Defence from Floods and Floodplain Management

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Kluwer Academic Publishers

Dordrecht / Boston / London

Published in cooperation with NATO Scientific Affairs Division

Chapter III.7

ENVIRONMENTALLY AND SOCIALLY SOUND UTILIZATION OF FLOOD-PLAINS; SOME AUSTRIAN EXPERIENCES

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Abstract. Only a few free-flowing sections of the Danube remain within Austrian territory; the longest is located downstream of Vienna. Large floodplains with a high biological diversity and covering about 80 km^2 are to be found here. Besides the biological resources, the water resources and the hydropower potential are of great economic interest. Several proposals have been put forward in the last ten years, ranging from environmental protection (by declaring a national park) to various alternatives for hydropower utilization. No compromise has been achieved, owing to the obvious conflicting objectives. The aim of this chapter is to provide a framework for the comparison of the alternative development and management plans. The various proposals made for this section are summarized, criteria are established and a multicriterion approach is applied to rank the alternatives. The sensitivity of the ranking procedure on the preference structure is then investigated. This approach should assist in formulating an ecologically and socially sound development plan for this important floodplain region.

1. Introduction

Around 1900, the area of riverine forests along the Austrian Danube was estimated at 33,840 ha. By 1975, only 28,100 ha remained and it can be assumed that this figure is still decreasing owing to impoundment works. In the section downstream of Vienna about 8,000 ha are located along the Danube and about 3,500 ha are situated along the River March. The total forested area including some areas with hybrid poplar stands is estimated to be 160 km^2. Considering the spatial distribution of riverine water bodies in Austria the importance of this region is also underlined (Fig. 1) The biological resources are described in some detail.

The Danube provides an important international waterway with an economically attractive hydropower potential which is almost completely utilized. Nine hydropower schemes (Fig. 2), jointly operated by the FRG and Austria, generate about 30 % of the

J. Gardiner et al. (eds.), Defence from Floods and Floodplain Management, 539–554.

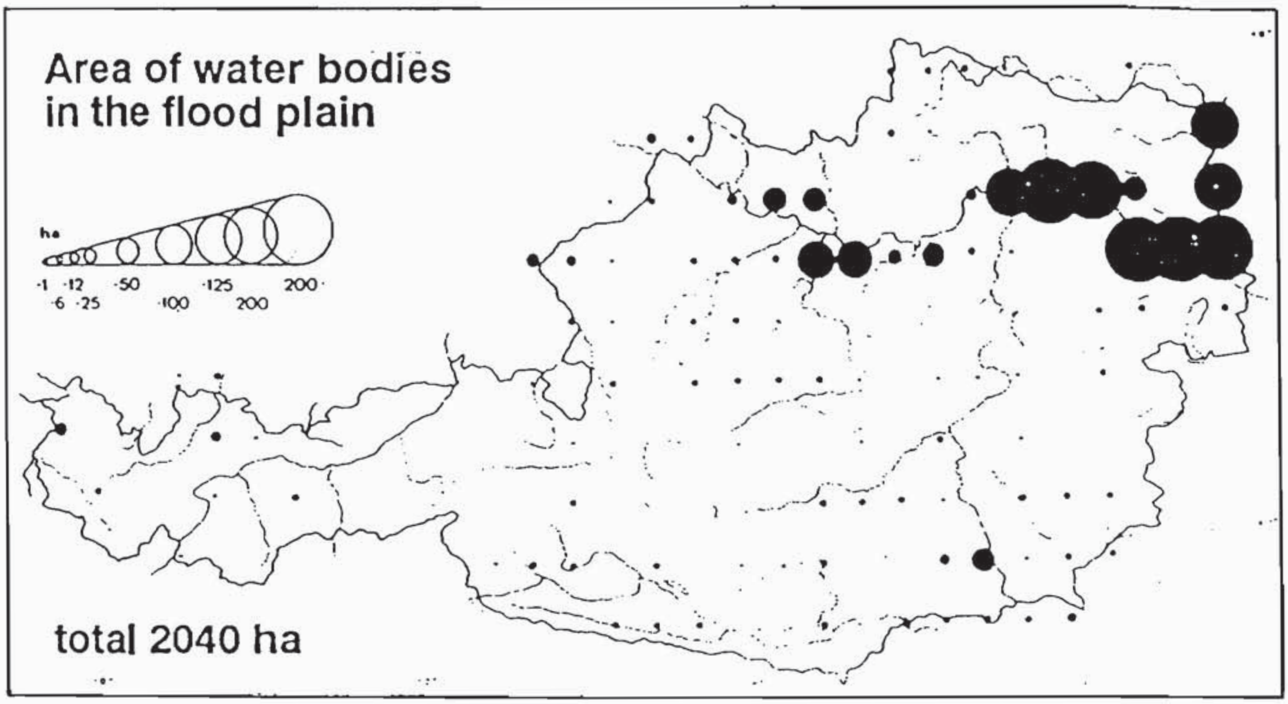

Figure 1. Spatial distribution of riverine water bodies in Austria
(in ha; from GEPP, 1985a)

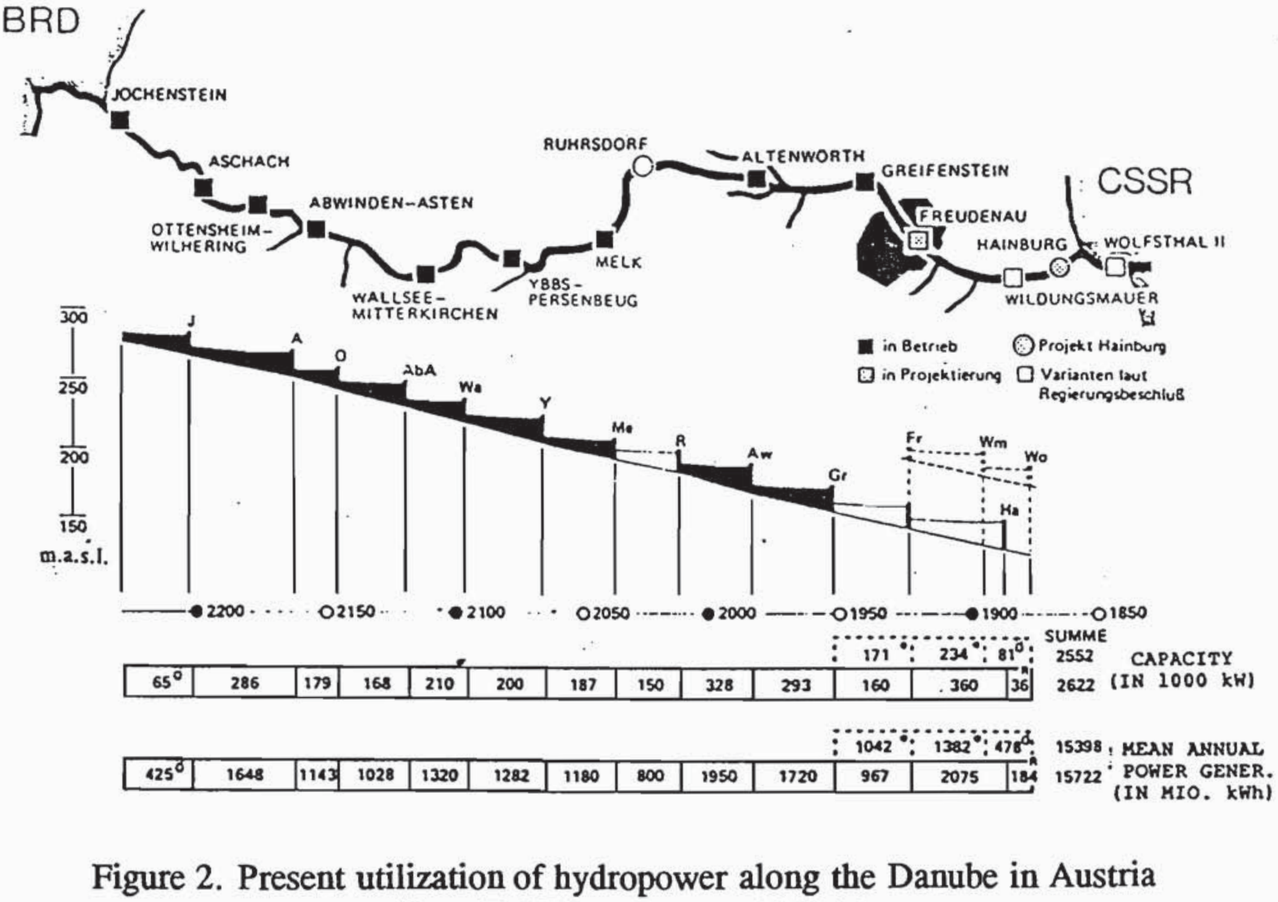

Figure 2. Present utilization of hydropower along the Danube in Austria
(from DONAUKRAFT, 1989 b)

Austria's hydropower electricity. To stress the importance of hydropower in Austria it is worth noting that it produces about 2/3 of the electric energy consumption. Simultaneously, the run-of-river schemes along the Danube serve the navigation purpose. The respective recommendations for the dimension of the waterway are summarized in the declaration of the Danube commission.

In 1984 the hydropower company responsible by law for the utilization of the potential of the River Danube submitted a project (Donaukraft, 1984) to be authorized by the Supreme Water Law Authority which is associated with the Austrian Ministry of Agriculture and Forestry. The goal of the proposal was to implement the last hydropower station along the Austrian Danube a few miles upstream of the Austrian-Slovakian border. The proposed plant was a run-of-river type station with characteristics similar to all the Austrian Danube power stations. The negotiation process performed under the Supreme Water Law Authority, acting as a lead agency, resulted in the approval of the project although several improvements were additionally imposed to protect the environment.

However, great concern was raised by eco-activist groups who received strong support from the public, especially from some newspapers. These groups finally claimed the project site and the clearing works had to be postponed. Later on, the Supreme Administrative Court annulled the water law concession.

To resume negotiations the Federal Government established an Ecological Advisory Board to detail proposals for the future management of the respective Danube section. Although this Board was composed of environmentalists, engineers and regional planners it worked with surprising efficiency and the members finally recommended that the last unimpounded section from Vienna downstream to Wolfsthal (Fig. 3) should be protected from any economic utilization. A final decision is pending.

This chapter attempts to show how a rational comparison of conflicting objectives might be achieved. A framework considering economic, ecological and social criteria is defined and a methodology for identifying a compromise solution is explained. The number of criteria discussed and suggested by the Ecological Advisory Board is quite large and it can be assumed that some of the criteria are somehow interrelated. In other words, several criteria express the same characteristics of the system. To avoid any bias and noise in the evaluation procedure a set of the most discriminating criteria should be identified.

2. Description of the Resources Downstream of Vienna

2.1. FLOODPLAIN FORESTS

In Austria more than 75 % of water bodies typical of floodplain areas are located along the Danube. They cover an area of 1,540 ha from which 730 ha are found downstream of Vienna (Gepp, 1985 a). The importance of this floodplain area becomes more evident when only surface waters which still exhibit natural dynamics and which are frequently subjected to frequent flooding are considered.

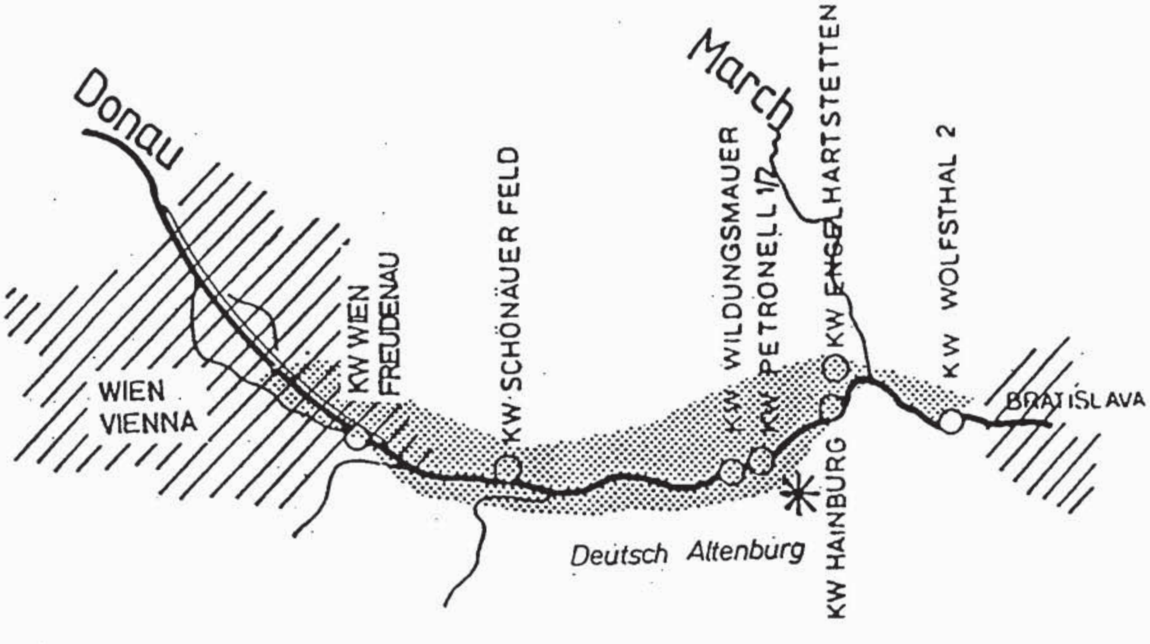

Figure 3. Alternative plans for hydropower utilization

Preliminary investigations and preparatory planning activities to establish a national park in this region indicate a total area of 230 km^2 to be protected. The "kernel area" is about 110 km^2 which should be excluded from any economic utilization. Additionally, 94 km^2 of riverine zones along the tributary River March should be integrated into the planned national park (Schulz, 1986).

With respect to biological diversity it is estimated that approximately 12,000 species (fauna and flora) are found in the Austrian floodplain areas (GEPP, 1985 b). In the concluding paper of the Ecological Advisory Board (1985) an estimate of 5000 faunal species is given for the region. Several of them are on the list of endangered species.

About 80 %, which is equivalent to 109 species, of the birds hatching in Austria are native to the floodplain areas. Further, this region is of vital importance in serving as a resting place during the migration of birds.

Oxbow lakes and stagnant shallow waters constitute the spawning grounds for numerous fish species. 57 species (Jungwirth & Rehahn 1986; Schiemer, 1986) are observed in the Danube of which 32 species are abundant. These backwater areas serve also as a spawning ground and habitat for amphibia which require shallow water zones, bankside vegetation and sunny patches. Flood events stimulate their reproduction and subsequently enhance cyclic migration into the remote backwater areas.

2.2. GROUNDWATER SYSTEM

The Danube River recharges a groundwater system extending over 1,000 km^2 on the left bank. This area is intensively used for agriculture and covers its water requirements by groundwater pumping. The main source of recharge is the Danube which strongly interacts with the groundwater aquifer. Additionally, a small percentage of the water requirements of the city of Vienna is covered by pumping bank-filtrated water. On both sides of the Danube there are some wells to satisfy domestic water requirements. All these wells strongly depend on the surface water level of the Danube.

2.3. HYDROPOWER

The raw energy potential which refers to the complete utilization of the discharge over the full head along the section is given in Table 1.

It is worth noting that the lowest subsection in the Danube constitutes the border between Austrian and Slovakia and thus the hydropower potential has to be properly allocated between these two countries .

A hydropower scheme which is just under construction will soon utilize the hydropower potential from Greifenstein down to Freudenau, located a few kilometres downstream of Reichsbrücke.

Table 1. Raw energy potential downstream of Greifenstein in GWh/a (Donaukraft, 1990)

Subsection	Stream location (km)	Raw Energy potential (Gwh)
Greifenstein-Vienna (Reichsbrücke)	1948.88-1929.09	1281
Vienna (Reichsbrücke)-Hainburg	1929.09-1883.9	3022
Hainburg-Mouth of river March	1883.9-1880.1	311
Mouth of river March-border	1880.1-1872.70	524
Greifenstein-Border	1948.88-1872.70	5138

3. Identification of Goals Relevant for this Section of Danube

3.1. ENVIRONMENTAL PRESERVATION

In 1978 and 1979 major areas of the floodplain forests were legally protected by the respective provinces. Because of the unique ecological characteristics of this area, planning activities have been initiated in recent years to delimit a natural preserve worthy of becoming a national park.

Recently, the institutional framework has been defined as a result of a governmental agreement in 1987. Obviously, the preservation of the floodplain forests and of the riparian wetlands by establishing a national park constitutes an important objective for that region. Surprisingly, proposals for the implementation of a national park were not enthusiastically received by the inhabitants in this region.

In accordance with some internationally agreed definition, a national park would be incompatible with any major human use such as hydropower schemes. It is worth noting that the preservation of the free-flowing section of the Danube also presents major problems because of a serious degradation (3-4 cm/year) of the river bed. The degradation will decrease in the long-term and the frequency of the flood plain inundation will also cause a lowering of the groundwater table. Subsequently the wetland region will dry out, as has already been observed in some parts downstream of Vienna.

Recent research investigated alternative measures such as artificial armouring of the river bed by augmentation with coarse-grained bedload material (Zottl, 1988; Ogris, 1989). The theoretical results are interesting but require detailed analysis and would anyway be quite costly. Field experiments which are just in preparation will provide a more rational basis for further decisions.

3.2. HYDROPOWER

A governmental agreement (which was achieved in Pertisau, 1987) underlined once more the importance of hydropower utilization downstream of Vienna but simultaneously asked for planning steps to establish a national park in the floodplain area of Danube and March Rivers. Goals related to power generation and energy management are included in the energy reports issued regularly by the Ministry of HGI. The principles of governmental energy and environmental policies include the following set of guidelines:

* reduction of primary energy consumption,
* increased utilization of renewable resources, especially of hydropower, and
* minimization of environmental impacts related to power generation and consumption.

3.3. NAVIGATION

The Danube section from Braila (170 km) to Kehlheim, FRG (2,414.7 km), is classified as category IV according to the European waterways standards (Fekete, 1990). This requires for unimpounded sections a minimum depth of 1.85-2.50 m and a width of 40-180 m for navigation. In impounded sections the minimal prescribed depth is 3.5 m. For the respective Austrian stretch of the Danube the recommendations of the Danube commission include a minimum depth of 2.10 m downstream of Vienna to the border of Slovakia and a width of 150 m. During low-flow periods, several river bars with a water depth of 2 m or less restrict economic navigation and frequent dredging works are required to maintain the waterway. Thus, it is an important goal to guarantee at least the minimum requirements for navigation throughout the year.

3.4. SOCIAL OBJECTIVE

The social objective refers to satisfying the drinking water requirement, increasing employment opportunities, and increasing water-related facilities for recreation. One of the goals of the regional water management is the protection of the extended alluvial aquifers bordering the Danube. This resource partly serves the Viennese drinking water supply and also some villages in the vicinity of the Danube. In this context the emphasis is also on the protection of a medicinal spring which is supplied from a karstic aquifer located close to the Danube.

The increase of employment opportunities, especially for long-term jobs, is important for the region, from which many people commute to Vienna.

4. Definition of Criteria

There are three conflicting areas of interest related to sustainable development in this particular area, namely economic, ecological and sociological interests. Sustainable water resources development aims at identifying economically attractive, technically feasible, socially acceptable and ecologically sound water resources projects in a form that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). Evidently, acceptable levels of high reversibility, low risk and high equity are the conditions of sustainable water resources development.

Reversibility can be measured by the degree to which an engineered natural resource such as a contaminated groundwater system can be cleaned up. It may take a long time and considerable effort to clean up a contaminated aquifer. Thus the reversibility level of the original groundwater development could have been quite low. Here, reversibility is expressed by the degree to which specific habitats are preserved. Floodplain forests require about one to two hundred years to develop their typical plant composition and spatial pattern. Especially, the preservation of river morphology, of floodplain forests and the diversity of faunistic species is used as an indicator for reversibility.

Risk can be defined as the possible adverse consequences and uncertainties facing water resources development. Risk will occur because planning criteria such as economic benefits or just reversibility can be estimated for the planning horizon of water resources development only with some degree of uncertainty. The various types of risk (economic, social and ecological) should be defined and combined in order to select sustainable water resources alternatives with the new minimum. Risk is not considered explicitly in this chapter but it is obvious that any major losses in typical habitats will increase the probability of irreversible changes in the riverine ecosystem. Many Red List species already endangered by extinction are only found in the remaining floodplain forests. Therefore, the preservation of species can be seen as a risk-reducing objective which might be achieved by natural protection of large areas of the river corridor.

Equity can be defined as the degree of fair distribution of benefits and losses among various parties influenced by water resources development at different times. For instance, this refers to equity between present and future generations or equity among societal strata having quite different preference structures. In this chapter equity is seen as the outcome of a trade-off procedure between ecological and economic interests.

Table 2. Goals, criteria and Units for Hydropower Utilization

Goals	Subgoals	Criteria	Units	Number
maximize economical utilization of resources	maximize power generation,	annual power output,	Gwh	C 1
	minimize costs	investment costs,	Mrd. ATS	C 2
		operation costs	ordinal	C 3
increase social welfare	increase of employment rate,	short-term employment,	man-years	C 4
		long-term employment,	number of jobs	C 5
	improve recreational opportunities,		ordinal	C 6
	improved navigation,	duration of restricted navigation risk	days/year	C 7
	protection of the medicinal spring		ordinal	C 8
preserve the specific ecosystem in this region	preservation of the floodplain forests,	losses due to construction,	ha	C 9
		area of initial vegetation,	ha	C 10
		losses of inundated area,	%	C 11
		area of floodplain forests,	ha	C 12
		forest edges,	km	C 13
		forest galleries,	km	C 14
	preservation of typical faunistic populations	impact on water fowl,	ordinal	C 15
		impact on other populations,	ordinal	C 16
		compatibility with national park requirements	ordinal	C 17

Table 2. (continued) Goals, criteria and Units for Hydropower Utilization

Goals	Subgoals	Criteria	Units	Number
preservation of the specific ecosystem in this region	preservation of the morphometric variability of riverbanks	ratio of impoundment to free flowing section	km/km	C 18
		length of remaining riverbanks	km	C 19
		length of water-bank line at low flows	km	C 20
		length of water-bank line at mean discharge	km	C 21
		shallow water zones at low flows	ha	C 22
		shallow water zones at mean discharge	ha	C 23
		gravel banks at low flows		
		gravel banks at mean discharge	ha	C 24
		connectivity between main river	ha	C 25
		and oxbows	number	C 26
		rate of degradation of the river bed		
	preservation of the water quality	saprobic scale	ordinal	C 27
		change in groundwater quality	ordinal	C 28
		length of impervious dams	ordinal	C 29
		area with changes in the mean	km	C 30
		groundwater table (> 0.5 m)	km^2	C 31
		area with groundwater dynamics (0.5-1.0 m)	km^2	C 32
		area with groundwater dynamics (> 1.0 m)	km^2	C 33

The list of criteria given in Table 2 were mainly discussed by the Ecological Advisory Board and have therefore been included here. It is obvious that some of the criteria express similar characteristics to the outcomes of alternatives. This might introduce some bias and instability in the ranking procedure. Therefore, it seems appropriate to reduce the number of criteria to achieve a subset which could clearly discriminate between the alternatives.

To cope with the different number of criteria allocated to the three main objectives, weights were assigned to the objectives and then allocated among the respective criteria.

5. Description of Alternatives

A project to build a hydropower station at Freudenau was identified by the Donaukraft (1989-a). This scheme is located in Vienna and is already being implemented. It will be put into operation within the next three years.

Therefore, in this chapter only the stretch downstream is considered and a time horizon of twenty-five years is assumed.

Various hydropower alternatives have been developed in the last six years (Kaniak, 1986; Donaukraft, 1984, 1989 a,b; Regio, 1989). The level of definition varies among the alternatives from a general plan to a detailed engineering plan. The alternatives are characterized (Table 3) by their location and their capacity. Additionally, every alternative is split into a pure economic alternative and a "softer alternative", include secondary measures for the compensation of hydrological impacts caused by the hydropower scheme.

Table 3. List of hydropower alternatives

No of Alternative	A2 Hainburg	A3 Schönauer Feld- Petronell 1 Wolfsthal 2	A4 Petronell 2 Wolfsthal 2	A5 Wildungs- mauer Wolfsthal 2	A6 Engelh. stetten
Location (km)	1883	1906		1892.5	1883
		1890	1890		
		1873	1873	1873	
No of Power Stations	1	3	2	2	1
Installed Capacity (MW)	360	247	327	327	352
Annual Energy Generation (Gwh)	2075	1700	1920	1920	2035
Investment Costs (Mrd.öS)	11.4	24.9	15.9	15.6	12.2

The status quo is considered by alternative A1 which itself is split up into two subalternatives. The first excludes any hydropower utilization downstream of Vienna, while A2 additionally substitutes the non-utilized hydropower with imported energy.

The run-of-river schemes upstream of Vienna trap the sediments of the Danube, especially the coarse material. As a consequence, degradation downstream of the last power station is observed. The mean annual degradation of the river bed has been estimated at 2.5-3.5 cm/a (Kresser, 1984) and measures have to be taken to cope with this process. Several measures including artificial armouring of the river bed and addition of coarse-grained bed material to decrease the degradation process were analyzed (Ogris, 1989; Zottl, 1988; Bernhart, 1988).

Based on the analysis in the previous chapters a set of subgoals has been defined. In Table 2 each goal is expressed by a set of criteria and measures (Nachtnebel et al., 1990). The impacts of each alternative are characterized with respect to the full set of criteria and the respective measures in Table 4.

6. Identification of Compromise Solutions for the Utilization of Floodplains

For ranking the alternatives, weights expressing the importance of a criterion have to be defined and a common scale for a trade-off among the criteria has to be established. This part of the procedure is value dependent and highly subjective. Various methods have been developed to assist in multicriteria and/or multiobjective decision making (Goicoechea et al. 1982; Nachtnebel, 1988). Because of some of the criteria are expressed in an ordinal scale the ELECTRE method (Benayoun et al., 1966) or multicriterion Q-analysis (MCQA-I..III; Chin et. al., 1991; Hiessl et al., 1985; Eder, 1993) are recommended for ranking the alternatives. Without discussing the ELECTRE method in detail (see Roy, 1968, 1979) it can be summarized that this method is based on a pairwise comparison of alternatives A_i and A_j. A concordance index C_{ij} counts how often - with respect to certain criteria - A_i is better than A_j and expresses the preference by the respective sum of weights. A discordance D_{ij} index considers how strong the assumption A_i better than A_j is violated with respect to a certain criteria. Obviously, an alternative should exhibit a high concordance index and a low discordance index to be among the preferred alternatives. To select a subset of preferred alternatives, threshold levels for concordance indices and discordance indices have to be defined, named p and q respectively.

$$C(i,j) = \frac{\text{Sum of weights for criteria where } i > j}{\text{total sum of weights}}$$

$$D(i,j) = \frac{\text{maximum interval where } j > i}{\text{total range of scale}} \tag{1}$$

Criteria	Unit	A_1	A_{1a}	A_2	A_{2a}	A_3	A_{3a}	A_4	A_{4a}	A_5	A_{5a}	A_6	A_{6a}	Weight	Scale	Best	Worst
C1	GWh	0	2075	2075	2075	1700	1700	1990	1990	1791	1791	2075	2075	20	20	2075	0
C2	Mrd. öS	0.1	22.3	11.4	12.0	24.9	26.1	15.9	16.7	15.6	16.4	12.2	12.8	20	20	0.1	26.1
C3	ordinal	2.0	2.0	3.0	3.0	5.0	5.0	5.0	5.0	5.0	5.0	3.0	3.0	6	5	1.0	5.0
C4	manyears	0.5	0.5	17.1	18.0	37.5	39.2	23.9	25.1	23.4	24.6	18.3	19.2	15	15	39.2	0.5
C5	number	30.0	30.0	70.0	70.0	210.0	210.0	140.0	140.0	140.0	140.0	70.0	70.0	10	10	210.0	30.0
C6	ordinal	1.0	1.0	4.0	4.0	3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	12	10	1.0	5.0
C7	days	111.0	111.0	116.0	116.0	11.0	11.0	11.0	11.0	11.0	11.0	116.0	116.0	12	15	11.0	116.0
C8	ordinal	2.0	2.0	3.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	3.0	5	5	1.0	5.0
C9	ha	0.0	0.0	740.0	740.0	660.0	660.0	655.0	655.0	465.0	465.0	496.0	496.0	3	10	0.0	740.0
C10	ha	18.2	18.2	0.8	0.8	7.1	7.1	1.4	1.4	3.1	3.1	1.1	1.1	4	15	18.2	1.1
C11	%	0.0	0.0	86.4	86.4	25.0	25.0	62.0	62.0	52.0	52.0	87.8	8.78	10	20	0.0	87.8
C12	ha	120.2	120.2	18.3	18.3	55.0	55.0	32.5	32.5	38.9	38.9	24.0	24.0	1	10	120.2	18.3
C13	km	33.8	33.8	2.9	2.9	1.6	1.6	12.1	12.1	19.0	19.0	3.4	3.4	1	10	33.8	2.9
C14	km	16.0	16.0	5.9	0.6	8.7	8.7	7.6	7.6	10.3	10.3	6.4	6.4	1	10	16.0	5.9
C15	ordinal	4.0	4.0	4.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0	4.0	4.0	2	10	1.0	5.0
C16	ordinal	1.0	1.0	5.0	5.0	3.0	3.0	4.0	4.0	4.0	4.0	5.0	5.0	16	15	1.0	5.0
C17	ordinal	1.0	1.0	5.0	5.0	3.0	3.0	4.0	4.0	4.0	4.0	5.0	5.0	6	15	1.0	5.0
C18	%	1.0	1.0	0.3	0.3	0.2	0.2	0.1	0.1	0.2	0.2	0.3	0.3	8	15	1.0	0.1
C19	km	96.0	96.0	23.0	23.0	36.5	36.5	35.5	35.5	40.1	40.1	23.0	23.0	3	10	96.0	23.0
C20	km	113.8	113.8	83.7	83.7	81.6	81.6	82.7	82.7	85.0	85.0	83.7	83.7	1	10	113.8	81.6
C21	km	100.0	100.0	83.7	83.7	81.6	81.6	82.7	82.7	85.0	85.0	83.7	83.7	1	10	100.0	81.6
C22	ha	165.5	165.5	57.8	57.8	47.0	47.0	39.8	39.8	48.6	48.6	57.8	57.8	3	10	165.5	39.8
C23	ha	166.2	166.2	52.5	52.5	47.0	47.0	39.8	39.8	48.6	48.6	52.5	52.5	3	10	166.2	39.8
C24	ha	168.1	168.1	1.4	1.4	0.0	0.0	0.0	0.0	12.9	12.9	1.4	1.4	2	10	168.1	0.0
C25	ha	6.8	6.8	0.0	0.0	0.0	0.0	0.0	0.0	2.1	2.1	0.0	0.0	1	10	6.8	0.0
C26	number	42.0	42.0	11.0	11.0	25.0	25.0	20.0	20.0	23.0	23.0	12.0	12.0	4	10	42.0	11.0
C27	ordinal	5.0	5.0	2.0	2.0	3.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	7	10	1.0	5.0
C28	ordinal	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	4	15	1.0	5.0
C29	ordinal	2.0	2.0	5.0	4.0	3.0	2.0	4.0	3.0	3.0	2.0	5.0	4.0	2	10	1.0	5.0
C30	km	0.0	0.0	57.8	58.8	15.5	15.5	42.5	42.5	31.5	31.5	57.8	57.8	4	15	0.0	57.8
C31	km^2	65.5	65.5	68.3	6.3	69.5	29.7	67.3	23.5	61.9	20.8	68.3	6.3	4	15	6.3	69.5
C32	km^2	51.8	51.8	4.1	4.1	14.3	10.1	12.4	9.2	12.4	9.2	4.1	4.1	4	15	51.8	4.1
C33	km^2	35.9	35.9	4.1	4.1	8.0	8.5	8.7	7.4	8.7	7.4	4.1	4.1	5	15	35.9	4.1

Table 4. Preference Matrix: Alternatives Versus Criteria Array

Multi-criterion Q-analysis is also based on concordance and discordance measures.

It is evident that the ranking process is heavily dependent on the weights expressing the preference structure. Without any calculation it can be concluded that the alternative A_1 - free flowing river section - fails completely with respect to power generation. Thus, a large discordance index results. At the same time this alternative is ecologically attractive and one of the very few alternatives which is fully compatible with a national park. Therefore, it exhibits a high concordance index.

Some rankings based on threshold levels p and q are given in Table 5 and the concordance and discordance matrices are given in Table 6.

Assuming equal weights for the three main objectives, the alternatives A_1 to A_3 are dominated by A_4 to A_6. Further, alternative A_{5a} achieves the best compromise among the objectives. Even when the weight for the ecological objective is increased, alternative A_{5a} remains among the best until it is finally dominated by alternative A_{1a}. This holds only if weights greater than 0.7 are assigned to the ecological objective, 0.3 for the social and less than the economic objectives.

A sensitivity analysis was additionally performed to consider the uncertainty inherent in the figures given in Table 4. It can be summarized that the dominance of 5 and 4 is stable within a broad variation of the outcomes of the alternatives.

Table 5. Ranking of Alternatives for Different Threshold Levels p and q

$p = 0.6,\ q = 0.2$		$p = 0.6,\ q = 0.1$
4 > 2	5a > 2	5 > 4
4 > 6	5a > 2a	5a > 4a
4a > 6	5a > 4a	
5 > 2	5a > 6	
5 > 4	5a > 6a	
5 > 6		

7. Summary and Conclusions

The floodplains downstream of Vienna are of great ecological, social and economic interest. The development and management plans proposed so far emphasize a single objective approach and this is probably the main reason that no decision has been taken until now.

In this chapter a methodology has been presented to assist in decision-making. In the first step a pure impact assessment was performed within an extended framework considering economic, ecological and social tasks. To achieve sustainable water management, criteria were selected which refer to reversibility, risk and economic aspects. A set of 33 criteria characterized quantitatively - as far as possible - the outcome of each alternative with respect to the goals and the corresponding subgoals.

Table 6. Discordance and Concordance Indices for Development and Management Alternatives

Concordance Matrix

	A1	A1a	A2	A2a	A3	A3a	A4	A4a	A5	A5a	A6	A6a
A1	0.00	0.50	0.67	0.65	0.73	0.71	0.63	0.61	0.61	0.61	0.67	0.65
A1a	0.50	0.00	0.72	0.70	0.63	0.61	0.63	0.61	0.61	0.61	0.72	0.70
A2	0.32	0.27	0.00	0.50	0.39	0.37	0.38	0.38	0.36	0.36	0.50	0.49
A2a	0.34	0.29	0.50	0.00	0.39	0.39	0.40	0.40	0.38	0.38	0.52	0.50
A3	0.26	0.36	0.61	0.61	0.00	0.49	0.61	0.63	0.51	0.53	0.60	0.60
A3a	0.29	0.39	0.63	0.61	0.50	0.00	0.61	0.64	0.51	0.53	0.62	0.60
A4	0.36	0.36	0.62	0.59	0.38	0.38	0.00	0.52	0.40	0.44	0.60	0.58
A4a	0.38	0.38	0.62	0.60	0.36	0.36	0.48	0.00	0.40	0.40	0.60	0.58
A5	0.38	0.38	0.64	0.62	0.49	0.49	0.60	0.60	0.00	0.52	0.64	0.62
A5a	0.39	0.39	0.64	0.62	0.47	0.47	0.55	0.60	0.48	0.00	0.64	0.62
A6	0.32	0.27	0.50	0.48	0.40	0.38	0.39	0.39	0.36	0.36	0.00	0.50
A6a	0.34	0.29	0.51	0.50	0.40	0.40	0.42	0.41	0.38	0.38	0.50	0.00

Discordance Matrix

	A1	A1a	A2	A2a	A3	A3a	A4	A4a	A5	A5a	A6	A6a
A1	0.00	0.85	0.42	0.70	0.72	0.75	0.71	0.71	0.71	0.71	0.39	0.70
A1a	1.00	0.00	1.00	1.00	0.82	0.82	0.96	0.96	0.86	0.86	1.00	1.00
A2	0.98	0.98	0.00	0.74	0.75	0.75	0.75	0.75	0.75	0.75	0.16	0.74
A2a	0.98	0.98	0.02	0.00	0.75	0.75	0.75	0.75	0.75	0.75	0.16	0.16
A3	0.68	0.95	0.52	0.75	0.00	0.47	0.35	0.55	0.36	0.58	0.49	0.75
A3a	0.68	1.00	0.57	0.54	0.07	0.00	0.39	0.36	0.40	0.37	0.53	0.51
A4	0.75	0.75	0.17	0.72	0.42	0.45	0.00	0.52	0.15	0.55	0.14	0.72
A4a	0.75	0.75	0.20	0.20	0.42	0.42	0.05	0.00	0.15	0.15	0.17	0.20
A5	0.67	0.67	0.16	0.66	0.31	0.38	0.10	0.46	0.00	0.49	0.14	0.66
A5a	0.67	0.67	0.19	0.17	0.31	0.31	0.10	0.10	0.05	0.00	0.16	0.17
A6	1.00	1.00	0.03	0.74	0.75	0.75	0.75	0.75	0.75	0.75	0.00	0.74
A6a	1.00	1.00	0.05	0.03	0.75	0.75	0.75	0.75	0.75	0.75	0.02	0.00

In a subsequent step, aspiration levels and weights were assigned to each criterion to achieve a tradeoff among the objectives. A compromise solution including two hydropower schemes downstream of Vienna was identified. This solution exhibited its preference within a broad variation of the weights. In the case of a pronounced preference of the ecological objective the alternative without any hydropower utilization became dominant. However, the evaluation procedure performed in the second step is subjected to subjectivity inherent in any preference structure.

The methodology shown provides a tool to trade-off differently expressed criteria, to aggregate the measures of efficiency and finally to rank the alternatives. Subsequently, a sensitivity analysis was applied with respect to preference values or judgements for each criterion. This methodology, first proposed in the 1970s, has been developed by the application of fuzzy set theory, used in ELECTRE 3 and 4.

8. References

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