zone at some locations, while the humidity may remain unchanged at others, but no decrease of humidity could be observed. The opposite conclusion could be drawn in the case of a decrease of ground-

water levels. Concrete measurements indicate that, after the Gabčíkovo structures were put into operation, the average water content in the zone of aeration did not reach wilting point in any quarter of any year, and the observed integral water contents in the upper part of the Danubian lowland, in its central part and downstream from Gabčíkovo, as well as in some locations in the inundation territory, were higher than former average levels (Šútor, 1995). Results also suggest that water in the zone of aeration reacts to sudden changes with inertia and imply the possibility of the optimization of the water regime in cover layers in the inundation territory by changing the groundwater levels and/or flooding the territory within the framework of operating the Gabčíkovo structures. While providing a useful indicator of the interlinkages between different environmental elements, however, water dynamics in the zone of aeration was not included in the joint monitoring system most likely because of financial considerations related to the establishment of a relevant monitoring system in Hungary and the maintenance and updating of the existing one in Slovakia, and in view of the close linkages between the regime of water in the zone of aeration and soil moisture monitoring, which is included among the jointly observed environmental components.

Impact on agriculture

In addition to the interlinkages between the anthropogenic factors and the environment, as reflected by water dynamics in the zone of aeration, the monitoring of the impact of the water regulation works in both Hungary and Slovakia before 1995 attempted to quantify some of the direct influences of the construction and operation of the Gabčíkovo part of the GNP in socioeconomic terms. Experts in the two countries, for example, attempted, independently of each other, to measure the impact of the GNP project on agriculture through the results of soil monitoring carried out in the affected areas. In the Slovak Republic, for example, crop production of agricultural cooperatives in the affected area was monitored together with a wide set of basic physical and chemical soil parameters, pedogenic processes, and chemical compositions of soil and groundwater since 1984 (Fulajtár, 1995b). Results from the soil moisture monitoring and agricultural production studies in the Žitný ostrov area suggested that the pre-dam state of soil quality parameters, processes, and development trends in the monitored plots was preserved and agricultural production in the areas remained unchanged, except in the region adjoining the Čunovo reservoir, where agricultural conditions improved (Fujaltár, 1995a).

In Hungary, the impact of the construction and the putting into operation of the Gabčíkovo part of the GNP was analyzed by the Production-Development Department of Pannon University of Agricultural Sciences,

which carried out phenological surveys on 47 agricultural fields, examining the growth, the development, and the health of stands in the main development phases of plants, in farm production conditions, together with regular measurements of the water content of soil at 48 agricultural and 6 forest observation points in selected localities. Starting in 1989, measurements, adjusted to the weather conditions at the different development stages of plants, were carried out on 12–13 occasions between the end of March and the beginning of November. Agricultural utilities surveys based on field data from 17 agricultural units and 11 species covering 90% of the arable land of the examined region were evaluated, with controls for the effects of the methods of production on the size of the yield, as well as for weather and other factors such as nutrient supply (Palkovits, 1997). Groundwater level and irrigation changes which determined water supply were examined as limiting factors for agricultural production in the years following the damming of the Danube. Results from the agricultural monitoring on Szigetköz demonstrate the close relationship between groundwater levels and agricultural production and suggest that the decrease of groundwater supply in the territory following the diversion of the river accelerated the negative impact of the unfavorable weather conditions in the years following the diversion of the Danube and the associated decrease of groundwater levels on 19% of the territory of the island (Palkovits, 1997). Currently, while not directly included in the joint monitoring, the impact of groundwater and thus soil moisture changes on agriculture is evaluated through the soil monitoring on agricultural areas in the two countries. The link between agricultural production and soil moisture changes, however, is not analyzed in the Joint Annual Reports. Nevertheless, the linkages between agriculture and the environment are studied independently in the two countries, for example within the framework of the "National Agri-environmental Programme in Hungary" (Institute of Environmental Management, Szent István University, 2003).

House cracking in settlements in Szigetköz (Hungary)

Another socioeconomic-oriented consequence of the environmental changes in the area of Szigetköz resulting from the construction and the putting into operation of the Gabčíkovo part of the GNP was the reported cracking of houses in certain settlements on the island following the damming of the Danube. The results from the study of the hydrological and soil mechanical conditions on the affected areas, commissioned by the Hungarian Ministry of Environment and Regional Policy and carried out by the Eötvös Loránd Geophysical Institute, the Geological Institute of Hungary, and the Geotechnical Department of the Budapest Technical University, suggested that the drying up of clay soil

as a consequence of the drop of the groundwater level in the region due to the diversion of the Danube led to a 5–20% decrease in volume of the clay soil and that the sinking of the relief associated with it could be a reason for the observed house cracking (Nemesi and Pattantyús-Ábrahám (1997).

Climatic trends (Slovakia)

In Slovakia, monitoring of climatic trends was initiated in view of the importance of long- and short-term climatic trends and conditions for the evaluation of observed changes in the environment. A long-term climatological study revealed the significance of regional time trends of critical climatic elements during the period 1901–1994 in the area affected by the construction and operation of the Gabčíkovo part of the project. The results presented by Lapin (1995) show that regional trends of air temperature and potential evapotranspiration are unambiguously increasing. Within 90 years (1901–1990) air temperature rose by about 0.8 degrees Celsius, while potential evapotranspiration increased by about 14%. In warm half years (April to September), air temperature increased by 0.5 degrees Celsius and potential evapotranspiration by 11%. On the other hand, the trends of total precipitation, sunshine duration, and relative air humidity decreased. Precipitation dropped by 15% (in warm half-years by 20%), sunshine duration declined by 2% (in warm half-years by 3%), and relative humidity was lower by 5% (also by 5% in warm half-years). These trends suggest that, during the last 90 years, regional climate has been subjected to changes that have significantly affected several factors in the environment. The rise in air temperature and the simultaneous drop in precipitation and relative humidity have led to the increased potential for evapotranspiration. Because of these trends, requirements for soil moisture have increased while soil humidity, groundwater levels, and river discharges have declined in a larger area. The last decade was marked by particularly low precipitation, especially in the summer half-years.

The entire 1991–1993 period was characterized by above normal temperatures, especially in summer, with no month's temperatures falling below normal. Analysis of relative air humidity suggests that in each year of the period values were lower than the long-term means of the period 1951–1980, as well as those of the dry period 1981–1990. Potential evaporation reached 791 millimeters in the decade 1961–1970, 784 millimeters in 1971–1980, and 821 millimeters in 1981–1990, with no significant differences found within the area. These observed climatic trends and conditions served as a basis for an evaluation of the observed changes in the environment from a long-term perspective.

They were also used to draw attention to the expected positive long-

term impact of the construction of the hydroelectric power station in view of its air pollution-saving capacity, as compared to other sources of energy. According to some estimates, the production of net energy associated with savings of fossil fuels was expected to contribute to a decrease of Slovak emissions of SO_2, NO_x and ash by 5–7%. The actual energy-saving impact of the hydropower station, its possible associated economic benefits for Slovakia in view of the Kyoto Protocol, and its impact on long-term climatic trends, however, have not been addressed within the framework of long-term climatic trend observations, which were discontinued because of financial and technical considerations (Matečný et al., 1995a).

The monitoring of changes in the zone of aeration in the areas affected by the GNP, the studies of the project's actual and potential impacts on agriculture in Hungary and Slovakia, on human settlements, and on the broader climatic trends, as well as the analysis of long- and short-term climate changes as a background for evaluating changes in the local environment, draw attention to the multidimensional relationships among environmental changes and their socioeconomic impacts. These issues, however, have been left out of the joint environmental monitoring framework in view of the objective of the programme to provide an unbiased basis for decision making by separating the environmental from the sociopolitical aspects of the debate. The extent to which the joint monitoring programme has managed to fulfill its objective is illustrated by the results from the joint monitoring which have been accumulated over the first six years of its operation.

Joint monitoring results

Hydrological regime of surface water

Results of the joint monitoring of the hydrological regime of surface water were evaluated on the basis of the jointly agreed discharges and levels specified in the 1995 Agreement. In particular, the provisions of the Agreement state that, in case of an average annual discharge of 2,025 m^3/s at Bratislava, an annual average of 400 m^3/s should be discharged into the old Danube, as it flows parallel to the Gabčíkovo navigation canal downstream of Čunovo. During the vegetation period, the discharge should fluctuate between 400 and 600 m^3/s; in the non-vegetation period it should not be less than 250 m^3/s. In case of floods, the amount of water above 600 m^3/s discharged through the inundation weir is not taken into consideration when the annual average is calculated. In addition, 43 m^3/s of water is to be discharged into the Mosoni

Danube. Also the distribution of the additional supply of water in Hungarian territory is to be monitored (Joint Annual Report, 2001).

In hydrological year 2001, based on results of the monitoring, the average annual discharge at station number 1250, above Bratislava, was 2,169.76 m^3/s, about 7% higher than the long-term average for that section of the river. The average annual discharge flowing into the Danube downstream of the Čunovo dam during the same year was 487.04 m^3/s or 436.61 m^3/s, excluding the flood discharges. Both measures exceed the 428.60 m^3/s of discharges that the Slovak Republic was obliged to release according to the Agreement. Daily discharges during the year also fluctuated within the limits set in the Agreement, except for three occasions in the winter, when they fell below the agreed minimum. Thus, according to the Joint Annual Report (2001), Slovakia fulfilled its obligations under the 1995 Agreement regarding discharges downstream from Čunovo. It should be noted, however, that, as indicated by the earlier Joint Annual Reports (1996–2000), daily discharges regularly fell below the required minimum in the winter seasons and sometimes exceeded the agreed maximum during the vegetation period.

According to the Joint Annual Report (2001), Slovakia fulfilled its requirements also for discharges into the Mosoni Danube. The agreed discharge of 43 m^3/s was composed of the discharge of 40 m^3/s released to the Mosoni Danube through the intake structure at Čunovo and of the discharge of 3 m^3/s through the seepage canal. Although the actual values fell below the set requirements, taking into account technical constraints, measurement accuracy, and the lack of control over the seepage canal discharges, which had been decreasing slowly over the past several years, the two parties agreed that the obligation concerning water discharges into the Mosoni Danube was fulfilled. The river branches on Hungarian territory also received a regular supply of water, according to the results of the joint monitoring.

Surface water quality

According to the Joint Annual Report (2001), fluctuations of surface water quality in the main stream and in the river arms downstream from Gabčíkovo coincided with surface water quality changes in the Danube measured at Bratislava. That correspondence has been noted as a general trend following the introduction of a continuous water supply in the river arm system below the Gabčíkovo regulation works in 1995. Thus, the general improvement of water quality observed in the Danube upstream from Bratislava was reflected in positive changes downstream and in the river arms affected by the temporary measures that were realized according to the 1995 Agreement. In particular, improvements were ob-

served in the oxygen regime, dissolved solids, iron concentration, and COD. Unfavorable values of some parameters, however, such as coliform bacteria, BOD, nitrates, phosphorus sulphates, and a saprobic index, were also noted in the Mosoni branch before its confluence with the Danube. In addition to water quality in the Danube upstream, those parameters were affected by the water quality of the tributaries and the pollution of local settlements. As a whole, no significant changes in the water quality were recorded in the hydrological year 2001, in comparison with that of the previous year.

The Joint Annual Report (2001) points out, however, that observations from selected sampling sites (Rajka and Medved'ov) indicate that the measurements made by the Slovak and the Hungarian parties do not always correspond. Notable differences exist among the following parameters: pH, dissolved oxygen, suspended solids, sulphates, nitrites, total nitrogen, ammonium ions, total phosphorus, BOD_5, saprobic index, as well as iron, manganese, and other heavy metals. Differences also include systematic deviations between the data measured by the two parties (e.g., sulphates or saprobic index), differences in trends (e.g., dissolved oxygen, BOD_5, etc.), and high deviation in values in cases of similar tendencies. The time span of the discrepancies varies from occasional to periodic to year-round. According to the Joint Annual Report (2001), experts from the two parties are working jointly on identifying the causes and the possible solutions to those discrepancies.

Hydrological regime of groundwater

As mentioned earlier, groundwater levels in the area influenced by the water supply are jointly evaluated on the basis of groundwater level differences for comparable hydrological situations in the period before and after the introduction of the water supply. In particular, differences for low, average, and high discharge conditions in the Danube, corresponding to discharges of approximately 1,000, 2,000 and 3,000 m^3/s, were compared for the years 1993–2000, based on data that included results from the pre-1995 groundwater monitoring activities in the region.

According to the Joint Annual Report (2001), at low and average discharge conditions, groundwater level during the period 1993–2001 increased by 0.3–1.0 meters and 0.5–1.0 meters, respectively, in the monitored areas, in particular in the Hungarian regions affected by the additional water supply. The slight increase in groundwater levels observed in the inundation area on the Slovak side was related to the different water supply regime there. In the area around the Bagoméri River branch system, where no additional water supply was provided, groundwater levels remained similar to levels in 1993. This region is influenced

by the drainage of the tailrace canal. The observed decrease on the left side of the reservoir was related to the lower water level in the reservoir as compared with that of 1993 and to the decrease in permeability of the reservoir bottom. In addition, partial deepening of the tailrace canal and erosion of the Danube riverbed downstream from the confluence have resulted in a slight decrease of groundwater levels upstream from the confluence of the old Danube riverbed. As a whole, however, the Joint Annual Report notes, groundwater levels at present are much higher at low- and medium-discharge conditions than they were before the construction of the dam. During high discharges, the additional water supply has limited, if any, impact on groundwater levels. The insufficiency of water supply in the Ásványi River and Bagoméri River branch systems and on the left side of the Danube was most strongly pronounced.

These results confirm the groundwater trends in the region observed in the years immediately after the introduction of the additional water supply. Differences in groundwater levels for low- , medium- , and high-discharge conditions at Bratislava during the period 1993–1997 indicate that, the supply of water to the right side of the river guaranteed under the 1995 Agreement increased groundwater levels in the concerned area, In low- and medium-discharge conditions, however a decrease of groundwater levels was observed at the lowest part of the inundation area, where no additional water was supplied – the downstream part of the Ásványi River branch and the Bagoméri River branch, as well as the lower part of the reservoir – because of a different water level management of the seepage canal on the left side (figs. 18 and 19). In high-discharge conditions, while high precipitation in the mountainous areas of the upper Danube River basin and those bordering the Danube floodplain in 1997 resulted in a general increase in groundwater levels on the boundaries, a significant decrease in groundwater levels in the area along the old Danube riverbed was observed (fig. 20). The latter was partly related to the fact that the measurements for the period in 1993 were made just after the passing of the high discharge in the old Danube riverbed, while for the period in 1997 the measurements were made a few days later.

As the results from the monitoring suggest, the water supply of the right side river branch system ensured a general increase of groundwater levels in Szigetköz at low and average discharge. According to the Joint Annual Report (2001), the decrease of groundwater levels in the lower part of the region (the area around the Ásványi River and Bagoméri River branch systems) characteristic for high discharge conditions, could be addressed through an extension of the water supply system. The report suggests that an increase of groundwater levels in the strip along the old Danube riverbed on both sides could be ensured by the technical so-

lution applied at Dunakiliti at rkm 1843 and realized according to the 1995 Agreement.

Groundwater quality

Unlike the joint approach to the evaluation of the hydrological regime of groundwater taken in the annual reports, groundwater quality is evaluated separately by the two sides, though results and analysis thereof are based on jointly agreed methodologies and limits. For the evaluation of the results, both countries take into account long-term groundwater quality trends indicated by the pre-1995 groundwater quality monitoring in the respective areas where possible.

According to the Joint Annual Report (2001), in Hungary, water quality at the observed sites changed in certain wells most likely because of changes in ground flow direction. In particular, in 2001 a decrease of iron and manganese was observed in the region of Dunakiliti and Kisbodak, and a decrease of organic matter in the region of Arak and Ásványráró. Increasing salinity was detected in the inland area around Mosonmagyaróvár, Püski, and Győrzámoly. Deteriorating tendencies were observed at Rajka and Vámosszabadi, where iron content increased, and at Rajka, Ásványráró, and Győrzámoly, where an increase of ammonium ion concentrations was recorded. Analysis of the monitoring results suggests that the drinking water supply around Győr is characterized by low iron, manganese, and ammonium concentrations. In other areas, where drinking water is supplied from a higher depth, water quality according to the joint report is excellent, and the water composition is characterized by high stability.

In Slovakia, according to the Joint Annual Report (2001), the values of the basic physical and chemical parameters, the cations, the anions, and the oxygen regime parameters of all of the objects satisfy the agreed limits for groundwater quality. The decrease in conductivity at some wells in 2001, associated with a decrease of salinity, was ascribed to groundwater flow direction changes in the area around the reservoir. A decreasing trend in nitrate content was observed at Rusovce, Čunovo, and Dobrohošt; an increase in manganese was detected at Rusovce and Sap; and a slight increase of iron was detected at Kalinkovo.

Soil monitoring

Soil moisture results from the different observation sites in both Hungary and Slovakia differed, depending on their location with regard to the Danube and the river branches and in accordance with the soil layer thickness, composition, and the depth of the groundwater level in the re-

spective areas. Furthermore, the two depth intervals monitored, namely, that from 0 to 100 centimeters and that from 110 to 200 centimeters, differently reflected changes in climatic conditions and the hydrological regime of groundwater. Fluctuations of soil moisture in the depth interval of 0–1 meters were most strongly affected by the climatic conditions during the year; soil moisture in the depth interval of 1–2 meters fluctuated in accordance with groundwater level changes. Thus, while the high groundwater levels ensured by the additional water supply on Hungarian territory in 2001 provided moisture in the deeper soil layers, the low amount of precipitation during the year resulted in a deficiency of soil moisture in the upper layers in upper and middle Szigetköz. While the position of the groundwater level did not allow it to compensate for the climatic conditions in March and September, partial moisturing of the shallow profiles was made possible by the sufficient rise of groundwater levels related to the higher water level in the old Danube riverbed. A similar situation was observed on the Slovak side. However, soil moisture there during the vegetation period was supplied by the increased groundwater levels during an artificial flood simulation.

Forest monitoring

Joint forest monitoring, just as forest monitoring before 1995, was carried out mainly in poplar forest sites in the inundation area. The measured indicators included annual growth increment, weekly girth growth, and the general health of the forests. According to the Joint Annual Report (2001), yearly growth increment data indicate that the negative impact of the old Danube riverbed's strong drainage effect on forest stands in the Szigetköz region decreased after the water supply was introduced, ensured by the underwater weir. However, the water supply for the forest stands situated along the old Danube riverbed is still an issue to be addressed if willow stands in the area are to be preserved. While conditions have improved as a result of the introduction of an additional water supply, according to the data, girth growth of willow stands still lags behind the expected values and does not reach the level recorded in the period before the damming of the Danube. The situation is more favorable for poplar stands, as indicated by their stabilized weekly girth growth measurements. Observations of the general health of forest stands in the region confirm the above findings. While willow stands and forest stands on shallow soils demonstrate moderate health in general, in the area upstream from Dunasziget and Kisbodak villages, a remarkable deterioration was observed. The destruction of willows resulted in the accumulation of a high calcium content in the soil, which could allow for cultivation of willows only in the presence of a plentiful water supply.

On the Slovak side, the groundwater level decrease, after the diversion of a significant part of the discharge in the Danube, affected forest stands as well. The problem was to a large extent addressed through the provision of additional water supply through the intake structure at Dobrohošt' and by a set of cross weirs in the river branch system. As on the Hungarian side, however, the low surface water level in the old Danube riverbed and the associated low groundwater levels are still considered unfavorable for the development of forest stands in the area. In 2001 artificial floods on some of the monitored areas mitigated the problem, and the results of weekly girth growth measurements proved the significant influence of precipitation at the beginning of the vegetation period. The construction of appropriate underwater weirs that could lead to a rise of the water level in the old Danube and mitigate the influence of insufficient precipitation, especially at the beginning of the vegetation period, was suggested as a possible permanent solution to the problem.

Biota monitoring

Joint biota monitoring focuses on eight main groups of aquatic and terrestrial flora and fauna. Results are reported in an integrated manner rather than separately by the two countries. According to the Joint Annual Report (2001), while biota indicators indicated significant signs of improvement compared to the situation before the introduction of the additional water supply in 1995, biological indicators in some areas in the river branch system continued to indicate water supply insufficiency. With respect to phytocenological communities, species dominance during the observation period remained the same, but the values of dominance changed. While in some areas the drying was stopped as a result of the introduced water supply, in several monitoring sites higher numbers of species characteristic of drier biotopes were observed. Monitoring of terrestrial mollusks indicated a tendency of a return of the original hygrophilous species.

Changes in aquatic fauna in 2001 reflected the changes in the river arm system. The number of species in general, and of rheophilous species in particular, i.e., species living in flowing water, rose in the areas where additional water was supplied and species composition stabilized. The increased water amount and flow velocity in the river branches influenced the development of aquatic macrophyte communities, leading to a decrease of species diversity and abundance. At the same time the water supply in several places supported the development of original species. The water supply also led to the partial reestablishment of a connection between the main riverbed and the branch system, to which the re-

appearance of some rheophilous species and the changes in the ichthyofauna observed in the branch system in recent years have been ascribed.

Evaluation and recommendations

The environmental monitoring in the middle Danubian basin shared by Hungary and Slovakia developed in relation to the joint project for the construction of a system of locks for flood control, hydropower generation, and improvement of navigation conditions in the section of the Danube flowing as a border between the two countries. The monitoring was established in response to public concern about the environmental implications of the project, which began to mount in Hungary in the early 1980s, and in relation to the political conflict over the fate of the GNP that developed subsequently, along with the processes of the political and economic reforms taking place in the two countries. Domestic pressure in Hungary led to the termination of work on the Hungarian side of the project in 1989. In 1992 Slovakia responded by unilaterally completing and putting into operation the Gabčíkovo part of GNP. The two countries submitted the case for judgment to the International Court of Justice in 1993 as a result of pressure from the European Union, toward membership in which they aspired. In 1997 the court pronounced its decision, which legitimized the status quo and urged the two parties to agree on a solution for dealing with the current situation.

In the meantime, first an independent and later a joint system for monitoring the environmental impacts of the project developed in both Hungary and Slovakia. The original goal of the monitoring programmes was to provide a scientific basis for evaluating the environmental consequences of the project and thus an objective justification in support of each party's claims. The need to depoliticize and formalize the political debate was encouraged by the international institutional frameworks, within which the GNP case was handled, and by the international consensus concerning the norms of sustainable water resources management that had emerged during the decades-long incubation of the case.

The technical infrastructure, human capital, and financial requirements for the establishment of those independent monitoring systems on the two sides of the middle Danube were provided by relevant preexisting technical and scientific experience and by the socioeconomic and political environments in the two countries at the time. The long-term hydrological monitoring of the Danubian basin in both Hungary and Slovakia, dating back to the eighteenth century when the territories of both countries constituted parts of a common political unity under the Habsburgs

and carried on to the present under the obligation of the Danube Convention, facilitated the establishment of the surface water and groundwater monitoring systems on the GNP-affected areas. Earlier studies and accumulated expertise on relevant aspects of the biological environment in the region provided the scientific and human capital requirements for the establishment of biological monitoring. The recognition of the concept of biological diversity and sustainable development on the international arena provided an additional incentive, justification, and support. Vested political interests in the escalating international conflict over the fate of the GNP ensured the financial basis for the launching of the environmental monitoring programmes in Hungary and Slovakia. They were commissioned by the governments of the two states and carried out by relevant departments in the national academies of sciences, state universities, and consulting companies enlisted as advisory bodies for the construction and operation of the GNP.

The independent monitoring efforts in the two countries were ultimately integrated once domestic political dynamics in Hungary and Slovakia and the associated international goals and priorities of the two countries ensured the political will for cooperation. The latter was necessitated also by the realization of the limited legitimacy and thus usefulness of the results from the independent environmental monitoring as an unbiased basis for decision making. In 1995 Hungary and Slovakia signed an agreement for implementing certain technical measures to provide additional water supplies to the old Danube riverbed and the Mosoni Danube as a temporary solution to the most critical environmental problems that had resulted from the construction and putting into operation of the Gabčíkovo part of GNP. The agreement gave rise to the obligation for joint monitoring and evaluation of the environmental impact of the technical measures agreed and implemented in 1995. The joint monitoring constitutes an ongoing effort on the part of the two countries. It is a substantial one, in view of the scale and nature of the joint monitoring initiative. The scientific complexities and uncertainties, the difficulties of cross-border communication and agreement, and the number of resources necessary to support them, raise the question: Is the joint monitoring a worthwhile effort?

In view of the goals of sustainable development, the joint monitoring system established in 1995 undoubtedly added value to the preexisting monitoring activities carried out independently by the two countries on the areas affected by the Gabčíkovo part of the GNP. By integrating the efforts of the two riparian states directly affected by the project, the joint monitoring and assessment of the environmental impact of the water regulation works ensured a more equitable and efficient basis for making sustainable water management decisions in the region. The attempt to

eliminate the artificial political division of the geographic and ecosystem unity of the river basin is in itself a step in the direction toward a more sustainable management of the middle Danube and its floodplain, given the fact that, as indicated by the environmental consequences of earlier water regulation works in the Danube and of the unilateral implementation of the Gabčíkovo part of the project itself, the discrepancy between the political and the environmental borders of river basin ecosystems constitutes a major reason for the unsustainable management of freshwater resources and basins. In this sense, the joint monitoring system can be seen as an improvement over the preexisting independent systems.

In view of the operational efficiency and effectiveness of monitoring programmes, the basic principles of environmental monitoring suggest the need for clearly defined goals, which can provide a basis for the selection of an appropriate design and methodology of the monitoring, a baseline for the evaluation of its effectiveness, flexibility allowing for modifications in line with changing information needs and circumstances, and a clearly defined exit point. In the case of the joint monitoring of the areas affected by the Gabčíkovo part of the GNP, the goals of the monitoring are defined in accordance with the monitoring obligations under the 1995 Agreement. However, they are used mainly to modify the design of the preexisting independent monitoring programmes rather than to determine it. That does not necessarily constitute a problem, since the general goal of both the independent and the joint monitoring is a common one, namely, detecting and evaluating environmental changes in the area affected by the construction and operation of the GNP and elaborating technical recommendations for addressing the observed problems. Furthermore, a flexible mechanism allowing for the necessary modifications seems to be in place, in view of the regular meetings of the joint working groups. The effectiveness of that mechanism and thus of the joint monitoring itself is illustrated by the extent to which the joint monitoring programme has proved capable of achieving its professed goals.

As classified above, the three main goals of the joint monitoring are regulatory, evaluatory, and policy-oriented. The regulatory function of the monitoring, referring to the provision of evidence and the evaluation of compliance with the discharges into the old Danube riverbed and into the Mosoni Danube agreed in 1995, seems to be adequately fulfilled by the Joint Annual Reports, which meticulously elaborate and evaluate the hydrological regime of surface water in the Danube and the side arm system, with a particular focus on the respective discharges and levels.

The fulfillment of the second function of the monitoring, however, has proved less straightforward. As is obvious from the annual joint monitoring reports, the two parties attempt to evaluate the results from a long-term perspective, when pre-1995 data are available, and in an in-

tegrated manner, when the results indicate the need for such. Nevertheless the following problems are clearly notable:

- The focus of the reports is on reporting the annual changes of the observed indicators rather than analyzing trends. That is related to the 1) limited time series data available, especially for the evaluation of biological changes and processes; as well as to the 2) the complexity in evaluating environmental changes in view of the difficulty in tracing the particular cause of the observed changes, given the simultaneous influence of numerous factors on the monitored indicators.
- Results concerning the different monitored components of the environment are presented as independent elements rather than as interrelated parts of the whole ecosystem being monitored. While some of the interlinkages among them were examined in the earlier reports from the independent monitoring in the two countries, they have been left out in the process of integration and systematization of the jointly agreed monitored information.
- The joint reports continue to present the results for most of the monitored elements as subject to a political divide, since the monitoring is conducted separately and continuing discrepancies in measurement methodologies make an integrated presentation and interpretation of the results difficult.

The achievement of the third goal of the joint monitoring programme, namely that of providing an unbiased scientific basis for decision making and recommendations for improvement of the monitoring system and for the necessary technical measures for resolving the observed environmental problems, has been similarly constrained. Indeed the input of the joint monitoring does provide jointly agreed data and thus a politically unbiased ground for decision making. Furthermore, the monitoring experts incorporate recommendations for optimization of the monitoring, which are taken into account and subsequently implemented as reported in the activities of the joint working groups and in the section on the fulfillment of the previous year's recommendations included in the Joint Annual Reports. However, recommendations for improvement of the current water management regime in the examined section of the Danube basin are scarce. This may be due to the above-mentioned analytical constraints as well as to the difficulties in determining and reaching an agreement on the relative value of the observed environmental changes and affected species.

While specific policy recommendations developed based on the joint monitoring results are few, however, the information about the state of the environment in the GNP-affected areas accumulated over the past eight years provides an adequate idea of the major environmental problems and their scope. Nevertheless, no measures have so far been taken

either to resolve them or to optimize the socioeconomic benefits from the existing waterworks structures or the original GNP plan. Political negotiations on settling the GNP are still continuing and so is the joint environmental monitoring, whose exit point is politically bound. The political dependence of the joint monitoring programme in the context of a political stalemate makes it a costly endeavor, the potential benefits of which are not being adequately used. Thus a reassessment of its rationale, nature, and scope is required.

If sustainable water management is to become the primary objective of the existing environmental monitoring programme, it would need to be integrated into the Danube basin-wide institutional framework of environmental monitoring and water management coordinated by the ICPDR. This is exacted by the transboundary nature of environmental problems arising from water development works, which is illustrated by the history of water management in the Danube and in the middle Danube. The concept of Integrated River Basin Management, which constitutes the broadly recognized means of responding to this problem, underlies the basin-wide water management structures established in the Danubian basin over the past decade. Thus an integration of the GNP-related monitoring programme into the basin-wide structures would allow for optimization of the existing technical infrastructure, human capital, and the already invested financial resources in line with the goal of the sustainable management of the river basin by providing the necessary geographic unity and continuity in time.

The institutional basis and mandate for such restructuring of the joint monitoring programme exist. The Joint Working Group on Water Management, Ecology, Navigation, and Energy could serve as a forum of discussion of the requirements for and feasibility of integration of the GNP-specific environmental monitoring into the basin-wide monitoring and water management structures coordinated by the ICPDR. Harmonization of the joint environmental monitoring and water management systems with the international standards for environmental protection and sustainable development and with the requirements of international river legislation, respectively, are explicitly mentioned in the mandate of the Working Group. International water management norms and environmental standards, however, as indicated by the limited usefulness of the decision of the ICJ concerning the GNP, may be poor guides in resolving practical water management questions and concerns. The Danube basin, with its existing institutional water management structures and environmental standards, developed in view of the physical and sociopolitical characteristics, needs, and capacities of the region, could provide the institutional framework and practical criteria for evaluating the efforts of the experts and the delegations of the two countries.

The expected entry of Hungary and Slovakia into the European Union in 2004 provides a compelling political reason for their making use of existing institutional bases for integration of the GNP-monitoring into the relevant basin-wide river management structures. As EU members, the two countries would need to abide by EU standards for environmental quality and sustainable development. The EU framework directive on water, in particular, promotes the principles of IRBM, information sharing, and stakeholder involvement in water management decisions. This means that any decision regarding the GNP case would need to take into account the interests of the upstream and downstream riparian states, as well as the other stakeholders involved. In this sense, the environmental monitoring results need to be made accessible to a wider public than the government delegations of and the decision-making authorities in the two countries involved. The existing Danube basin-wide structures for information exchange and public outreach would facilitate fulfillment of this requirement. To enable evaluation of the basin-wide implications of decisions regarding the GNP and the management of the middle Danubian basin, however, the monitoring methodologies, standards, and criteria for interpretation, as well as the formats of presentation of the results which are currently employed in the joint environmental monitoring on the GNP-affected areas, would need to be harmonized with those of the environmental monitoring conducted by other riparian states. The basin-wide monitoring network would provide the necessary basis for this. Thus, integration of the environmental monitoring in the GNP-affected areas into the Danubian water management structures developed under the framework of the ICPDR could be seen not only as a necessity from the point of view of sustainable and efficient use of resources but also as a political imperative.

The GNP case and the joint environmental monitoring system on the middle Danube raise the need for caution in reliance on science and, in particular, on environmental monitoring for finding solutions to international water management political debates. The fact that monitoring activities on the areas affected by the GNP in Hungary and Slovakia developed parallel to the political debate gives a hint of the complexity involved. International consensus around the need for environmentally sustainable development is turning science into a tempting tool for justification of conflicting political positions and claims. At the same time, growing economic and political interdependence in the world is fostering a political will to cooperate. In this context, science could emerge as a bridge among warring riparian states. Whether the states employ scientific knowledge for elaborating and implementing sustainable water management solutions, however, would depend not on the will to cooperate but on the readiness and ability to compromise. In the absence of

the latter, political dependence of the launch and exit point of joint scientific endeavors may lead to the paradoxically unsustainable use of scarce resources for the purpose of sustainable development.

Indeed, the political will to cooperate is indispensable for scientific and technical cooperation in the case of international water disputes, especially among developing states, where the establishment and maintenance of an international monitoring system, for example, would be close to impossible without a political agreement and support from the states in view of the significant complexities and costs. To optimize the benefit of such cooperation, however, the end points of project-specific monitoring need to be tied to environmental rather than political benchmarks and goals. Mechanisms that allow for nonpolitically bound reassessments of the rationale and objectives of the specific programme rather than its operation efficiency alone need to be incorporated into the design. Furthermore, if environmental sustainability is to turn into a sustainable concept, the readiness and the ability to optimize rather than to maximize alternative objectives need to be fostered, along with technical and political cooperation.

5

Managing international waters: Concluding remarks

Sharing and jointly managing international waters is a challenging task. Political will to cooperate is a necessary prerequisite for beginning to address the complex transboundary issues and conflicting claims and demands. The GNP-case, however, illustrates that it is hardly a sufficient one. Indeed, political will can facilitate international legal and technical cooperation. International law could encourage the formalization and objective justification of conflicting environmental claims. Efforts to justify alternative perspectives, though initially confrontationally motivated, may paradoxically turn into a basis for technical cooperation. The latter is critical for resolving the physical problems which arise from unsustainable water management policies and about which international law is currently incapable of providing practical guidance. However, a set of preexisting capacities, as well as international incentives and support for sustainable development and sustainable water management solutions, is essential for overcoming the financial and technical hindrances for establishing an unbiased information basis for joint decision making. Furthermore, various time, scientific, organizational, and judgmental constraints may limit the ability of such a joint information base to provide policy-relevant advice. Policies are ultimately the outcome of decisions, based on subjective evaluation criteria, which are shaped by diverging perspectives and goals.

Bridging different objectives through synergies among partners is one of the four key elements of Vision 21 on Water and Sanitation adopted at

the Second World Water Forum in 2000. This idea recently brought together representatives from NGOs, the private sector, governments, and international organizations in an attempt to evaluate the socioeconomic and environmental implications of dams. The basis for this was provided by the World Commission on Dams (WCD), established with the support of the World Bank and the World Conservation Union upon an agreement reached at a joint workshop in Gland, Switzerland, in April 1997.

The final report of the WCD, presented in November 2000, proposed a new framework for decision making on the question of the development effectiveness of dams based on the core values of equity, sustainability, efficiency, participatory decision making, and accountability (Bird and Wallace, 2001). While recognizing that "dams have made an important and significant contribution to human development, and the benefits from them have been considerable," the report points out that "in too many cases an unacceptable and often unnecessary price has been paid to secure those benefits, especially in social and environmental terms" (WCD, 2000). With regard to the environmental impacts of dams, the report concludes that they have been more negative than positive and in many cases have led to irreversible losses of species and ecosystems. Furthermore, efforts to counteract these impacts, according to the report, have been hampered by the poor quality and uncertainty of predictions about anticipated impacts and the only partial implementation and success of the implemented mitigation measures (WCD, 2000). The poorly accounted-for environmental and social costs of dams have made the economic evaluation of their profitability an elusive issue as well. According to the WCD, negotiating outcomes "by bringing to the table all those whose rights are involved and who bear risks associated with different options for water and energy resource development" can ensure the development efficiency of water and energy projects (WCD, 2000).

The difficulties of negotiations among the different stakeholders, however, have been brought home by the controversial reactions to the WCD report itself. International water resource development organizations, such as the International Commissions on Large Dams (ICOLD), the International Commission on Irrigation and Drainage (ICID), the International Hydro-power Associations (IHA), the Institute of Civil Engineers (in the UK), and the water resource development government authorities in India, Russia, Japan, and other developing and developed countries, have contested the findings of the report and have accepted with qualifications or rejected the recommendations of the WCD (2001), thus bringing back the questions: Should dams be built? Or should plans for new ones be discarded? Should current dams be dismantled – even as they are in the progress of being constructed?

While thousands of dam projects throughout the world are currently

underway, numerous water regulatory works in developing countries, such as "Sardar Sarovar" and "Their" in India and "Arun III" in Nepal, have been frozen midway. In developed countries, governments have been subjected to growing pressure to dismantle existing dam structures. Illustrations of that pressure are the El-Wha dam complex in the United States, where more than 200 dams have been removed over the past decade because of financial, social, and environmental costs, and the Arase dam in Japan, the first of the 2,700 dams existing in the country which is to be reconstructed (Frederick, 2002) but not the last. At the World Water Forum held in Kyoto in March 2003, United States and Japanese experts launched a joint dam committee with the goal of examining Japan's notorious love affair with dams and drawing on the United States' experience in reviewing and decommissioning such projects (Murakami, 2003).

Since the concrete answer to the question of whether to dam or not is inevitably dependent on the physical-geographic environment and the political and socioeconomic settings of the individual cases, the issue inevitably brings to the forefront of the debate the conflicting interests of the different stakeholders involved. Against the background of conflicting claims, the cooperative efforts of Hungary and the Slovak Republic highlight the possibility of an alternative, integrative perspective. The GNP case suggests that the discrepancy between diverging views could be seen as a gap of knowledge. Recognizing this is a promising first step. The ongoing search for a viable solution to the GNP dispute itself, however, indicates that the gap is often more than a step wide. The next step is the realization that entities – states, institutions, as well as individuals themselves – constitute complex and dynamic elements in an organic whole. Thus what should be sought after is not bridge-building knowledge. Bridges cannot be sustained since they can only be attached to perishable fractions of the dynamic whole. What is necessary therefore is knowledge that fosters wisdom or the ability to see the world from a broader perspective and to guide it toward a higher common goal.

Acronyms and abbreviations

United Nations organizations and agencies

ICJ	International Court of Justice
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNU	United Nations University
UNUP	United Nations University Press
WB	World Bank

International organizations, agencies, and agreements

CBD	Convention on Biological Diversity
CIS	Commonwealth of Independent States
CEE	Central and Eastern Europe
CEU	Central European University
COMECON	Council for Mutual Economic Cooperation
DRP	Danube Regional Project
DRPC	Danube River Protection Convention
EBRD	European Bank for Reconstruction and Development
EC	European Commission

ECPP	European Commission Phare Programme
EEA	European Environment Agency
EIB	European Investment Bank
EIA	Environmental Impact Assessment
EU	European Union
ÉDUKF	Laboratories of Hungary (Györ)
EPDRB	Environmental Program for the Danube River Basin
FAO	Food and Agricultural Organization
GEF	Global Environment Facility
GEMS	Global Environmental Monitoring System
GIS	Geographic Information System
GNP	Gabčíkovo-Nagymaros Project
GWP	Global Water Partnership
ICID	International Commission on Irrigation and Drainage
ICOLD	International Commission on Large Dams
ICPDR	International Commission for the Protection of the Danube River
IHA	International Hydropower Association
IO	International Organization
IRBM	Integrated River Basin Management
IWAC	International Water Assessment Center
IWRM	Integrated Water Resources Management
KÖDUKF	Laboratories of Hungary (Budapest)
NATO	North Atlantic Treaty Organization
NGO	Nongovernmental Organization
NMASR	Nominated Monitoring Agent of the Slovak Republic
SHMÚ	Slovak Hydrometeorological Institute
USGS	United States Geological Survey
VITUKI	Water Resources Research Center (Budapest)
WEHAB	Water, Energy, Health, Agriculture, and Biodiversity
WFD	Water Framework Directive
WWF	World Wildlife Fund for Nature Conservation
WCD	World Commission on Dams
WRI	Water Research Institute (Bratislava)

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Glossary

aeration zone – That portion of the lithosphere in which the functional interstices of permeable rock or earth are not (except temporarily) filled with water under hydrostatic pressure.

abiotic – Nonliving.

advection – The usually horizontal movement of a mass of fluid.

allochtonous – Of nonlocal origin, introduced.

alluvial fan – The alluvial deposit of a stream where it issues from a gorge upon a plain or of a tributary stream at its junction with the main stream.

amphibian – Of a class of cold-blooded vertebrates intermediate between fishes and reptiles and having gilled aquatic larvae and air-breathing adults.

aquifer – A water-bearing stratum of permeable rock, sand, or gravel.

aquitard – A water-saturated sediment or rock whose permeability is so low it cannot transmit any useful amount of water.

autocorrelation – The correlation between paired values of a function of a mathematical or statistical variable taken at usually constant intervals that indicates the degree of periodicity of the function.

basin – Catchment area.

benthos – Organisms that live on or in the bottom of a body of water.

biological diversity – The number and abundance of species found within a common environment. This includes the variety of genes, species, ecosystems, and the ecological processes that connect everything in a common environment.

biomass – The total weight of all living organisms in a biological community.

biota – Plant and animal life of a particular region.

biotope – A region uniform in environmental conditions and in the populations of animals and plants inhabiting it.

biotype – The organisms sharing a specified genotype.

canopy – The part of any stand of trees represented by the tree crowns. It usually refers to the uppermost layer of foliage, but it can be used to describe lower layers in a multistoried forest.

capillarity – The effect of surface tension in drawing water up into narrow pores (against gravity).

capillary fringe – The water held above the atmospheric pressure surface by the capillarity, but not including the specific retention.

cover type (forest cover type) – Stands of a particular vegetation type that are composed of similar species.

crustacean – Any of a large class of mostly aquatic organisms that have a chitinous or calcareous and chitinous exoskeleton, a pair of often much modified appendages on each segment, and two pairs of antennae and that include the lobsters, shrimps, crabs, wood lice, water fleas, and barnacles.

cryptogams – A plant (such as a fern, moss, alga, or fungus) reproducing by spores and not producing flowers or seed.

dendrochronology – The science of dating events and variations in the environment in former periods by comparative study of growth rings in trees and aged wood.

dendrology – The study of trees.

ecology – The interrelationships of living organisms to one another and to their environment, or the branch of science concerned with them.

ecophysiology – The science of the interrelationships between the physiology of organisms and their environment.

ecosystem – The complex of a community of organisms and its environment functioning as an ecological unit.

endemic – Characteristic of or prevalent in a particular field, area, or environment; restricted or peculiar to a locality or region.

Environmental Impact Assessment – A statement of environmental effects of a proposed action and alternatives to it.

eolian – Borne, deposited, produced, or eroded by the wind.

erosion – The wearing away of land surface by wind or water.

eutrophication – The process by which a body of water becomes enriched in dissolved nutrients that stimulate the growth of aquatic plant life, usually resulting in the depletion of dissolved oxygen.

evapotranspiration – Loss of water from the soil both by evaporation and by transpiration from the plants growing thereon.

fluvial – Of, relating to, or living in a stream or river; produced by the action of a stream.

fauna – Animal life, the animals characteristic of a region, period, or special environment.

felling – Cutting down trees.

floodplain – Level land that may be submerged by floodwaters; a plain built up by stream deposition.

flora – Plant or bacterial life characteristic of a region, period, or special environment.

forest health – A measure of the robustness of forest ecosystems. Aspects of forest health include biological diversity; soil, air, water productivity, natural disturbances; and the capacity of the forest to provide a sustaining flow of goods and services for people.

geomorphology – A science that deals with the relief features of the earth or of another celestial body and seeks a genetic interpretation of them.

Geographic Information Systems (GIS) – A database designed to handle geographic data and a set of computer operations that can be used to analyze the data.

groundwater – Water stored in the open spaces within underground rocks and unconsolidated material.

habitat – The area where a plant or animal lives and grows under natural conditions.

hydraulic – Operated, moved, or effected by means of water.

hydraulic conductivity – A measure of the ease of flow through aquifer material.

hydraulic gradient – In channel flow, the mean surface gradient; in unconfined groundwater, the mean water table gradient in the direction of the flow; in confined aquifers, the pressure gradient in the direction of the flow.

hydrology – The science dealing with the properties, distribution, and circulation of water on and below the earth's surface and in the atmosphere.

hydrolysis – The chemical process of decomposition involving the splitting of a bond and the addition of the hydrogen cation and the hydroxide anion of water.

hygrophilous – Living or growing in moist places.

hygroscopic – Readily taking up and retaining moisture; taken up and retained under certain conditions of humidity and temperature.

hydrostatic pressure – The pressure, expressed as a total of quantity or per unit of area, exerted by a body of water at rest; in the case of groundwater, the pressure is generally due to the weight of water at higher levels in the same zone of saturation.

ichthyofauna – The fish life of a region.

indigeous (species) – Having originated in and being produced, growing, living, or occurring naturally in a particular region or environment.

in situ – In the natural or original position or place.

invertebrates – Lacking a spinal column.

landscape – A large land area composed of interacting ecosystems that are repeated due to factors such

as geology, soils, climate, and human impacts.

lacustrine – Of, relating to, formed in, living in, or growing in lakes.

loess – An unstratified, usually buff-to-yellowish-brown loamy deposit chiefly deposited by the wind.

lentic – Characterized by still water.

lotic – Characterized by running water.

litter (forest litter) – The freshly fallen or only slightly decomposed plant material on the forest floor.

macrophyte – A member of the macroscopic plant life especially of a body of water.

mollusk – Any of a large group of invertebrate animals (such as snails, clams, or squids) with a soft unsegmented body usually enclosed in a calcareous shell.

morphogenetic – Relating to or concerned with the development of normal organic form.

morphology – The external structure of rocks in relation to the development of erosional forms or topographic features.

neutron probe – A technique for measuring the hydrogen content (and hence by implication the water content) through a borehole section.

organic soil – Soil at least partly derived from living matter, such as decayed plant material.

oxidation-reduction – A chemical reaction in which one or more electrons are transferred from one atom or molecule to another.

parapotamon – The dead arm of the main channel that remains connected to the river throughout the year at its downstream end.

pedology – Soil science.

permeability – Capacity to transmit a fluid.

pH – A measure of acidity and alkalinity of a solution that is a number on a scale on which a value of 7 represents neutrality and lower numbers indicate increasing acidity and higher numbers increasing alkalinity and that is the negative logarithm of the effective hydrogen-ion concentration or hydrogen-ion activity in gram equivalents per liter of the solution.

phenology – A branch of science dealing with the relations between climate and periodic biological phenomena (as bird migration or plant flowering).

photosynthesis – Synthesis of chemical compounds with the aid of radiant energy and especially light; formation of carbohydrates from carbon dioxide and a source of hydrogen in the chlorophyll-containing tissues of plants exposed to light.

phytocenoses – The totality of animal communities inhabiting a natural community.

phytoplankton – Planktonic plant life.

porosity – The ratio of the volume of interstices of a material to the volume of its mass.

productive – The ability of an area to provide goods and services and to sustain ecological values.

Quaternary – Of, relating to, or being

the geological period from the end of the Tertiary to the present time or the corresponding system of rocks.

recharge – The addition of water to groundwater by natural or artificial processes.

rheophilous – Species living in flowing water.

riparian – Relating to or living or located on the bank of a natural watercourse (as a river).

saprogenic – Of, causing, or resulting from putrefaction, i.e., from the decomposition of organic matter, typically through anaerobic splitting of proteins by bacteria and fungi with the formation of foul-smelling, incompletely oxidized products.

seepage – Diffused groundwater emergence at the surface, as opposed to a spring; the loss of water by infiltration from a canal, reservoir, or a body of water, or from a field.

silviculture – A branch of forestry dealing with the development and care of single trees and the forest as a biological unit.

stand – A group of trees that occupies a specific area and is similar in species, age, and condition.

sustainability (ecosystem) – The ability of an ecosystem to maintain ecological processes and functions, biological diversity, and productivity over time.

sustainable – The yield of a natural resource that can be produced continually at a given intensity of management is said to be sustainable.

synecology – A branch of ecology that deals with the structure, development, and distribution of ecological communities.

thinning – A cutting made in an immature stand of trees to accelerate growth of the remaining trees or to improve the form of the remaining trees.

tracer – Any distinctive substance that can be used to quantitatively or qualitatively "fingerprint" water. Tracers can be used to determine groundwater flow directions, discrete groundwater pathways, the mixing efficiency of two water sources or, by dilution gauging, surface water discharges.

vegetation type – A plant community with distinguishable characteristics.

watershed – The entire region drained by a waterway (or into a lake or reservoir); an area of land above a given point on a stream that contributes water to the stream flow at that point.

water table – The upper limit of the portion of the ground wholly saturated with water.

wetlands – Areas that are permanently wet or are intermittently covered with water.

xerophilous – Thriving in or tolerant or characteristic of a xeric environment, i.e., an environment characterized by only a small amount of moisture.

zoocenoses – The totality of animal communities inhabiting a natural community.

zooplankton – Plankton composed of animals.

Note: The explanations of the terms included in the glossary draw upon the following (and other) sources:

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Appendices

Appendix 1

No. 17134

HUNGARY
and
CZECHOSLOVAKIA

Treaty concerning the construction and operation of the Gabcikovo-Nagymaros system of locks. Signed at Budapest on 16 September 1977

Authentic texts: Hungarian and Slovak.
Registered by Hungary on 18 October 1978.

HONGRIE
et
TCHÉCOSLOVAQUIE

Traité relatif à la construction et au fonctionnement du système d'écluses de Gabcikovo-Nagymaros. Signé à Budapest le 16 septembre 1977

Textes authentiques : hongrois et slovaque.
Enregistré par la Hongrie le 18 octobre 1978.

[TRANSLATION — TRADUCTION]

TREATY[1] BETWEEN THE HUNGARIAN PEOPLE'S REPUBLIC AND THE CZECHOSLOVAK SOCIALIST REPUBLIC CONCERNING THE CONSTRUCTION AND OPERATON OF THE GABČÍKOVO-NAGYMAROS SYSTEM OF LOCKS

The Hungarian People's Republic and the Czechoslovak Socialist Republic,

Considering their mutual interest in the broad utilization of the natural resources of the Bratislava-Budapest section of the Danube river for the development of water resources, energy, transport, agriculture and other sectors of the national economy of the Contracting Parties,

Recognizing that the joint utilization of the Hungarian-Czechoslovak section of the Danube will further strengthen the fraternal relations of the two States and significantly contribute to bringing about the socialist integration of the States members of the Council for Mutual Economic Co-operation, have therefore

Decided to conclude an Agreement concerning the construction and operation of the Gabčíkovo-Nagymaros system of locks, and have for this purpose appointed as their plenipotentiaries:

The Presidium of the Hungarian People's Republic:

Mr. György Lázár, Chairman of the Council of Ministers of the Hungarian People's Republic;

The President of the Czechoslovak Socialist Republic:

Dr. Lubomír Štrougal, Prime Minister of the Czechoslovak Socialist Republic,

who, having exchanged their full powers, found in good and due form, have agreed as follows:

CHAPTER I. PURPOSE OF THE TREATY

Article 1. THE JOINT INVESTMENT

1. The Contracting Parties shall construct the Gabčíkovo-Nagymaros system of locks (hereinafter referred to as the "System of Locks") as a joint investment; the System of Locks shall comprise the Gabčíkovo system of locks and the Nagymaros system of locks and shall constitute a single and indivisible operational system of works.

2. The principal works of the Gabčíkovo system of locks shall be as follows:

(*a*) The Dunakiliti-Hrušov head-water installations in the Danube sector at r.km. (river kilometre(s)) 1860-1842, designed for a maximum flood stage of 131.10 m.B. (metres above sea-level, Baltic system), in Hungarian and Czechoslovak territory;

(*b*) The Dunakiliti dam and auxiliary navigation lock at r.km. 1842, in Hungarian territory;

[1] Came into force on 30 June 1978, the date of the exchange of the instruments of ratification, which took place at Prague, in accordance with article 28 (2).

(*c*) The by-pass canal (head-water canal and tail-water canal) at r.km. 1842-1811, in Czechoslovak territory;

(*d*) Series of locks on the by-pass canal, in Czechoslovak territory, consisting of a hydroelectric power plant with installed capacity of 720 MW, double navigation locks and appurtenances thereto;

(*e*) Improved old bed of the Danube at r.km. 1842-1811, in the joint Hungarian-Czechoslovak section;

(*f*) Deepened and regulated bed of the Danube at r.km. 1811-1791, in the joint Hungarian-Czechoslovak section.

3. The principal works of the Nagymaros system of locks shall be as follows:

(*a*) Head-water installations and flood-control works in the Danube sector at r.km. 1791-1696.25 and in the sectors of tributaries affected by flood waters, designed for a maximum flood stage of 107.83 m.B., in Hungarian and Czechoslovak territory;

(*b*) Series of locks at r.km. 1696.25, in Hungarian territory, consisting of a dam, a hydroelectric power plant with installed capacity of 158 MW, double navigation locks and appurtenances thereto;

(*c*) Deepened and regulated bed of the Danube, in both its branches, at r.km. 1696.25-1657, in the Hungarian section.

4. The concept of the System of Locks shall include the joint investment programme. The technical specifications relating to the System of Locks shall be included in the joint contractual plan drawn up as provided in the Agreement, signed at Bratislava on 6 May 1976, between the Government of the Hungarian People's Republic and the Government of the Czechoslovak Socialist Republic concerning the drafting of a joint contractual plan for the Gabčíkovo-Nagymaros System of Locks (hereinafter referred to as "the Agreement").

Article 2. NATIONAL INVESTMENT

1. With a view to taking advantage of the opportunties afforded by the System of Locks, the Contracting Parties may, in addition to the joint investment, also undertake national investments exclusively in their own interest and for their own purposes.

2. The costs of national investment shall be borne in full by each Contracting Party.

3. National investment may not have a detrimental effect on the results of the joint investment.

CHAPTER II. EXECUTION OF THE TREATY

Article 3

1. Operations connected with the realization of the joint investment and with the performance of tasks relating to the operation of the System of Locks shall be directed and supervised by the Governments of the Contracting Parties through delegates (hereinafter referred to as "government delegates") appointed by them for that purpose.

2. The government delegates shall establish appropriate permanent and temporary joint agencies for the performance of their functions and, pending the ap-

proval of the joint contractual plan, shall make regulations governing the organization and activities of those agencies.

3. The principal functions of the government delegates shall be as follows:

(*a*) At the time of the realization of the joint investment:

(1) To ensure that construction of the System of Locks is properly co-ordinated in the territories of the Contracting Parties and is carried out in accordance with the approved joint contractual plan and the project work schedule;

(2) To provide for supervision over labour and supplies and for co-ordination between the agencies of the Contracting Parties;

(3) To approve proposals for the modification of the technical procedures adopted in the joint contractual plan;

(4) To determine the justification for and extent of additional costs arising from the circumstances specified in article 7;

(5) To provide for and approve the records and settlement of differences relating to the apportionment of labour and supplies in equal measure in the cases specified in article 7;

(6) To provide for the acceptance of individual works from the supplying agencies and the delivery thereof to the authorized operating agencies.

(*b*) At the time of the operation of the System of Locks:

(1) To establish the operating and operational procedures of the System of Locks and ensure compliance therewith;

(2) To ensure the performance of tasks connected with the operation, maintenance and possible reconstruction of jointly-owned works of the System of Locks, including the performance of tasks connected with the generation and distribution of electric power;

(3) To approve the technical-economic plans and the reciprocal settlement of accounts relating to the operation, maintenance and possible reconstruction of the works of the System of Locks;

(4) To supervise compliance with the water balance approved in the joint contractual plan;

(5) To supervise and co-ordinate the activities of national operating agencies in times of flood or ice disposal.

4. The activities of the government delegates shall be governed by the joint statute approved by the Governments of the Contracting Parties.

CHAPTER III. REALIZATION OF THE SYSTEM OF LOCKS

Article 4. PREPARATION AND REALIZATION OF THE JOINT INVESTMENT

1. The joint investment shall be carried out in conformity with the joint contractual plan, which, for the purposes of the preparation of the joint investment, shall be drawn up by the agencies of the Contracting Parties on the basis of the Agreement.

2. The joint contractual plan shall:

(*a*) Determine the main dimensions of the works of the System of Locks, the technical specifications of technical equipment, the final project work schedule and responsibility for the costs referred to in article 12, paragraph 2;

(*b*) Serve as a basis for:
   (1) Ordering the technical equipment, construction materials, machinery and steelwork for the System of Locks;
   (2) Drawing up the construction plans and specifications.

3. Approval of the joint contractual plan shall be effected in conformity with the national laws and regulations of the Contracting Parties, and the government delegates shall inform each other of its approval.

4. Operations relating to the joint investment shall be organized by the Contracting Parties in such a way that the power generation plants will be put into service during the period 1986-1990.

Article 5. RESPONSIBILITY FOR THE COSTS OF THE JOINT INVESTMENT, APPORTIONMENT OF LABOUR AND SUPPLIES

1. The costs of carrying out the joint investment shall be borne by the Contracting Parties jointly in equal measure.

2. The Contracting Parties shall defray their portion of the costs of carrying out the joint investment on the basis of an apportionment of labour and supplies in equal measure according to the labour and supplies actually provided.

3. The costs of carrying out the joint investment shall be as follows:

(*a*) Costs of the research, exploration and planning operations required for drawing up the joint contractual plan and the construction plans and specifications;

(*b*) Costs of carrying out the works provided for in the joint investment, including such costs of carrying out works in the nature of joint investment and coming within the joint investment programme as were incurred by the Contracting Parties before the entry into force of this Treaty and as have by mutual agreement been included in the joint contractual plan;

(*c*) Costs of acquiring immovable property which, either on a temporary or a permanent basis, is required for carrying out the joint investment.

4. The apportionment of planning, research and exploration operations under the joint contractual plan shall be provided for in the Agreement.

5. The labour and supplies required for the realization of the joint investment shall be apportioned between the Contracting Parties in the following manner:

(*a*) The Czechoslovak Party shall be responsible for:
   (1) The Dunakiliti-Hrušov head-water installations on the left bank, in Czechoslovak territory;
   (2) The head-water canal of the by-pass canal, in Czcechoslovak territory;
   (3) The Gabčíkovo series of locks, in Czechoslovak territory;
   (4) The flood-control works of the Nagymaros head-water installations, in Czechoslovak territory, with the exception of the lower Ipel district;
   (5) Restoration of vegetation in Czechoslovak territory;

(*b*) The Hungarian Party shall be responsible for:
   (1) The Dunakilite-Hrušov head-water installations on the right bank, in Czechoslovak territory, including the connecting weir and the diversionary weir;
   (2) The Dunakilite-Hrušov head-water installations on the right bank, in Hungarian territory;

(3) The Dunakiliti dam, in Hungarian territory;
(4) The tail-water canal of the by-pass canal, in Czechoslovak territory;
(5) Deepening of the bed of the Danube below Palkovičovo, in Hungarian and Czechoslovak territory;
(6) Improvement of the old bed of the Danube, in Hungarian and Czechoslovak territory;
(7) Operational equipment of the Babčíkovo system of locks (transport equipment, maintenance machinery), in Czechoslovak territory;
(8) The flood-control works of the Nagymaros head-water installations in the lower Ipel district, in Czechoslovak territory;
(9) The flood-control works of the Nagymaros head-water installations, in Hungarian territory;
(10) The Nagymaros series of locks, in Hungarian territory;
(11) Deepening of the tail-water bed below the Nagymaros system of locks, in Hungarian territory;
(12) Operational equipment of the Nagymaros system of locks (transport equipment, maintenance machinery), in Hungarian territory;
(13) Restoration of vegetation in Czechoslovak territory.

6. The apportionment of labour and supplies under the joint investment as provided in paragraph 5 shall be evaluated by the Contracting Parties in monetary terms in the joint contractual plan. The valuation of the labour and supplies shall not affect the apportionment of the works (labour) specified in paragraph 5; however, any amount due for settlement may not exceed 2.5 per cent of the budgetary value of the work and deliveries to be carried out by the Contracting Parties in accordance with paragraph 5. The settlement of any difference as aforesaid shall also take the form of labour and supplies. The costs of carrying out the joint investment shall be specified in the joint contractual plan on the basis of the mutually agreed budgetary figures and shall be expressed in the Hungarian forint and the Czechoslovak koruna at the annual rate of exchange in effect on 1 January 1975.

7. Each Contracting Party shall bear the full amount of all costs of works to be carried out and labour and supplies to be provided by it in accordance with the apportionment of labour and supplies under the joint investment.

8. The Contracting Parties shall, on the basis of the apportionment of labour and suplies under the joint investment, prepare construction plans and specifications for the works to be carried out and the operations to be performed by them within their sphere of authority in accordance with the approved joint contractual plan, and they shall, on the basis of such plans and specifications, ensure within their sphere of authority the execution of the said works.

9. The Contracting Parties shall ensure, and shall be responsible to each other for doing so, that the planning and execution of works and operations are in accord with the approved joint contractual plan.

Article 6. AGENCIES RESPONSIBLE FOR THE REALIZATION OF THE JOINT INVESTMENT

1. The Contracting Parties shall rely on their own investment agencies to ensure that the objectives connected with the realization of the joint investment are achieved.

2. Supervision and co-ordination of the activities of the investment agencies of the Contracting Parties shall be ensured by the government delegates.

Article 7. SETTLEMENT OF COSTS IN EXCESS OF THE JOINT INVESTMENT

1. Subsequent to the apportionment of labour and supplies under the joint investment, there shall be no settlement between the Contracting Parties of additional costs under the joint investment relating to the construction of the System of Locks, save in the following cases:

(*a*) Damage arising in the course of the realization of the investment by reason of unavoidable circumstances (*vis major*);

(*b*) The emergence of unforeseeable geological conditions;

(*c*) Mutually agreed modifications of the technical procedures adopted in the approved joint contractual plan.

2. The expression "unforeseeable geological conditions" means a situation where the geological conditions determined in the course of construction differ markedly from the conditions determined on the basis of the exploration conducted for the purposes of the joint investment programme and the joint contractual plan. Additional costs arising from faulty exploration, planning errors or faulty methods of construction may not be regarded as consequences of unforeseeable geological conditions.

3. Costs arising in consequence of the cases enumerated in paragraph 1 shall be borne by the Contracting Parties in equal measure after approval by the government delegates.

4. The Contracting Parties shall endeavour, if possible in the course of the construction, to settle, in the form of labour and supplies, any differences that arise subsequent to the apportionment in equal measure of labour and supplies.

Article 8. OWNERSHIP OF WORKS CARRIED OUT UNDER THE JOINT INVESTMENT

1. Among the works of the System of Locks carried out as joint investment, the following shall be jointly owned by the Contracting Parties in equal measure:

(*a*) The Dunakiliti dam (article 1, paragraph 2 (*b*));

(*b*) The by-pass canal (article 1, paragraph 2 (*c*));

(*c*) The Gabčíkovo series of locks (article 1, paragraph 2 (*d*));

(*d*) The Nagymaros series of locks (article 1, paragraph 3 (*b*));

2. On the basis of the joint ownership, the Contracting Parties shall have the rights and obligations arising from the relevant provisions of this Treaty.

3. Ownership of the other works of the System of Locks carried out as joint investment shall vest in the Contracting Party in whose territory they were constructed.

CHAPTER IV. OPERATION OF THE WORKS OF THE SYSTEM OF LOCKS

Article 9. SHARE OF THE CONTRACTING PARTIES IN THE USE OF THE SYSTEM OF LOCKS

1. The Contracting Parties shall participate in the use and in the benefits of the System of Locks in equal measure.

2. The output of the hydroelectric power plants shall be available to the Contracting Parties in equal measure, and they shall participate in kind, in equal

measure, in the base-load and peak-load power generated at and conducted from the said plants.

3. In the event of the construction of planned locks on the Danube directly above or below the System of Locks, the Contracting Parties shall individually agree on taking the impact of the works on each other into consideration.

Article 10. METHOD OF OPERATION OF THE WORKS OF THE SYSTEM OF LOCKS

1. Works of the System of Locks constituting the joint property of the Contracting Parties shall be operated, as a co-ordinated single unit and in accordance with the jointly-agreed operating and operational procedures, by the authorized operating agency of the Contracting Party in whose territory the works were built.

2. Works of the System of Locks owned by one of the Contracting Parties shall be independently operated or maintained by the agencies of that Contracting Party in the jointly prescribed manner.

3. The Contracting Parties shall ensure that the agencies operating the System of Locks maintain, in accordance with the regulations in force, operating conditions that satisfy the requirements for co-ordinated and effective operation of the entire System of Locks.

4. The following principles shall in particular be observed in the operation of the power-plant facilities of the System of Locks:

(*a*) The hydroelectric power plants of the two series of locks in the System of Locks shall be so operated as not only to take into account the requirements of the energy-related agencies of the Contracting Parties but also to satisfy the demands of efficiency and economy;

(*b*) Electric output and the distribution and consumption of electric power shall be determined by agreement between the State load-distribution dispatchers of the Contracting Parties.

Article 11. AGENCIES OPERATING THE WORKS OF THE SYSTEM OF LOCKS

1. The Contracting Parties shall entrust the operation of those structures of the jointly-owned works of the System of Locks which are in their territories to the following national operating agencies:

(*a*) To energy-related agencies in the case of energy-related works;

(*b*) To water-resource management agencies in the case of water-resource-management and navigational works.

2. Supervision and co-ordination of the activities of the national agencies responsible for the operation of the System of Locks shall be ensured by the government delegates.

Article 12. RESPONSIBILITY FOR THE PAYMENT AND ACCOUNTING OF THE OPERATING COSTS OF THE SYSTEM OF LOCKS

1. Operating, maintenance (repair) and reconstruction costs of jointly-owned works of the System of Locks shall be borne jointly by the Contracting Parties in equal measure.

2. Those works constituting the property of one of the Contracting Parties the operating, maintenance (repair) and reconstruction costs of which are borne jointly by the Contracting Parties in equal measure shall be specified in the joint contractual plan.

3. Costs not mentioned in paragraphs 1 and 2 and flood-control costs incurred in their own territory shall be borne separately by each of the Contracting Parties.

4. Only direct costs may be included under the heading of operating, maintenance and reconstruction costs. The sphere of direct costs shall be defined by the operators before operations begin. The definition thereof shall be approved by the government delegates. Direct costs may not be construed as including general (overhead) costs, taxes and State levies, amortization costs, and charges for water used for the production of electric power.

5. The planning and accounting of the jointly-borne costs referred to in paragraphs 1, 2 and 4 shall be effected in the following manner:

(*a*) The operating agencies shall draw up annual operating, maintenance and reconstruction plans, which shall be approved by the government delegates. These plans shall include a breakdown of the operations according to whether they were performed by the operating agencies or by outside undertakings;

(*b*) The accounting of operations performed by outside undertakings shall be carried out on the basis of invoices verified by the operators;

(*c*) The accounting of the operations which are carried out on the basis of the plans shall be approved each year by the government delegates;

(*d*) Detailed instructions on planning and accounting procedures shall, before the commencement of the operations, be drawn up by the operating authorities, with the agreement of the financial authorities of the Contracting Parties, in accordance with guidelines given by the government delegates.

6. The annual amount of jointly-borne operating costs shall be expressed in national currencies converted into transferable roubles. If, at the commencement of operations, no generally applicable exchange rates are available, the financial authorities of the Contracting Parties shall come to a decision on them.

7. The Contracting Parties shall endeavour to ensure that any differences arising from operating costs are, so far as possible, settled by work performed within the framework of the annual operating, maintenance and reconstruction plan of the System of Locks. The procedure for the settlement of differences still outstanding shall be determined by agreement between the competent authorities of the Contracting Parties.

CHAPTER V. WATER-RESOURCE MANAGEMENT FUNCTIONS

Article 13. FLOOD CONTROL AND ICE DISCHARGE

1. Flood-control operations shall be carried out by the water-resource management authorities of the Contracting Parties.

2. On the occasion of flooding or ice movement in the System of Locks, the government delegates shall ensure co-ordination of the activities of the flood-control authorities of the Contracting Parties.

3. On the occasion of flooding or ice movement, the opertions of the works of the System of Locks shall be subject to flood-control requirements.

4. High water and ice shall be discharged through the head-water installations and the series of locks of the System of Locks in accordance with the operating and operational procedures of the System of Locks.

Article 14. WITHDRAWAL OF WATER FROM THE DANUBE

1. The discharge specified in the water balance of the approved joint contractual plan shall be ensured in the bed of the Danube between r.km. 1842 and r.km. 1811 unless natural conditions or other circumstances temporarily require a greater or smaller discharge.

2. The Contracting Parties may, without giving prior notice, withdraw from the Hungarian-Czechoslovak section of the Danube, and make use of, the quantities of water specified in the water balance of the approved joint contractual plan.

3. In the event that the withdrawal of water in the Hungarian-Czechoslovak section of the Danube exceeds the quantities of water specified in the water balance of the approved joint contractual plan and the excess withdrawal results in a decrease in the output of electric power, the share of electric power of the Contracting Party benefiting from the excess withdrawal shall be correspondingly reduced.

Article 15. PROTECTION OF WATER QUALITY

1. The Contracting Parties shall ensure, by the means specified in the joint contractual plan, that the quality of the water in the Danube is not impaired as a result of the construction and operation of the System of Locks.

2. The monitoring of water quality in connection with the construction and operation of the System of Locks shall be carried out on the basis of the agreements on frontier waters in force between the Governments of the Contracting Parties.

Article 16. MAINTENANCE OF THE BED OF THE DANUBE

Maintenance of the bed of the Danube, including the old bed of the Danube, shall be incumbent upon the competent State agencies of the Contracting Parties. Maintenance operations shall be carried out in accordance with the approved operating and operational procedures of the System of Locks and with due regard for the provisions of the agreements on frontier waters in force between the Governments of the Contracting Parties.

Article 17. WATER-USE PERMITS AND WATER-USE SUPERVISION

The water-use permits and water-use supervision of structures in their territories constituting jointly-owned works of the System of Locks shall be provided for by the Contracting Parties in accordance with their own laws and regulations.

CHAPTER VI. NAVIGATION

Article 18

1. The Contracting Parties, in conformity with the obligations previously assumed by them, and in particular with article 3 of the Convention concerning the regime of navigation on the Danube, signed at Belgrade on 18 August 1948,[1] shall ensure uninterrupted and safe navigation on the international fairway both during the construction and during the operation of the System of Locks.

2. The construction of the System of Locks will, when the Dunakiliti dam is put into service, make it necessary to re-route shipping and, for a short time, to interrupt shipping. Shipping shall be re-routed through the Dunakiliti navigation lock in such a way as to require the minimum interruption of navigation. The re-routing of shipping and the movement of shipping through the Dunakiliti lock shall take place

[1] United Nations, *Treaty Series*, vol. 33, p. 181.

at the time of least shipping traffic so as to be able to continue for the minimum period specified in the joint contractual plan.

3. Navigation in the System of Locks shall be governed by the regulations of the navigation authorities of the Contracting Parties.

4. The conditions for navigation in the old bed of the Danube shall be specified in the operating and operational procedures.

CHAPTER VII. PROTECTION OF THE NATURAL ENVIRONMENT

Article 19. PROTECTION OF NATURE

The Contracting Parties shall, through the means specified in the joint contractual plan, ensure compliance with the obligations for the protection of nature arising in connection with the construction and operation of the System of Locks.

Article 20. FISHING INTERESTS

The Contracting Parties, within the framework of national investment, shall take appropriate measures for the protection of fishing interests in conformity with the Danube Fisheries Agreement, concluded at Bucharest on 29 January 1958.[1]

CHAPTER VIII. PROVISION OF LAND

Article 21

The Contracting Parties shall in good time prepare and make available to each other the land required for the preparatory construction stage, the construction and the operation of the works of the System of Locks.

CHAPTER IX. DETERMINATION OF THE BOUNDARY LINE OF THE STATE FRONTIER AND CROSSING OF THE STATE FRONTIER

Article 22. DETERMINATION OF THE BOUNDARY LINE OF THE STATE FRONTIER

1. The Contracting Parties have, in connection with the construction and operation of the System of Locks, agreed on minor revisions of and changes in the character of the State frontier between the Hungarian People's Republic and the Czechoslovak Socialist Republic, as follows:

(*a*) Subsequent to the construction of the System of Locks, the movable character of the State frontier in the old bed of the Danube between the r.km. 1840 and r.km. 1811 segments shall remain unchanged, and the position of that frontier shall be defined by the centre-line of the present main navigation channel of the river;

(*b*) In the r.km. 1842-1840 sector, up to the division of the bed, the State frontier shall run, as though fixed, along the centre-line of the present main navigation channel;

(*c*) In the Dunakiliti-Hrušov head-water area, the State frontier shall run from r.km. 1842 along the centre-line of the present main navigation channel up to boundary point 161.V.O.á.;

(*d*) In the Dunakiliti-Hrušov head-water area, the State frontier shall run from boundary point 161.V.O.á. to boundary stone No. I.5. in a straight line in such

[1] United Nations, *Treaty Series*, vol. 339, p. 23.

a way that the territories affected, to the extent of about 10-10 hectares, shall be offset between the two States.

2. The revision of the State frontier and the exchange of territories provided for in paragraph 1 shall be effected by the Contracting Parties on the basis of a separate treaty.

3. The Contracting Parties shall, in the tail-water canal and head-water canal, and in the main shipping lane in the Dunakiliti-Hrušov head-water area extending to r.km. 1850.4, continue without change to exercise the rights and comply with the obligations to which they were entitled, or by which they were bound, in this sector of the river before the conclusion of this Treaty, notwithstanding that the international shipping lane has in this sector been shifted to the tail-water canal or head-water canal, respectively, situated in Chechoslovak territory.

Article 23. Crossing of the State frontier

1. In the course of the preparations for and the construction and operation of the System of Locks, the two Contracting Parties shall ensure that authorized persons possessing the appropriate documents are able to cross the State frontier, subject to extremely simplified formalities, for the purpose of performing the tasks arising from this Treaty, and that the necessary conditions are provided for the performance of the said tasks in their territories.

2. The competent authorities of the Contracting Parties shall agree separately on detailed regulations concerning the crossing of the State frontier in accordance with paragraph 1 and the stay of the relevant persons in the territory of the other Contracting Party.

CHAPTER X. CUSTOMS PROVISIONS

Article 24

1. Separate agreements shall be concluded by the competent authorities of the Contracting Parties concerning the transfer to the territory of the other Contracting Party of documents, machinery and materials required for operations connected with the preparations for and the realization and operation of the System of Locks.

2. The Contracting Parties shall make available to each other, free of financial levies (duties, taxes, fees, etc.), the electric power to which the other Contracting Power is entitled from the power produced in the System of Locks.

CHAPTER XI. LIABILITY OF THE CONTRACTING PARTIES AND PAYMENT OF DAMAGES

Article 25. Joint liability of the Contracting Parties and payment of damages

1. The Contracting Parties shall be jointly liable in respect of:

(*a*) The content of the approved joint contractual plan;

(*b*) The execution of the Treaty during the construction and operation of the System of Locks, the jointly-adopted measures and decisions of the government delegates, and the joint measures and decisions of the joint agencies.

2. In consequence of their liability under paragraph 1, the Contracting Parties shall jointly and in equal measure:

(*a*) Make compensation for damage resulting from acts giving rise to their joint liability and pay the costs arising from such compensation;

(*b*) Compensate a third party for damage suffered by him as the result of acts giving rise to their joint liability.

3. The Contracting Parties shall jointly and in equal measure make compensation for damage arising in the course of the realization of the joint investment and during the period of operation of the jointly-owned works, and shall pay the costs arising from such compensation:

(*a*) In the case of damage resulting from unavoidable circumstances (*vis major*);

(*b*) In the case of damage caused by a third party, on condition that the investor or operator could not have prevented the damage even though the exercise of the diligence that might have been expected of him.

Article 26. EXCLUSIVE LIABILITY OF THE CONTRACTING PARTIES AND PAYMENT OF DAMAGES

1. Each of the Contracting Parties shall be separately and exclusively liable in respect of:

(*a*) The accomplishment of the work and deliveries which, on the basis of the apportionment of labour and supplies under the joint investment, are carried out by them, in accordance with the provisions of the approved joint contractual plan and within the time-limits specified in the project work schedule;

(*b*) The operation, and the systematic maintenance in good working order, of the jointly-owned works constructed in their territories, and the preservation of the plant and equipment of those works;

(*c*) The operation, and the systematic maintenance in good working order, of works constituting the property of one of the Contracting Parties as provided in article 8, paragraph 3, and the preservation of the plant and equipment of those works.

2. In consequence of their liability under paragraph 1, the Contracting Parties shall separately and exclusively:

(*a*) Make compensation for damage which results from acts giving rise to their exclusive liability in connection with the operations and works referred to in paragraph 1, sub-paragraphs (*a*) and (*b*), or damage which results from the action of a third party, on condition that the investor or operator could have prevented such damage through the exercise of the diligence that might have been expected of him, and shall pay the costs arising from such compensation;

(*b*) Make compensation for all damage arising from operations of the works referred to in paragraph 1, sub-paragraph (*c*), and shall pay the costs arising from such compensation;

(*c*) Compensate the other Contracting Party or a third party for damage resulting from the late or improper performance of work and deliveries carried out by them, from the deterioration of the plant and equipment of the works referred to in paragraph 1, and from operations not in conformity with the approved operating and operational procedures.

3. Determination of the extent of damage compensable and the amount of costs payable under the provisions of paragraph 2, and determination of the causes of the damage and the ensuing obligations to pay compensation or damages shall, as

regards the common interests of the Contracting Parties, come within the sphere of authority of the government delegates.

4. Payment of compensation between the Contracting Parties shall be governed by the provisions of article 12.

CHAPTER XII. SETTLEMENT OF DISPUTES

Article 27

1. The settlement of disputes in matters relating to the realization and operation of the System of Locks shall be a function of the government delegates.

2. If the government delegates are unable to reach agreement on the matters in dispute, they shall refer them to the Governments of the Contracting Parties for decision.

CHAPTER XIII. FINAL PROVISIONS

Article 28

1. This Treaty shall be ratified, and the instruments of ratification shall be exchanged at Prague.

2. The Treaty shall come into force on the date of the exchange of the instruments of ratification.

IN WITNESS WHEREOF the plenipotentiaries have signed this Treaty and have affixed thereto their seals.

DONE at Budapest, on 16 September 1977, in duplicate, in the Hungarian and Slovak languages, both texts being equally authentic.

For the Government of the Hungarian Peopleś Republic:	For the Government of the Czechoslovak Socialist Republic:
[GYÖRGY LÁZÁR]	[LUBOMÍR ŠTROUGAL]

Appendix 2

SPECIAL AGREEMENT

for Submission to the International Court of Justice of the Differences between the Republic of Hungary and the Slovak Republic Concerning the Gabcikovo-Nagymaros Project

[*jointly notified to the Court on 2 July 1993*]

The Republic of Hungary and the Slovak Republic,

Considering that differences have arisen between the Czech and Slovak Federal Republic and the Republic of Hungary regarding the implementation and the termination of the Treaty on the Construction and Operation of the Gabcikovo- Nagymaros Barrage System signed in Budapest on 16 September 1977 and related instruments (hereinafter referred to as "the Treaty"), and on the construction and operation of the "provisional solution";

Bearing in mind that the Slovak Republic is one of the two successor States of Czech and Slovak Federal Republic and the sole successor State in respect of rights and obligations relating to the Gabcikovo-Nagymaros Project;

Recognizing that the Parties concerned have been unable to settle these differences by negotiations;

Having in mind that both the Czechoslovak and Hungarian delegations expressed their commitment to submit the differences connected with the Gabcikovo- Nagymaros Project in all its aspects to binding international arbitration or to the International Court of Justice;

Desiring that these differences should be settled by the International Court of Justice;

Recalling their commitment to apply, pending the Judgement of the International Court of Justice, such a temporary water management regime of the Danube as shall be agreed between the Parties;

Desiring further to define the issues to be submitted to the International Court of Justice,

Have agreed as follows:

Article 1

The Parties submit the questions contained in Article 2 to the International Court of Justice pursuant to Article 40, paragraph 1, of the Statute of the Court.

Article 2

(1) The Court is requested to decide on the basis of the Treaty and rules and principles of general international law, as well as such other treaties as the Court may find applicable,

(a) whether the Republic of Hungary was entitled to suspend and subsequently abandon, in 1989, the works on the Nagymaros Project and on the part of the Gabcikovo Project for which the Treaty attributed responsibility to the Republic of Hungary;

(b) whether the Czech and Slovak Federal Republic was entitled to proceed, in November 1991, to the "provisional solution" and to put into operation from October 1992 this system, described in the Report of the Working Group of Independent Experts of the Commission of the European Communities, the Republic of Hungary

and he Czech and Slovak Federal Republic dated 23 November 1992 (damming up to the at river kilometre 1851,7 on Czechoslovak territory and resulting consequences on water and navigation course);

(c) what are the legal effects of the notification, on 19 May 1992, of the termination of the Treaty by the Republic of Hungary.

(2) The Court is also requested to determine the legal consequences, including the rights and obligation for the parties, arising from its Judgment on the questions in paragraph 1 of this Article.

Article 3

(1) All questions of procedure and evidence shall be regulated in accordance with the provisions of the Statute and the Rules of Court.

(2) However, the Parties request the Court to order that the written proceedings should consist of:

(a) a Memorial presented by each of the Parties not later than ten months after the date of notification of this Special Agreement to the Registrar of the International Court of Justice;

(b) a Counter-Memorial presented by each of the Parties not later than seven months after the date on which each has received the certified copy of the Memorial of the other Party;

(c) a Reply presented by each of the Parties within such time-limits as the Court may order.

(d) The Court may request additional written pleadings by the Parties if it so determines.

(3) The above-mentioned parts of the written proceedings and their annexes presented to the Registrar will not be transmitted to the other Party until the Registrar has received the corresponding part of the proceedings from the said Party.

Article 4

(1) The Parties agree that, pending the final Judgment of the Court, they will establish and implemented a temporary water management regime for the Danube.

(2) They further agree that, in the period before such a regime is established or implemented, if either Party believes its rights are endangered by the conduct of the other, it may request immediate consultation and reference, if necessary, to experts, including the Commission of the European Communities, with a view to protecting those rights; and that protection shall not be sought through a request to the Court under Article 41 of the Statute.

(3) This commitment is accepted by both Parties as fundamental to the conclusion and continuing validity of the Special Agreement.

Article 5

(1) The Parties shall accept the Judgment of the Court as final and binding upon them and shall execute it in its entirety and good faith.

(2) Immediately after the transmission of the Judgment the Parties shall enter into negotiations on the modalities for its execution.

(3) If they are unable to reach agreement within six months, either Party may request the

Court to render an additional Judgment to determine the modalities for executing its Judgment.

Article 6

(1) The present Special Agreement shall be subject to ratification.

(2) The instruments of ratification shall be exchanged as soon as possible in Brussels.

(3) The present Special Agreement shall enter into force on the date of exchange of instruments of ratification. Thereafter it will be notified jointly to the Registrar of the Court.

In witness whereof the undersigned, being duly authorized thereto, have signed the present Special Agreement and have affixed thereto their seals.

Done is Brussels, this 7th day of April 1993, in triplicate in English.

For the Republic of Hungary, *Janos Martonyi*.
For the Slovak Republic, *Jan Lisuch*.

Appendix 3

AGREEMENT
BETWEEN THE GOVERNMENT OF THE SLOVAK REPUBLIC
AND GOVERNMENT OF THE REPUBLIC OF HUNGARY
CONCERNING CERTAIN TEMPORARY TECHNICAL MEASURES
AND DISCHARGES IN THE DANUBE AND MOSONI BRANCH OF THE DANUBE

The Government of the Slovak Republic

and

the Government of the Republic of Hungary

have agreed as follows:

Article 1

1. Immediately following the conclusion of this Agreement, the Slovak Party will increase the discharge of water through the intake structure at Čunovo into the Mosoni branch of the Danube to 43 m^3/s subject to hydrological and technical conditions specified in Annex 1 to this Agreement. This value includes the flow of water through the seepage canal on the right side of the reservoir from Slovak territory into Hungarian territory.

2. The competent Slovak and Hungarian authorities shall take all necessary measures on their respective territories to enable the continuous flow of the increased discharge of water from Slovak territory into Hungarian territory.

3. The water will be distributed, on Hungarian territory, between the branch system on the right side of the Danube, the protected area and the Mosoni branch of the Danube.

Article 2

1. The day following the conclusion of this Agreement the discharge into the main riverbed of the Danube below the Čunovo weir will be increased to an annual average of 400 m^3/s, in accordance with the rules of operation contained in Annex 2 to this Agreement. Discharges entering the main riverbed of the Danube through the inundation weir are excluded from the average calculation.

2. During the construction of the weir pursuant to Article 3 the discharge into the main riverbed of the Danube below the Čunovo weir will be regulated in accordance with Annex 3 to this Agreement.

Article 3

1. There will be a weir partly overflowed by water and constructed by the Hungarian Party in the main riverbed of the Danube, at rkm 1843. The main parameters of the weir are specified in Annex 4 to this Agreement.

2. The Parties undertake to ensure the issuance, without delay, of the administrative authorization required by their respective national legislation for the construction and maintenance of the weir in accordance with this Agreement.

3. The costs of the construction and maintenance of the weir will be borne by the Republic of Hungary.

4. The construction of the weir will begin not later that 10 days following the conclusion of this Agreement and is anticipated to be completed within a period of 50 days from the commencement of works.

Article 4

The Parties undertake to exchange those data of their environmental monitoring systems operating in the area that are necessary to assess the impacts of the measures envisaged in Articles 1-3. Collected data will be regularly exchanged and jointly and periodically-evaluated with a view to making recommendations to the Parties. The observation sites, parameters observed, periodicity of data exchange, the methodology and periodicity or joint assessment are contained in Annex 5 to this Agreement.

Article 5

1. In the event that either Party believes the other Party is not complying with this Agreement, and fail to persuade the other Party that it is in breach, the Party may invoke the good offices of the Commission of the European Union and both Parties agree to give close cooperation to the Experts of the Commission and to take duly into consideration any opinion rendered by them.

2. If, for whatever reason, the good offices are not provided or are unsuccessful and the material breach continues to exist, the Party affected will be entitled to terminate this Agreement with a one month notice.

Article 6

This Agreement has a temporary character, pending the judgment of the International Court of Justice in the case concerning the Gabčíkovo - Nagymaros Project and is without prejudice to

existing rights and obligations of the Parties as well as to their respective positions in the dispute before the Court and, in any event, unless otherwise agreed, it shall terminate 14 days after the judgment of the International Court of Justice in the case concerning the Gabčíkovo-Nagymaros Project.

Article 7

On the termination of this Agreement and unless otherwise agreed or decided, Hungary shall at its own expense remove the weir referred to in Article 3.

Article 8

This Agreement shall enter into force on the date of its signature.

Done at Budapest on the 19 day of April, 1995, in duplicate, in the Slovak, Hungarian and English languages, the English text to prevail in the event of any discrepancy.

For the Government
of the Slovak Republic

For the Government
of the Republic of Hungary

Annex No. 1

Hydrological and technical conditions
for the increase of the discharges into the Mosoni Danube

1/ The increase of the discharge into the Mosoni Danube and into the right side seepage canal of the Hrušov reservoir from 20 m^3/sec up to 43 m^3/sec will be ensured subject to the following hydrological and technical conditions:

1.1 Provided that minimum difference between the water-level of the Mosoni Danube and the Hrušov reservoir is 5.10 m.

1.2 Provided that the minimum water level of the Hrušov reservoir is 130.40 m above sea level.

1.3 Provided that the water-level of the Mosoni Danube does not exceed 125.30 m above sea level.

1.4 Provided that the entrances to the intake structure are unobstructed. Whenever the discharges of the Danube exceed 4000 m^3/sec (involving the inundation of the flood-plain), the water-borne materials will move to a greater extent this may restrict the amount of water which can be provided.

1.5 Provided that there is no failure in the electricity network system. If the network system is damaged or in the event of any other failure of the generating capacity, the energy system will turn off automatically and the capacity of the intake structure will be reduced to halt of the original.

2/ At the request of the Hungarian party the Slovak Party will moderate the discharge for a period specified by the Hungarian party.

3/ The selected site for the measuring of the discharge of the Mosoni Danube is a gauge at 0.160 km on the left bank of the canal on the territory of the Slovak Republic. The selected site for the measuring of the discharge of the right side canal of the Hrušov reservoir is on the regulating weir at 1.100 km on the territory of the Hungarian Republic

Annex No. 2

Rules of operation

The volume of water discharged through the Čunovo weir into the main river bed of the Danube to correspond to the annual average of 400 m^3/sec.

The annual average discharge in Bratislava corresponds to 2025 m^3/sec. The annual average discharge into the main Danube river bed in each specific year will correspond to the formula:

$$V_{Danube} = \frac{(V_{Devin} \times 400)}{2025}$$

where :

- $V_{Devín}$ is the average yearly discharge in the Devin profile in the specific year.
- V_{Danube} is the average yearly discharge to the main Danube river bed in the specific year.

- During the growing season the discharge into the main river bedwill be higher than during the dormant season.

- The discharge into the main river bed of the Danube will correspond to actual discharges in the Devin profile.

- The discharges released through the inundation weir during flood will not be included in the calculation.

The discharges in the Devin profile together with the corresponding discharges at the Čunovo weir.

January	February	March	April	May	June
600 250	600 250	600 250	600 400	600 400	600 400
2200 250	2000 250	1500 250	1100 400	700 400	700 400
2300 251	2100 258	1600 250	1200 400	800 400	800 400
2400 273	2200 280	1700 271	1300 400	900 400	900 400
2500 295	2300 301	1800 392	1400 400	1000 400	1000 418
2600 317	2400 323	1900 314	1500 400	1100 400	1100 440
2700 339	2500 345	2000 336	1600 400	1200 400	1200 462

2800 360	2600 367	2100 358	1700 400	1300 440	1300 483
2900 382	2700 389	2200 380	1800 400	1400 405	1400 505
3000 404	2800 410	2300 401	1900 414	1500 427	1500 527
3100 426	2900 432	2400 423	2000 436	1600 449	1600 549
3200 448	3000 454	2500 445	2100 458	1700 471	1700 571
3300 469	3100 476	2600 467	2200 480	1800 592	1800 592
3400 591	3200 498	2700 489	2300 501	1900 514	1900 600
3500 513	3300 519	2800 510	2400 523	2000 536	4600 600
3600 535	3400 541	2900 532	2500 545	2100 558	
3700 557	3500 563	3000 554	2600 567	2200 580	
3800 578	3600 585	3100 576	2700 589	2344 600	
3900 600	3700 600	3200 600	2800 600	4600 600	
4600 600	4600 600	4600 600	4600 600		

July	August	September	October	November	December
600 400	600 400	600 250	600 250	600 250	600 250
700 400	900 400	1100 250	1500 250	1800 250	2000 250
800 400	1000 400	1200 262	1600 250	1900 264	2100 258
900 400	1100 400	1300 283	1700 271	2000 286	2200 280
1000 400	1200 400	1400 305	1800 292	2100 308	2300 301
1100 400	1300 400	1500 327	1900 314	2200 330	2400 323
1200 400	1400 400	1600 349	2000 336	2300 351	2500 345
1300 400	1500 400	1700 371	2100 358	2400 373	2600 367
1400 405	1600 400	1800 392	2200 380	2500 395	2700 389
1500 427	1700 421	1900 414	2300 401	2600 417	2800 410
1600 449	1800 442	2000 436	2400 423	2700 439	2900 432
1700 471	1900 464	2100 458	2500 445	2800 460	3000 454
1800 492	2000 486	2200 480	2600 467	2900 482	3100 476
1900 514	2100 508	2300 501	2700 489	3000 504	3200 498
2000 536	2200 530	2400 523	2800 510	3100 526	3300 519
2100 558	2300 551	2500 545	2900 532	3200 548	3400 541
2200 580	2400 573	2600 567	3000 554	3300 569	3500 563
2300 600	2500 595	2700 589	3100 576	3400 591	3600 585
4600 600	2600 600	2800 600	3200 600	3500 600	3700 600
4600 600	4600 600	4600 600	4600 600	4600 600	

The capacity of the by-pass weir when open under conditions of a minimum water level in the reservoir (which is 128.2 m above sea level), is 290 m^3/sec. The discharge of 400 m^3/s can be assured under the condition that the water level in the reservoir is 128.45 m above sea level, and 600 m^3/sec under conditions of a water level of 129.05 m above sea level.

The water level in the reservoir is lowered only when required for construction or reparation works or when the discharge in Devin is below 925 m^3/s.

The possible differences in discharges which will be ascertained through monitoring by 31 Oct. will be adjusted within the shortest possible period by the end of the same year so that the average of 400 m^3/sec is attained.

The changes in the discharges through the Čunovo weir will occur at intervals of 200 m^3/sec. measured at the Devin site. Thus for instance at 800, 1000, 1200, 1400 ... 2000, 2200 m^3/sec.

This distribution of the water resources shall be in force for 1995 and will be adjusted before the 1996 growing season on the basis of the results of a joint evaluation of the monitoring.

Annex No. 3

Time table of planned underwater weir's construction at rkm 1843

No	Items	Days, weeks																																																
		1							2							3							4							5							6							7						
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
1	Preparation																																																	
2	Demolition of guide bank																																																	
3	Dredging of upstream guide channel																																																	
4	Bank and bed protection																																																	
5	Construction of dam and energy dissipater																																																	
6	Protection of bridgaplate of Dunakilid well																																																	
7	Putting into operation																																																	
8	Completing of bank protection and demolition of lamp energy supply																																																	
9	Water discharge during the construction m3/s	400					200									150 · 100							·				150 · 100														400 · 600			150 >				400 <		

Annex No. 4

*** Main parameters of the weir to be constructed at rkm 1843 of the Danube**

1. The weir which is partly overflowed by water will be constructed at rkm 1843 of the Danube.

2. Main parameters of the weir:

width between banks	300 m
width of the crest	5 m
width of the overflowed section	100 m
height of the center point of the overflowed section	121. 80 B. s .1.
gradient of the downstream slope	1 : 10
gradient of the upstream slope	1 : 3

3. The elevation of the weir crest will be established in such a way that at the discharge of 600 m^3/s, the backwater at rkm 1851.7 of the Danube and elevation of 124.00 Bsl would not exceed.

4. The water level regulation at rkm 1843 take place when the discharge of the Danube is between 250-1300 m^3/s.

5. A maximum quantity of 150 m^3/s will be discharged into the right side branch, system on the Hungarian side.

* Based on the documentation approved under the number

No. VOD 161/A 28/1993-V

No. 21.663/17/1993

Annex No. 5

Matters relating to monitoring of environmental impacts

Monitoring is divided into the following monitoring items:

Monitoring of surface water levels and discharges

the Danube:
profile at Devin
profile at Medved'ov
profile at Komárno - Komárom
profile at Štúrovo - Fsztergom
profile at Rajka
profile at Dobrohost
profile at Dunaremete
profile downstream and upstream of overflowed weir at rkm 1843, (water level only)
Reservoir at Čunovo and the Danube downstream and upstream of the by-pass weir (water level only)
Reservoir at Gabčíkovo (water level only)
Tailrace canal downstream of Gabčíkovo (water level only)

Malý Danube:
at Bratislava
at Trstice

Mosoni Duna:
downstream of the intake structure at Čunovo
at Mecsér
at Győr

Structures at Rajka
Seepage canal at Čunovo (on the Slovak territory)
No. 1. Lock of the outlet
No. 2. Lock of the water level control
No. 6. Lock of the water level control - Mosoni Duna
No. 1. Lock of the side branch Kiliti - Cikolai, Zátonyi Duna
No. 5. Lock at the seepage canal

Frequency of measurements: continuous on a daily basis

Monitoring of surface water quality

the Danube:

upstream Bratislava *
at Dobrohost'
at Gabčíkovo
at Medved'ov *
at Gönyű
at Komárno - Komárom
at Štúrovo – Esztergom

Reservoir, bypass canal, seepage canals, river branches:

- upper part of the reservoir at Rusovce *
- the reservoir at Kalinkovo (left and right side)
-downstream of Mosoni Danube the intake structure
-the profile at Šamorín (left, middle and right side)
- the power canal at the ferry station
-the tailwater canal downstream of Gabcíkovo *
-the seepage canal at Čunovo *
-the seepage canal at Hamuliakovo
-the Mosoni Duna at Rajka
-the Mosoni Duna at Mecsér
-the Mosoni Duna at Vének
-the Malý Dunaj at Kolárovo
-the river branches Helena and Doborgaz
-the Šulianske river branch

Frequency of measurement:

-stations marked by * - 12 times per year, between the 10th and 20th of each month,
-all other stations in: January, March, April, May, June, July, September, November, between the 10th and 20th of each month.

List of parameters:

-temperature, pH value, conductivity at 25°C, O_2
-cations: Li, Na, K, Ca, NH4, Mn, Mg, Fe
-anions: HC03, Cl, S04, N03, N02, P04, P
-trace elements: Hg, Zn, As, Cu, Pb, Cr, Cd, Ni, Vanadium
-COD, BOD, dissolved materials (mineralization)
-biological parameters: Saprobility index, bioseston, chlorophyll,

-number of algae, zooplancton, macrobenthos, according to the decision of the monitoring group
-microbiological parameters, coliform bacteria, mezophilic bacteria, psychrophilic bacteria
-organic matters, TOC, Nonpolar extractable - UV, - IR, EOX, AOX, phenols, humic acids,
-organic micropollutants, polyaromatic hydrocarbons, - polychlorobiphenyls (and others, to be agreed)

Sediments:

-at jointly selected stations, e.g. at places of surface water quality sampling,
-three places in the Slovak and three in the Hungarian flood plain

Extent of parameters:

granulometric curves, organic matters and other selected parameters

Frequency of measurement: once per year in autumn

Monitoring of ground water levels

Monitoring of ground water levels will be carried out on wells between the Malý Danube and the Lajta - Mosoni Danube. Wells to be chosen in profiles based on maps containing all observation wells. [At least at 150 wells on the Slovak territory and at least at 100 wells on the Hungarian territory to be chosen.]

Frequency of measurement: once per week

Monitoring of ground water quality

Ground water quality will be monitored on the municipal water supply [and ground water] wells between the Malý Danube and the Lajta - Mosoni Danube, [at least 10 localities on each territory. In addition to this other at least 10 selected ground water quality wells on each territory] should be monitored. These wells should be those which satisfy hygiene criteria for drinking water wells and sampling should be commonly agreed.

Frequency of measurement: once per month.

Quality should be evaluated according to the standards for drinking water in force in both countries.

Monitoring of soil moisture (aeration zone)

[At least 10] monitoring areas to be selected on each territory from among the localities already monitored.

Frequency of measurement: once every 10 days, but in winter (November, December, January and February) twice a month. Each locality should also include a ground water level monitoring well.

Monitoring of biota:

- microbenthos and macrobenthos in the Danube and river branches at places of water level measurements
-fish, in all surface waters
-[Forestry, on at least 8 selected places from among existing monitoring localities on each side]
-Special water related organisms as for example: Odonata, Ephemeroptera, Trichopetra, Braconidea and others, jointly selected.

Special monitoring

For the estimation of the impact of the overflowed weir special monitoring to be carried out. This will include measurements of flow velocities, water levels, water quality, micro and macro benthos, sediments, ground water quality in the impounded reach etc.

Submitting of data and reports:

Both sides will use data jointly agreed and will use jointly agreed methods of evaluation. All monitoring items and locations, and methods of measurements to be jointly agreed. Annual reports will include only measured data in tabulated, graphical and map forms with short explanations.

Joint and verification measurements will be carried out at any location where a discrepance occurs.

Data exchange will be carried out at three month intervals. Annual reports to be submitted as joint reports by the end of each calendar year and covering a period or a hydrological year.

Annual reports will be issued in English language with standardised graphical annexes in Hungarian or Slovak languages.

Statute

Monitoring will be carried out in accordance with the Statute of nominated Monitoring Agents. Statute will be prepared by: Ing. Árpád Kovács, Ministry of Environment (Hungary), Ing. Dominik Kocinger, Government plenipotentiary for the GNP (Slovakia)
Draft statute will be prepared jointly following the signing of this document and before 31. May 1995.
Text in square brackets [] contains Slovak proposals subject to agreement by the Monitoring Agents.

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Page references followed by *m* indicates a map; followed by *fig* indicates an illustrated figure; followed by *t* indicates a table.