European Topic Centre on Inland Waters

HUMAN INTERVENTIONS IN THE HYDROLOGICAL CYCLE

by

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Note

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EXECUTIVE SUMMARY

Project Objectives

This report describes a scoping study to set the terms of reference for a later study which will quantify and compare human interventions across all European Environment Agency (EEA) Member States. As such there is a need to define precisely human interventions and agree a methodology for quantifying their effects on water resources, water and ecological quality of the water and riparian areas. There will be a need to co-operate with other Topic Centres such as those on Nature and Soils. The comparison of the impacts and effects at a European level will also have to consider regionalisation, for example by biogeographic zone and/or hydrological regimes. At this stage comparison by biogeographic region appears to be inappropriate and comparison by hydrological (flow) regimes will have to be considered.

Human interventions can have profound effects on water resources, water quality and aquatic and riparian ecology. There is a need to quantify both their extent and importance, and to quantify the nature and significance of the effects they have. The inter-relationship between intervention and effect must be understood before proper planning and control can be undertaken and so that the benefits of the intervention can be properly balanced and assessed against any environmental effect. The importance of human interventions in terms of effects on ecological quality has been recognised by policy makers and are included in Article 4 of the proposed European Commission's Directive on Ecological Quality of Water (COM(93) 680). Under this proposal Member States will be required to assess the effects of 'any other anthropogenic factors which impair or might impair the ecological quality of surface waters'.

The Technical Work Programme for the 1995 Subvention of the Agency's Topic Centre on Inland Waters (ETC/IW) gives the objective of this work as *"to determine on a pan-European scale the significance and key issues from human interventions in the hydrological cycle*".

The report and the selection of the most significant interventions in the hydrological cycle is based on a consultation of experts at AWW (Austria), INAG (Portugal), IOW (France), NERI (Denmark) and NIVA (Norway). Therefore some aspects concerning other countries or regions may have been missed at this stage and will become evident in the further process.

Biogeographic Regions

The effects of human interventions in the hydrological cycle can have significant ecological effects. Considering this, a region-based process of prioritising the human interventions in the hydrological cycle was applied. For this scoping study, therefore, it was decided to use and appraise the appropriateness of the Biogeographic Regions used by the European Topic Centre on Nature Conservation (ETC/NC) for some aspects of its workprogramme. The 6 Biogeographic Regions (Boreal, Atlantic, Continental, Alpine, Mediterranean, Macronesian) have been determined by the European Commission (EC) for the purpose of the Natura 2000 process required for the EC Habitats Directive. The definition of the 6 Biogeographic Regions was considered by the Commission to be adequate for political purposes though ecologically it is not precise enough. A more accurate map of ecological regions at a pan-European level is being prepared by the ETC/NC and contains some 30 classes. As an alternative to Biogeographic Regions the use of hydrological flow regimes (such as used by the FRIEND programme) might be more appropriate; this will be considered in the next phase of this study.

Selection of Human Interventions

In order to detect the most significant human interventions in the hydrological cycle, the ETC/IW partners identified a maximum of six aspects from a list of possible human interventions, and at least one aspect from each main category, for each biogeographic region.

The main categories for human interventions were:

A. River, lake and estuary regulation

B. Water abstraction

C. Activities in the catchment

The selection conforms to the significance of the physical intervention and the importance of its effects. The contributors gave a short description and an explanation of the intervention, the extent, the benefits and both positive and negative effects. Examples of the interventions and their effects are also included in the contributions.

It should be noted that the following selection of the most significant human interventions in the hydrological cycle is solely for the contributing countries and their specific experiences, and cannot be extrapolated to the whole Europe without further work. These contributions also do not represent official statements from those countries but are the opinions of experts.

Main Interventions in the Hydrological Cycle

A number of significant human interventions have been highlighted in the report. These are:

- Damming for generating hydroelectricity, especially in the Alpine and Continental regions and in Norway (Scandinavia), appears to be the most significant human intervention within the river, lake and estuary regulation category.
- Groundwater abstraction for public water supply and irrigation purposes seems to be the most significant intervention involving water abstraction and is most obvious in the Atlantic, Continental and Mediterranean regions.
- Land sealing by urbanisation and land drainage for cultivation occur in each of the proposed regions and, where it occurs, seem to be most important activities in the catchment.
- Damming for public water supply and irrigation, river channelisation for flood control and drainage purposes, and the intensification of agriculture obviously play a major role in the hydrological cycle.

Bearing in mind that the selection of the interventions is restricted to the contributing countries, it can be seen that some human interventions occur in all biogeographic regions. For example, in this report the Norwegian Atlantic region is closely related to the Alpine region:

- Land sealing from urbanisation and land drainage for cultivation occurs in all biogeographic regions.
- Damming for public water supply and for irrigation purposes seems to be a typical intervention in the Atlantic and Mediterranean regions.
- A number of human interventions occur both in the Atlantic and the Continental regions and seem to be significant just in these regions:
  - Damming for flood control and fish farming;
  - Dredging of river channels to drain land;
  - Surface water abstraction for fish farming;
  - Wet cuts.
- River channelisation for drainage and intensive agriculture occur in the Atlantic and the Continental regions.

- Groundwater abstractions for public water supply and irrigation purposes are the main significant interventions in the Atlantic, Continental and Mediterranean regions.
- Dredging of river channels for mining river bed gravel and surface water abstractions for hydropower and for interbasin water transfer seem to be typical major interventions in the Alpine region and Norway.

Conclusions

Major human interventions with significant ecological impact have been identified in all participating countries. The most significant human interventions in the hydrological cycle have been made over the last decades. Today the negative effects of these interventions are recognised and analysed, and restoration activities are initiated. The perception of the importance of an intervention changes over time, as the understanding of the aquatic environment evolves.

Key figures and statistics concerning freshwater resources, freshwater abstractions, and major uses by countries are not readily comparable because of the different methods of assessment and calculation in each country. However, comparable data characterising the hydrological cycle, the water balance and water demand are necessary to quantify and judge the human interventions identified in this report, and on the basis of figures which characterise the extent of the impacts (quantity measures), to identify key issues relevant for the EEA.

One of the main difficulties in determining the significance of human interventions in the hydrological cycle on a pan-European scale appears to be the lack of appropriate criteria or regional scale for comparison. To that end the use of the regionalisation of the continent by the Biogeographic Regions used for the Natura 2000 process would be inappropriate. From the hydrological standpoint this division of Europe does not seem to be optimal due to the fact that hydrological characteristics vary strongly within a biogeographic region. Interventions in the hydrological cycle are not mainly based on the biogeographic regions itself but rather caused by human pressure (population density etc.) and cultural development. Further, distance between supply and demand, the pressure and the intervention, becomes relevant (e.g. upstream flood control of cities, distant hydropower generation etc.).

Recommendations

1. There is a need to increase the comparability of data with regard to human interventions and to extend data collection to all EEA countries.

2. The regionalisation of the continent should, if required for the comparison of human interventions, be based on hydrological characteristics and/or on human pressures and demand.

3. The investigation on significant human interventions in the hydrological cycle should be extended to all EEA countries to give a representative overview of the situation across Europe. The reasons for an intervention should, in particular, be outlined in a detailed way, which may help in defining the most appropriate comparative regions. The importance of interventions nationally, regionally and across Europe should then be able to be assessed.

4. Single interventions should also be investigated separately with more detailed assessments on the impacts on water quality.

5. At this stage of the Project the different human activities have not been fully quantified at a national or European level. For example, there appears to be no real information on the extent/intensity of different activities affecting the hydrological cycle. Information such as on the number of dams in a Member State and the catchment area affected, or the approximate length/% of river channelised or under flow regulation might be feasible to obtain in the near future. Indeed work undertaken by the ETC/IW on developing a reservoirs database has begun to quantify the number of dams, reservoirs and lakes across

the EEA area. The next phase of this study must address these issues and should suggest a list of data/information which each Member State could supply in the medium term (next two or three years).

6. It is recommended that the methodology and definitions used in this scoping study are further refined and developed in light of the experience obtained. Information gathering should then be extended to other EEA Member States. It should be noted that the work on human interventions affecting groundwater quality and quantity will be addressed in the Groundwater Quality and Quantity Monograph to be produced by the ETC/IW in 1997 under the 1996 subvention.

1. INTRODUCTION

1.1 Background

Water regulates life and as such is of fundamental importance to human, other animal and plant life. Because of the interaction between atmosphere, lithosphere, hydrosphere and biosphere and the consistency of the global water cycle, every change or modification in one of these spheres will consequently lead to a modification of the water cycle and water balance.

In this context humankind plays a special role. As part of the biosphere it massively influences other spheres, especially through water consumption influencing the global hydrosphere. Because of the complex physical and chemical properties of water it does not only serve humans as a source of food but also as a means of production in agriculture, aquaculture, forestry, industry, energy and as a means of transport.

Artificial alterations to the natural cycle of water has produced massive changes in agricultural landscape and in aquatic, riparian, wetland and other floodplain habitats. These interventions have had both positive and negative impacts on the problems that they were intended to solve. Some of these activities have greatly constrained the degree of interactions between the river channel and the associated floodplain with catastrophic effects on biodiversity.

1.2 Tasks

According to the European Environment Agency's Topic Centre of Inland Waters' (ETC/IW) Technical Work Programme for the 1995 Subvention (Feb. 1996), the main task is to determine, on a pan-European scale, the significance of and key issues arising from human interventions in the hydrological cycle.

The first step of defining a strategy on this issue will be the collation of readily available information on past and on-going activities relating to such physical impacts on the hydrological cycle throughout some countries in the EEA area. The basis of the information is the knowledge and experience of the ETC-IW partners. Contributors to the project (AWW-Austria, INAG-Portugal, IOW-France, NERI-Denmark and NIVA-Norway) have reported on the situation in their own countries and from other countries if information is available.

1.3 Structure of the Report

This report comprises four main parts and two Appendices:

Part 1 describes the background, tasks and investigation methods of the project. Hydrological data from different sources are also compared.

Part 2 deals with the Biogeographic Regions defined by the European Commission for the Natura 2000 process and the country-specific descriptions and adaptations on the biogeographic map.

Part 3 (sections 4 to 6) gives a brief overview of the main human interventions in the hydrological cycle selected by the contributing partners.

Part 4 (sections 7 and 8) gives the main conclusions from this scoping study and makes recommendations on how the study should proceed in the next phase during the 1996 subvention period.

Appendix A contains a list of possible human interventions in the hydrological cycle.

Appendix B presents the detailed description of the selected human interventions by the contributing partners.

1.4 Investigation Method

AWW provided a draft list of possible human interventions in the hydrological cycle. This draft was sent out to the relevant ETC-Partners contributing to this project for comment and completion (deadline: 18 March 96).

The final working paper including the list of "Human interventions in the hydrological cycle", complete with definitions and including an annex of proposed key words/figures to describe the human inventions was distributed to ETC/IW partners WRc, AWW, INAG, IOW, NERI and NIVA. Contributors had to select the most significant interventions up to a maximum of six, with up to three from each main category and for each biogeographic region (deadline for contribution: 19 April 96). The complete list of selected human interventions is attached in Annex 1.

The main categories for human interventions are:

A. River, lake and estuary regulation

B. Water abstraction

C. Activities in the catchment

The selection is based on the significance of the physical intervention and the importance of its effects. The significance of an intervention has been interpreted as being in terms of water volumes involved, economic aspects, population and surface area concerned and the frequency of an intervention in the region.

The importance of the effects, positive and negative, was assessed in terms of the number of people affected from the intervention, economic aspects, direct and indirect impacts on the environment, fauna and flora, aesthetic impacts and the significance of habitat modification.

The contributors were invited to give a short description and an explanation of the intervention, the extent, the benefits and both positive and negative effects. Added examples complete the contributions.

Note:

The following selection of significant human interventions in the hydrological cycle is based on a consultation of experts at AWW (Austria), INAG (Portugal), IOW (France), NERI (Denmark) and NIVA (Norway) and the results refer only to country specific experiences and cannot be extrapolated to the whole Europe without further work. These contributions do not represent official statements of the countries involved.

2. BIOGEOGRAPHIC REGIONS

The nature and impact of human interventions in the hydrological cycle will be influenced by a number of different factors and these will vary across the EEA area. Climate, geology, soil characteristics, topography, altitude, distance to the oceans and, not least, the historical and current land-use, play a major role regarding the amount of usable water.

Significance, as well as the effects, of a human intervention in the water cycle depend on ecological restrictions. Considering this, a regional-based process of priority evaluation for human interventions in the hydrological cycle was used, in which it was decided in the first case to use the Biogeographic Regions used by the European Topic Centre on Nature Conservation (ETC/NC) for some aspects of its workprogramme. The 6 Biogeographic Regions (Boreal, Atlantic, Continental, Alpine, Mediterranean, Macronesian) have been determined by the European Commission (EC) for the purpose of the Natura 2000 process required for the EC Habitats Directive. The definition of the 6 Biogeographic Regions was considered by the Commission to be adequate for political purposes though ecologically it is not precise enough. A more accurate map of ecological regions at a pan-European level is being prepared by the ETC/NC and contains some 30 classes.

The ETC/NC was consulted at the start of this project in order to obtain a consistent approach, where appropriate, between the various Topic Centres of the EEA on regional issues. However, this first overview demonstrates that an approach based on a finer regional scale would appear to be unavoidable.

Furthermore, from the hydrological standpoint, the biogeographical division of Europe does not seem to be logical due to the fact that hydrological characteristics and human pressures vary strongly within a biogeographic region (e.g. Atlantic region of France is separated into three parts). However, it does appear to be appropriate in some countries (e.g. Spain and Ireland). Different areas grouped in the same biogeographic region are sometimes not really comparable (e.g. Alps and Pyrénées are not equivalent and the Norwegian Atlantic region is more related to the Alpine region).

In the hydrological cycle, the geology, the pluviometric conditions, cultural reasons, the human pressure etc. seem to be more important than general climate and altitude, which control the biogeography. Regionalisation is necessary to establish comparability between different areas and nature of the land surface and subsurface and should be part of this classification. Hydrological regionalisation (flow regime classification) is well defined for the FRIEND area (FRIEND 1994). The monthly flow regimes in Europe are divided into 13 classes and their distribution has been mapped over Europe. As this study is further developed under the 1996 Subvention funded work programme we shall be exploring the advantages/disadvantages of biogeographical and hydrological classifications and will attempt to distil the best from each. However, for the purposes of this first phase of the project we persevered with the biogeographical approach.

At the end of this chapter the proposed map of the biogeographic regions used by the European Topic Centre on Nature Conservation and the maps of Austria, France and Norway with some country specific adaptations are given.

2.1 Country specific descriptions and relationship to biogeographic regions

2.1.1 Alpine/boreal

a) Norway

The main climatic gradients are west to east and the precipitation varies from up to 4000 mm/a in the West coast maximum zone to a minimum of <300 mm/a in the central mountain valleys. The country average is approximately 1400 mm with a runoff of 1200 mm.

East Norway is part of the Baltic shield, the western parts are influenced by the Caledonian buckling. All parts of Norway are strongly influenced by glacial and glaciofluvial processes. This results in a large number of lakes, short steep rivers in Western Norway, long rivers with moderate gradients in Eastern Norway, thin till-type soil cover over large areas and deep clay deposits under the upper marine limit exposed after the last ice age by isostatic uplift.

The arable land is, to a large degree, under the marine limit (~100-180 m asl) and the agricultural area is only 3 % of the total land area, while the forested area is approximately 30 %. The rest is high elevation and/or latitude, fairly barren ground, and approximately 1 % is glaciated. The cultivated area is mainly confined to a narrow strip around the coast and to the inland areas north of Oslo (especially the river Glomma) and around Trondheim. A significant portion of the forested area has low production potential and low harvesting rates, and generally the level of forest cultivation (draining, ploughing, fertilising, replanting etc.) is lower than for instance in Sweden.

2.1.2 Alpine region

a) Austria

The Alpine region in Austria coincides with the delimitation of the biogeographic regions outlined by the European Topic Centre on Nature Conservation.

b) France

It was considered that the Alps and the Pyrénées should perhaps be distinguished in terms of the interventions. The major intervention is damming for hydropower, but types of reservoir management and the effects of the damming are very different in the two mountain chains. In the Pyrénées, which can be considered much narrower and steeper than the Alps, water is often dammed and then transferred by long chutes to valley power stations, significantly reducing flow discharge in the mountain torrents. In the Alps, large reservoirs with adjacent power stations are more common, and they also control subsequent flows in many of the rivers flowing to the Mediterranean.

2.1.3 Atlantic region

a) Denmark

Western Jutland is classified in the Atlantic region in the biogeographic system. It is generally characterised by sandy soils with poor buffering capacity and relatively high precipitation (770 mm) and river flow (430 mm ~ 14 $l.sec^{-1} km^{-2}$).

b) France

The Atlantic region in France actually comprises three very distinct regions in terms of human interventions:

- The Southwest, where irrigation and water scarcity are important factors.
- The Northwest, which has been extended to include the Atlantic-influenced Massif Central. In this area, river flow regulation is important (in particular the Loire) in order to satisfy many diverse uses (hydropower, irrigation, sufficient flows for cooling water etc.) and there are several significantly modified estuaries (for flood control, navigation etc.). Interventions in the form of dikes and embankments on the river Loire is also important in this area.
- The North, where groundwater resources are under pressure in the Parisian to Lille (north-east) areas, generally due to poor surface water quality. Channelisation of the river Seine for navigation and flow regulation for water supply are significant interventions.

c) Portugal

The Atlantic region in Portugal is a very thin coastal strip north of the mouth of the river Tejo. It is generally characterised by cambisols, high rainfall (annual mean 2,000 mm) and river flow (annual mean 1,200 mm ~ 38 $l.sec.km^2$). Irrigation is very intensive and population density is high. Groundwater resources are essential for domestic and industrial water supply and irrigation even though this region does not have major aquifers.

2.1.4 Continental region

a) Austria

The Continental region in Austria coincides with the delimitation of the biogeographic regions outlined by the European Topic Centre on Nature Conservation.

b) Denmark

Eastern Denmark belongs to the Continental region and is generally characterised by more loamy soils with a high buffering capacity and relatively low precipitation (570 mm) and river flow (170 mm ~ 5 $l.sec/km^{-2}$).

c) France

The Continental region in France includes the Rhône corridor. It also includes the east of the country, but excludes the Atlantic-influenced Massif Central. In addition the very important upstream reservoirs of the Seine in this area are included. These are involved in flood defence, low flow enhancement, public water supply and downstream cooling water resources for the whole river Seine catchment.

2.1.5 Mediterranean region

a) France

With one notable exception, the French Mediterranean biogeographic region is a reasonably homogeneous area. The exception is the river Rhône, which is in fact a major continental river (it just happens to flow towards the sea through a Mediterranean region). The Rhône corridor contains an important chain of runoff-river hydropower dams, which also have other functions (diversion of water, navigation, flood control etc.). For the purposes of this project, the Rhône has been classified with the Continental region although, in reality it is a special case all of its own

The Mediterranean region comprises many lagoons (especially the Rhône delta area) where a number of major interventions in terms of flood control and drainage have been carried out. These are considered significant interventions because of their value as wetland habitats.

b) Portugal

Although being usually considered as almost entirely included in the Mediterranean region of Europe, the Portuguese territory, due to its latitudinal configuration, presents an increase in dry-climate severity patterns from north to south, a feature in common with other Mediterranean countries like Spain and Italy.

The Portuguese weather is characterised by two well-differentiated annual periods, dry season and wet season. The dry season occurs between May and September and the rest of the year belongs to the wet season. The dry and wet seasons are also characterised by high and low temperatures, respectively. The irregular temporal distribution of precipitation during the year is more evident in the south of Portugal which causes greater scarcity of water in this region. This makes dam building indispensable in order to assure public water supply with increased water demand, and irrigation during the dry season

The Mediterranean region is not a homogeneous area. In terms of surface water characteristics it may be divided into two main zones with the Tejo river acting as a natural border:

- northern part of Portugal (between Atlantic region and Tejo river) includes both an Atlantic-influenced and a Continental-influenced zone. In this area, river flow regulation is important in order to satisfy several uses such as hydropower, irrigation, water supply, recreation and fish farming.
- southern part of Portugal (below Tejo river to Algarve) where irrigation and water scarcity are important factors. The main uses of reservoirs are for public water supply and irrigation.

In terms of groundwater the Mediterranean region can be divided into four main zones:

- three zones of sedimentary rocks that correspond to: the occidental sedimentary fringe, the meridional sedimentary fringe, and the Tejo-Sado sedimentary basin. These zones constitute the main aquifer systems of Portugal.
- one zone covered by igneous and metamorphic rocks with low aquifer capacities, which corresponds to the main area of the country.

All these aquifer systems are important for public and industrial water supply and for irrigation and constitute the main source of water for these uses.

In the Algarve region the pressure on groundwater resources, sometimes important and significant, provokes local problems of salt water intrusion. Groundwater pollution by nitrates from intensive agriculture is a further problem in this region.

The following pages show the specific maps of the biogeographical regions:

Figure 2.1 Biogeographic Regions defined by the European Commission for Natura 2000

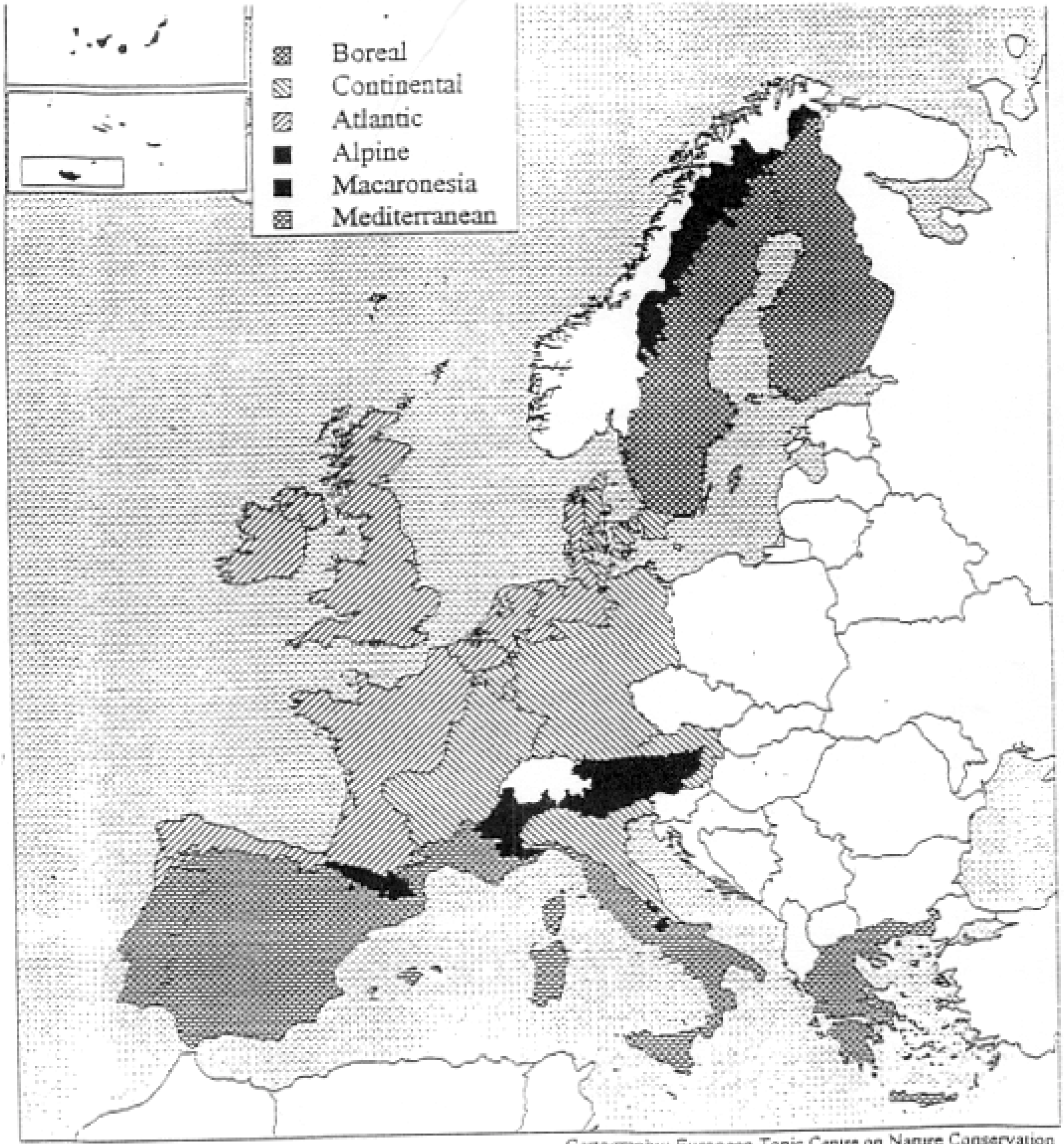
Figure 2.2: Biogeographic Regions of Austria

Figure 2.3 Biogeographic Regions of Norway

Figure 2.4 Biogeographic Regions of France

Figure 2.1 Biogeographic Regions defined by the European Commission for Natura 2000

Figure 2.1 Biogeographic Regions defined by the European Commission for Natura 2000



Cartography: European Topic Centre on Nature Conservation
Paris, November 1995

Map from: „Distribution of habitats and species by biogeographic region" - Annex I and II of Council Directive 92/43/EEC on the conservation of natural habitats and wild fauna and flora; Version EUR 15, draft N° 2 - 15.12.1995

Bio-climatic classification proposed by: RIVAS-MARTINEZ, S. (1991) „Bioclimatic belts of West Europe". in DUPLESSY, PONS & FANTHECHI (eds.) Climate and global change: Proceedings of the European school of Climatology and Natural Hazards course, Arles,. 1990, Pgs. 225-246. Commission of European Communities, Report EUR 13149

Figure 2.2: Biogeographic Regions of Austria

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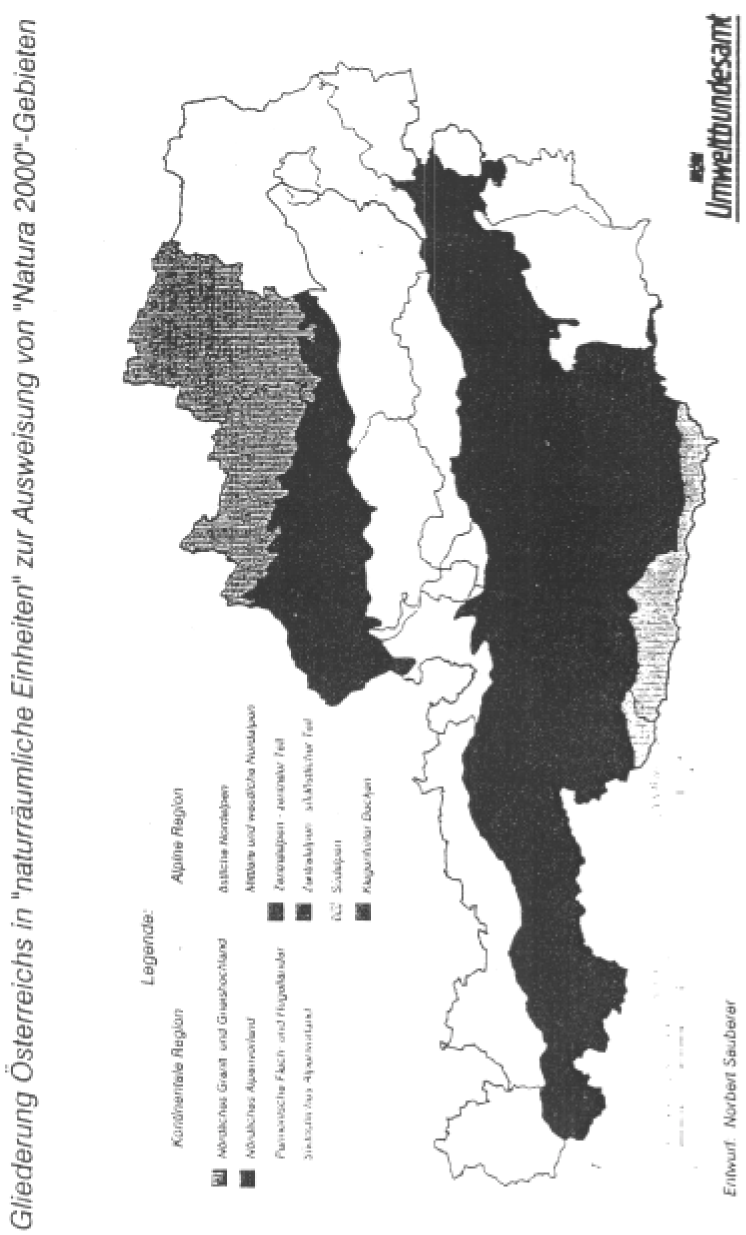

Figure 2.3 Biogeographic Regions of Norway

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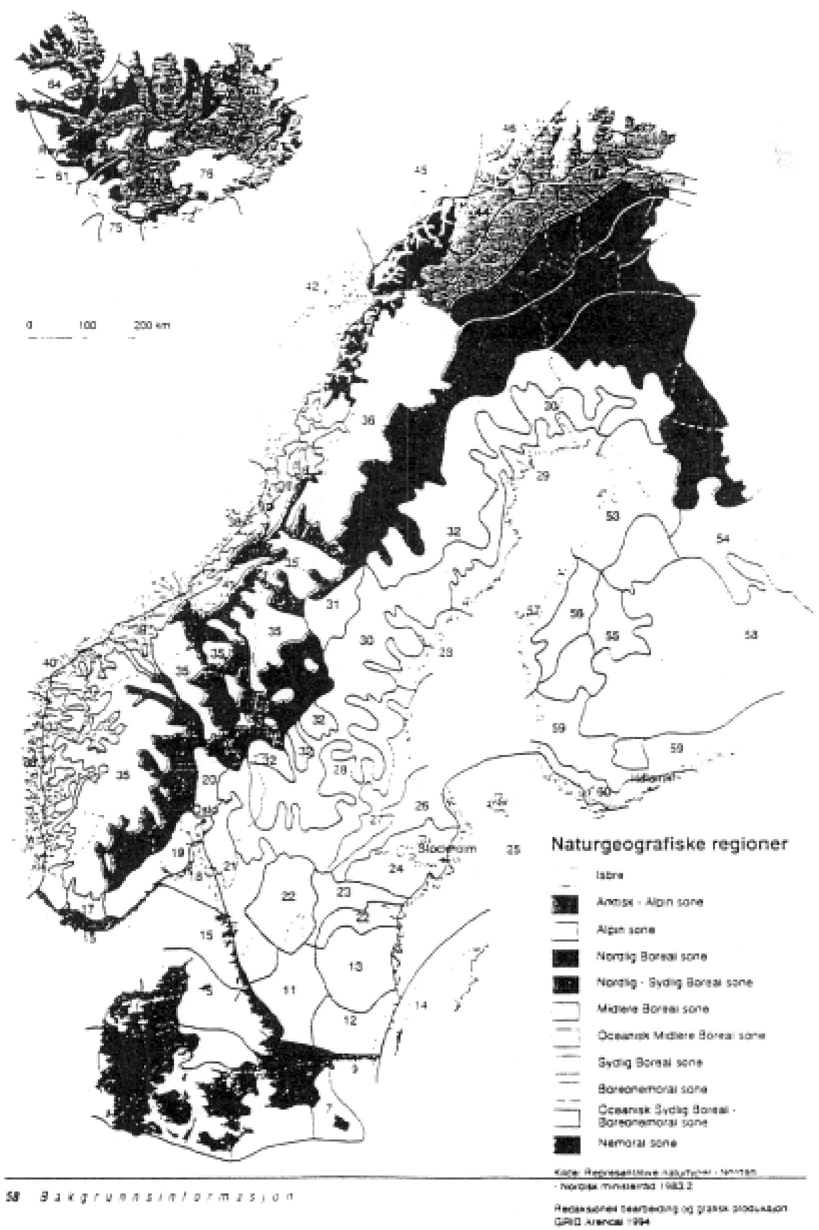

Figure 2.4 Biogeographic Regions of France

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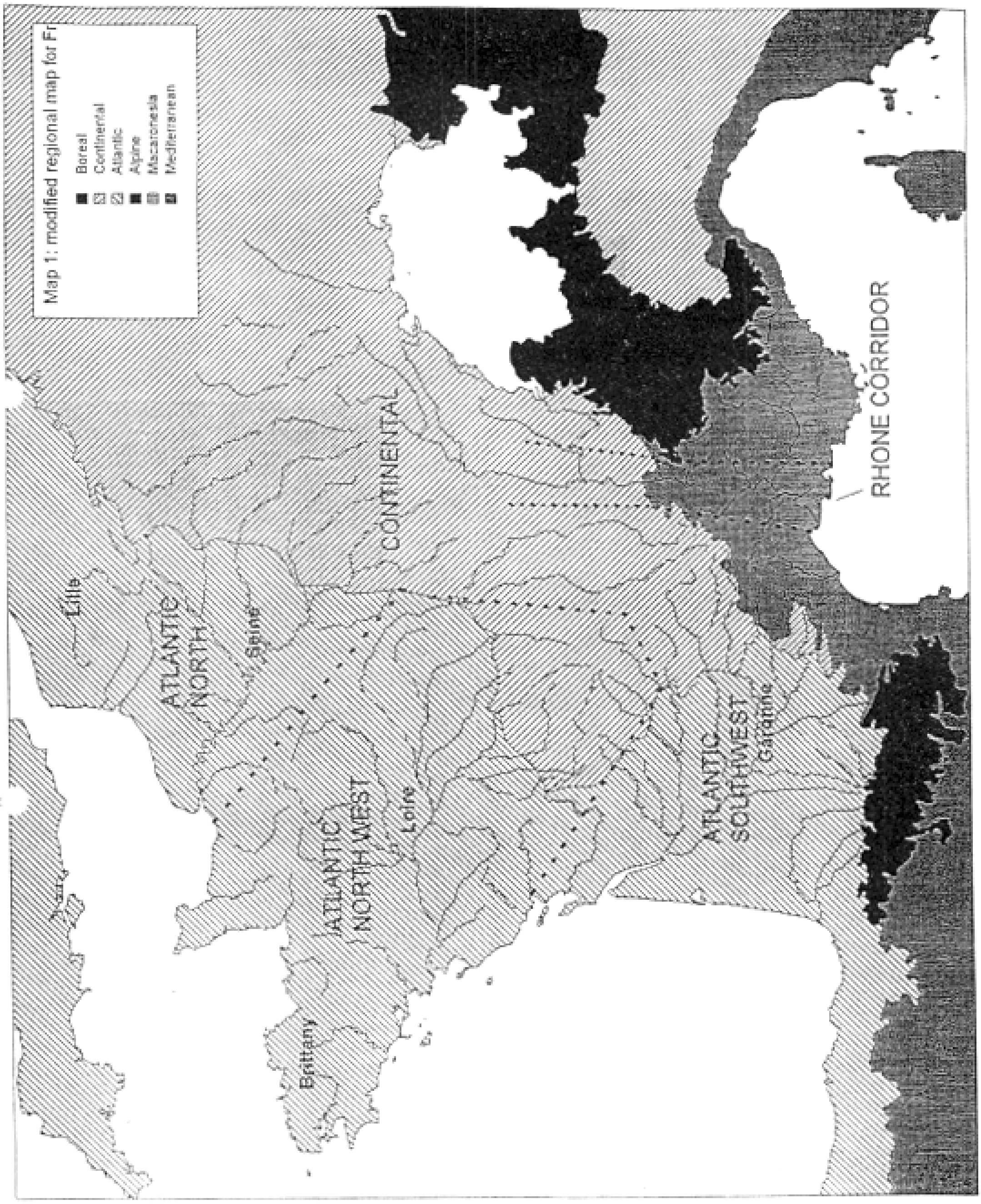

3. SUMMARY OF THE MAIN HUMAN INTERVENTIONS IN THE HYDROLOGICAL CYCLE

This section gives a summary of the main human interventions identified from the information collected in this study. The interventions have been divided into three main categories:

A. River, lake and estuary regulation;

B. Water abstraction; and,

C. Activities in the catchment'

Each human interventions have been classified into one these categories: some interventions inevitably occur in more than one category but the classification was considered to be appropriate for this investigation and for ease of description. Section 4 gives an overview of each of the 3 categories. More detailed descriptions and examples of the main categories and sub-classes are given in Appendix B.

Tables 3.1 to 3.3 give a summary of the most significant interventions in the hydrological cycle identified by the contributing partners according to biogeographic region.

It appears from the information obtained that the most common and significant human interventions in the hydrological cycle are:

1. Groundwater abstraction for public water supply and for irrigation purposes (in the Atlantic, Continental and Mediterranean regions).

2. Damming for generating hydroelectricity (in the Alpine, Continental and Mediterranean regions and in Norway).

3. Land sealing arising from urbanisation, and land drainage for the purposes of cultivation, occur in each biogeographic region and seem to be as significant as the other interventions described above.

4. Damming for public water supply and irrigation, river channelisation for flood control, drainage purposes and high intensity agriculture obviously exert a major impact on the hydrological cycle.

Examined more closely, and considering that the selection of the interventions is restricted to a relatively small number of countries, it can be seen that a number of human interventions occur in the same regions.

1. Land sealing by urbanisation and land drainage for cultivation occur in all regions but damming for public water supply and for irrigation seem to be typical interventions in the Atlantic and Mediterranean regions.

2. In the Atlantic and the Continental regions the following interventions are common:

- Damming for flood control and fish farming;
- Dredging of river channels to drain land;
- Surface water abstraction for fish farming;
- Wet cuts;
- River channelisation for drainage and agriculture.

3. Groundwater abstraction for public water supply and irrigation purposes are significant interventions mainly in the Atlantic, Continental and Mediterranean regions.

4. Dredging of river channels for mining river bed gravel and surface water abstractions for hydropower and for inter-basin water transfers seem to be typical only for the Alpine region and Norway.

Table 3.1 Major human interventions in the hydrological cycle regarding to category A "River, lake and estuary regulation".

Intervention	Reason		Region/Country					
			Alp.	Atl.	Cont.	Med.	N	FI
Damming, building and management of river reservoirs	Public water supply	of surrounding areas		F_{sw}		P		
		of far regions						
		lack of water quantity				F, P		
		lack of water quality		F_{nw}		P		
	Irrigation	of surrounding areas		F_{sw}		P		
		of far regions						
		lack of water quantity				F, P		
	Hydropower	Intermittent power plant	A, F		F	P	N	
		Runoff-river power plant	A		A, F	P	N	
		Pumped-storage plant	A			P	N	
		Diversion power plant	A, F		A		N	
	Flood control			F_{nw}	F			
	Low flow enhancement	Providing a reliable downstream water supply			F			
	Fish farming			DK	DK			
River channelisation	Flood control		A, F		A		N	
	Drainage of surrounding land			DK	DK		N	
	Navigation			F_n				
Building of weirs	Improving fish habitats, fishing possibilities						N	
Dredging of river channels	Drainage of surrounding land			DK	DK			
	Mining of river bed gravel		F				N	
Lake regulation	Lake shore modification	Natural lakes	A, F					
	Hydropower	Natural lakes					N	
	Restoration and care							FI
Estuary regulation	Flood control			F_{nw}				
Lagoon regulation						F		

Alp. *Alpine region* *A* *Austria* *Part of the Atlantic region in France:*
Atl. *Atlantic region* *DK* *Denmark* F_n *Northern part*
Cont. *Continental region* *F* *France* F_{nw} *North-western part*
Med. *Mediterranean region* *N* *Norway* F_{sw} *South-western part*
P *Portugal*
FI *Finland*

Table 3.2 Major human interventions in the hydrological cycle regarding to category B "Water abstraction".

Intervention	Reason		Region/Country				
			Alp.	Atl.	Cont.	Med.	N
Surface water abstraction	Public water supply	of far regions lack of water quantity				F	
	Industrial water supply				F		
	Irrigation	of surrounding areas of far regions lack of water quantity		F_{nw},F_{sw} F_{nw},F_{sw}			
	Fish farming			DK	DK		
	Hydropower	Diversion power plant Storage power plant	A A				N N
	Inter-basin transfer		F				N
Groundwater abstraction	Public water supply	of surrounding areas of far regions lack of water quantity lack of water quality		DK, F_n F_n F_n	DK F DK	P P P	
	Irrigation	of surrounding areas of far regions lack of water quantity		DK F_{sw}, F_n	A DK	P P	

Alp. Alpine region; Atl. Atlantic region; Cont. Continental region; Med. Mediterranean region
A Austria; DK Denmark; F France; N Norway; P Portugal
Part of the Atlantic region in France: F_n Northern part; F_{nw} North-western part; F_{sw} South-western part

Table 3.3 Major human interventions in the hydrological cycle regarding to category C "Activities in the catchment".

Intervention	Reason		Region/Country				
			Alp.	Atl.	Cont.	Med.	N/FI
Land drainage	Cultivation		A	F_{nw}	DK	F	N
	Infrastructure for traffic					F	
Land sealing	Urbanisation		A	F_{nw}	F	F	N
	Infrastructure for traffic				F	F	
	Tourism		A				
Wet cuts				F_{nw}	F		
Agricultural activities	Intensification of agriculture	Cultivation of crops with high water requirements Long-term changes of grassland to arable land Drainage of wetlands Water regulation in cultivation areas		F_n, F_{sw}	 A A A		 FI
Forestry	Deforestation	Cultivation Urbanisation Tourist reasons Fire				P P P P	
	Afforestation						N, FI

Alp. Alpine region; Atl. Atlantic region; Cont. Continental region; Med. Mediterranean region
A Austria; DK Denmark; F France; N Norway; P Portugal; FI Finland
Part of the Atlantic region in France: F_n Northern part; F_{nw} North-western part; F_{sw} South-western part

Because different human interventions in the hydrological cycle are made for similar reasons, the results of the contributions have been regrouped. The following table shows the intended purpose of an intervention in the hydrological cycle in the contributing countries.

Table 3.4 Intended reasons of human interventions in the hydrological cycle

Reason		**Region/Country**					**Intervention**
		Alp.	**Atl.**	**Cont.**	**Med.**	**N**	
Public water supply	of surrounding areas of far regions lack of water quantity lack of water quality		F_{sw} F_{nw} 		P F, P P		Damming, building and management of river reservoirs
	of far regions lack of water quantity				 F		Surface water abstraction
	of surrounding areas of far regions lack of water quantity lack of water quality		DK, F_n F_n F_n	DK F DK	P P P		Groundwater abstraction
Irrigation	of surrounding areas of far regions lack of water quantity		F_{sw} 		P F, P		Damming, building and management of river reservoirs
	of surrounding areas of far regions lack of water quantity		F_{sw},F_{nw} F_{sw},F_{nw}				Surface water abstraction
	of surrounding areas of far regions lack of water quantity		DK, F_{sw}, F_n	A, DK	P P		Groundwater abstraction
Hydropower	Intermittent power plant Runoff-river power plant Pumped-storage plant Diversion power plant	A, F A A A, F		F A, F A	P P P 	N N N N	Damming, building and management of river reservoirs
	Natural lakes					N	Lake regulation
	Diversion power station Storage power plant	A A				N N	Surface water abstraction
Flood control			F_{nw}	F			Damming, building and management of river reservoirs
		A, F		A		N	River channelisation
			F_{nw}				Estuary regulation
					F		Lagoon regulation
Low flow enhancement	To provide a reliable downstream water supply			F			Damming, building and management of river reservoirs

Table 3.4 continued

Reason		Region/Country					Intervention
		Alp.	Atl.	Cont.	Med.	N	
Fish farming and fishing			DK	DK			Damming, building and management of river reservoirs
						N	Building of weirs
			DK	DK			Surface water abstraction
Drainage of surrounding land			DK	DK			Dredging of river channels
			DK	DK		N	River channelisation
Mining of river bed gravel		F				N	Dredging of river channels
			F_{nw}	F			Wet cuts
Infrastructure for traffic					F		Land drainage
				F	F		Land sealing
Cultivation		A	F_{nw}	DK	F	N	Land drainage
Urbanisation		A	F_{nw}	F	F	N	Land sealing
Tourism		A					Land sealing
Navigation			F_n				River channelisation
Lake shore modification	Natural lakes	A, F					Lake regulation
Industrial water supply				F			Surface water abstraction
Inter-basin transfer		F				N	Surface water abstraction
Intensification of agriculture	Cultivation of crops with high water requirements		F_n, F_{sw}				Agricultural activities
	Long-term changes of grassland to arable land			A			
	Drainage of wetlands			A			
	Water regulation in cultivation areas			A			
Deforestation	Cultivation				P		Forestry
	Urbanisation				P		
	Tourist reasons				P		
	Fire				P		
Afforestation						N	Forestry

Alp. *Alpine region*
Atl. *Atlantic region*
Cont. *Continental region*
Med. *Mediterranean region*

A *Austria*
DK *Denmark*
F *France*
N *Norway*
P *Portugal*

Part of the Atlantic region in France:
F_n *Northern part*
F_{nw} *North-western part*
F_{sw} *South-western part*

4. OVERVIEW OF CATEGORY A INTERVENTIONS: RIVER, LAKE AND ESTUARY REGULATION

Natural rivers as well as lakes and estuaries including their riparian zones are among the most dynamic, diverse and complex ecosystems of the world and play a major role in the regulation and maintenance of biodiversity in the landscape. Every change in the water regime especially changes of water flow and water level fluctuations and the fragmentation of river systems leads to a destruction of several types of habitats like waterfalls, rapids and floodplain wetlands. As a result of this destruction numerous species of flora and fauna will be endangered and aquatic habitats as well as riparian become fragmented and get impoverished (Dynesius and Nilsson, 1994).

The main human interventions in the hydrological cycle in Europe in relation to river, lake and estuary regulation are subdivided for this report into the following topics:

- Damming, building and management of reservoirs;
- River channelisation;
- Building of weirs;
- Dredging of river channels;
- Lake regulation;
- Estuary regulation;
- Lagoon regulation.

4.1 Damming, Building and Management of Reservoirs

Damming of rivers has been identified as one of the most dramatic human impacts on the natural environment. It changes the environmental conditions for all riparian and aquatic organisms in the standing water body as well as in the flowing water. The natural river continuum (Vannote *et al*., 1980) is interrupted affecting a number of river ecosystem processes (upstream and downstream migration, stream metabolism (autotrophic/allochthonous C-sources) etc.). Other major effects can be seen in three ways (Dynesius and Nilsson, 1994):

- Habitats for organisms adapted to the natural discharge of the water-level regimes are impoverished;
- Ability of a river to serve as a corridor is reduced;
- Function of the riparian zone as a filter between upland and aquatic systems is greatly modified.

Dams create reservoirs where water has longer residence times than in the former river and, therefore, change the physico-chemical and nutrient balance in the reservoir water and in the downstream river.

A survey of reservoir characteristics and usage is given in the draft of "MW4/5 Synthesis Report on Importance of Reservoirs, Usage, Environmental Conditions, Trends and Causes". IFEN, (1996).

Reservoirs are often multi-purpose. The most important reasons for reservoir construction are:

- Public water supply;
- Irrigation;
- Hydropower;
- Flood control;
- Low flow enhancement;
- Fish farming.

4.1.1 *Public Water Supply and Irrigation*

In the French Atlantic and Mediterranean region damming for public water supply and irrigation purposes is primarily done because of a lack of freshwater resources (surface water and groundwater) in the receiving areas with growing or huge seasonal population, respectively, and difficult climatic conditions (long drought periods, violent autumn rains, torrential floods). The large reservoirs are used in multi-purpose ways, the smaller reservoirs provide high quality water for public water supply. In the French Mediterranean region this intervention also serves flood protection.

Agriculture is an important part of the regional economy and the irrigation demand is increasing rapidly, because of an increase in irrigated land which is influenced by the Common Agricultural Policy. Additionally the river levels have dropped due to dry weather conditions and the irrigation demand which is growing faster than available supplies. This led to a major reservoir building programme in the Atlantic region to guarantee a stable agricultural economy, security for public water supply and a minimum flow for the rivers, protecting river habitats.

In the northern part of the Portuguese Mediterranean region public water supply is a major reason for damming because of a lack of freshwater resources. The main problems can be seen as migration barriers for migratory fish and impacts on water quality due to eutrophication in the reservoir. In the southern part reservoirs are mainly used for irrigation purposes. Here the main problems occur in connection with water quality caused by intensive agriculture and waste discharges.

4.1.2 *Hydropower*

The contributions to this project show that damming for generating hydroelectricity is one of the most significant interventions, especially in the Alpine and Continental region of Austria and France, in the Mediterranean region of Portugal and in Norway.

Hydropower is considered as one of the cleanest sources of energy available, being renewable and non-polluting. Hydroelectric power plants operate at 85-90 per cent efficiency, about twice that of fossil fuel power stations and almost three times that of nuclear power stations (Veltrop, 1992).

In Austria ~70 % of the total electric power is generated by hydropower and the exploitation of the usable hydropower potential amounts 65 %. In France about 13 % of the national electricity production is operated by hydropower and about 75 % of the potential hydroelectricity is exploited. In Norway 100 % of the electricity production is hydropower and about 63 % of the potential is developed, while 20 % is protected against development. In Portugal about 40 % of the total energy production is operated by hydropower.

Especially in the Alpine region there are a large number of hydropower dams, and often are placed in nature protection areas. The reservoirs are characterised as long and relatively deep valley-filling, especially in the French Alps and Pyrénées.

In the Continental region dams for hydropower are multi-functional serving navigational purposes, water supply, flood protection, tourism and stabilising alluvial groundwater levels. The typical river Rhône dam in France affects about 10-20 km of upstream rivers and diverts flow to a short-circuited river.

The major impacts on the natural environment were identified as dams acting as migration barrier and fragmenting aquatic ecosystems. Temporal and spatial discharges of large quantities of water affect long lengths of river reaches and lead to disturbances of the flow regime, the flow velocities, the sediment transport, the physico-chemical properties of the water and of lateral (floodplains), longitudinal (river continuum) and vertical (groundwater) interactions, depending on the reservoir management. Often large volumes of water (about 50 to 90 % in some valleys in Alpine France) were transferred between different catchments, drying out tributaries and downstream river beds. This intervention further changes autochthonous species composition and biodiversity as well as variable habitat structures.

In Norway the natural hydrological regime is characterised by low winter run-off and concentrated melt-floods in spring/early summer, that is the water fluxes are not coincidental with the major fluctuations in the energy consumption. This gives demand for high seasonal regulation and large reservoirs. The impact on runoff distribution is strong, even on river reaches that carry the full volume of water. Rivers with small catchments and a high relief, inter-basin transfers and "gutter" schemes, cutting off creeks and small rivers at intake level through long tunnels with intakes, are common. In such schemes many small rivers are completely dried out downstream of the intake. Larger rivers usually have some compensatory releases. The impacts and influences on the lake and river ecosystems are quite drastic.

In Portugal damming for hydropower plays a special role north of Tejo river. Approximately 100 % of Portuguese hydropower will be generated in this area.

4.1.3 Flood Control and Low Flow Enhancement

Damming for flood control and low flow enhancement is a main purpose of the multi-functional reservoirs in the French Atlantic and Continental region beside hydropower and tourism.

The first priority is to defend urban and agricultural areas against floods and the second to guarantee sufficient flow ensuring water supply for public and industrial efforts (especially cooling water for nuclear power plants in the Atlantic region) due to a lack of quality and quantity of freshwater especially in the Parisian region (over 10 million people).

Further, low flow enhancement ensures minimum flows avoiding ecological impacts due to drying out of the river.

In France the major problems are seen in the artificial regulation of flows and the periodic emptying of large reservoirs which is required by law every 10 years .

4.1.4 Fish farming

In the Atlantic and Continental regions of Denmark damming for fish farming has been emphasised as the main intervention in the continuity of Danish rivers, hydrologically as well as ecologically. The total river length suited for fish production and located upstream of dams is estimated to be 2,600 km, about 1,900 km being affected by the dams (Jensen, 1991).

At the typical Danish fish farm, especially in the (dry) summers, even the total discharge of the river will be abstracted. Additionally due to the dam changing the function of the upstream river sections into depositing areas, the transport of organic matter from upstream to downstream areas is interrupted and hence ecosystem processes are significantly impacted.

4.2 River Channelisation

The contributions show that river channelisation primarily serves flood control, land drainage and navigation purposes and is commonly distributed.

4.2.1 Flood Control

River channelisation for flood control occurs in the Alpine and Continental region as a main human intervention in the hydrological cycle changing the autochthonous species composition and biodiversity as well as variable habitat structures of the riverbed, the riparian zone and the flood plains.

4.2.2 *Land Drainage*

On the Scandinavian peninsula and in Finland, drainage of wetlands in forested areas influence the hydrological regime. The great majority of Denmark's natural rivers have lost their natural physical properties due to channelisation which is among the most important causes of why two thirds of all rivers do not fulfil the politically decided quality objectives.

River channelisation for land drainage secures a high and stable agricultural production even in marginal areas but reduces the physical variability of the rivers, the hydraulic properties and further affects and impoverishes the macroinvertebrate and fish communities and strongly reduces habitat diversity.

In the last decade activities on restoration of rivers and associated riparian areas have taken place re-establishing the natural physical properties of channelled rivers in through re-meandering (and reopening of culverted brooks).

4.2.3 *Navigation*

A main reason for river channelisation in the Atlantic region of France is for navigation.

4.3 Building of Weirs to Improve Fish Habitats

In Norway weirs have been used to increase the water covered area and to improve fish habitat in rivers with strongly reduced discharge. Discharge can be strongly reduced because of the operation of hydropower dams. In salmon rivers there is a long tradition to construct weirs to improve fishing conditions. In Denmark weirs have been removed for ecological reasons.

4.4 Dredging of River Channels

The primary reasons for river dredging are for land drainage and mining of river bed gravel which was found in the Alpine, Atlantic and Continental regions.

4.4.1 *Land Drainage*

Dredging and weed cutting (stream maintenance) are often associated with channelisation and intervene in the hydrological cycle in the same way by improving the river discharge capacity. It secures a faster drainage of agricultural areas and reduces the risk of floods in the area channelised but may increase the risk of floods in downstream areas. Additionally macroinvertebrates and fish communities are significantly affected and impoverished due to the lowered water level and the less variable physical river environment.

In recent years more environmentally appropriate methods have been used in Denmark as a compromise between agricultural and environmental interests to maintain more habitats for plants, macroinvertebrates and fish.

4.4.2 *Mining of River Bed Gravel*

The dredging of rivers for gravel is related to wet cuts for mining alluvial gravel in the catchment area and occurs primarily in the Alpine region. It is an important and economically useful source of high quality aggregates but has adverse effects both on river hydraulics, habitat and erosion processes.

In Norway mining of river bed gravel for private use can be done without licence.

4.5 Lake Regulation

Lake regulation seems to be an intervention typical of the Alpine region and in Norway.

4.5.1 Lake Shore Modification in Natural Lakes

Most of these lakes play an essential role for tourism and the littoral zones (with reed stands, reclamation areas etc.) of a large number of lakes have been modified by the creation of hotels, second homes and guest-houses with bathing areas, promenades or roads.

These measures affect the biodiversity of these areas in a negative way. The occurrence of many species typical for standing water ecosystems such as birds, amphibians, fish, macroinvertebrates or many plant species depend on littoral areas with highly diversified structural components. These areas are also important for nutrient binding processes.

4.5.2 Hydropower Production at Natural Lakes

Especially in Norway natural lakes are regulated for the generation of hydropower which is the most significant impact on the hydrological cycle in this area.

4.6 Estuary Regulation for Flood Defence

The contributions showed that estuaries are primarily regulated for flood defence but also for water storage, land reclamation, upstream tidal control and sometimes for hydropower. Eliminating the risk of flooding in inhabited and agricultural areas affects the river by transforming long reaches from marine-influenced into a freshwater river. This will affect aquatic biodiversity and change the autochthonous species composition in the estuary. Additionally the estuary may silt up which will probably requires dredging to clear navigable channels.

4.7 Lagoon Regulation

In the Mediterranean region of France there are very important wetlands where lagoon regulation controls flooding and permits the agricultural use of the fertile delta plain. This regulation and the increasing agriculture lead to a progressive desertification effect due to the reduced freshwater and marine invasions of the delta area which means a loss of natural wetland areas. Human interventions in the catchment may reduce sediment loads to the delta, resulting in coastal retreat and a progressive ‘estuarisation’ of the delta. The river digs deeper into the river bed and river influence is greater than marine influence.

5. OVERVIEW OF CATEGORY B INTERVENTIONS: WATER ABSTRACTION

5.1 Surface Water Abstraction

5.1.1 Public Water Supply

This intervention is described in Section 4.1.1 (damming for public water supply).

5.1.2 Industrial Water Supply

This intervention is of economic importance in the Continental region of France.

5.1.3 Irrigation

This intervention is described in chapter 4.1.2 (damming for irrigation - Atlantic region).

5.1.4 Fish Farming

This intervention is described in chapter 4.1.5 (damming for fish farming).

Fish farms are a main "consumer" of surface water in Denmark by diverting water from the river which has a significant ecological impact on the river sections by reducing flow ("the dead rivers"). These "dead rivers" are the sections between the inlet (upstream of the dam) and the outlet of the fish farm.

The size of the water reduction varies between fish farms from river sections which dry up for several months each year, to river sections with more than 50 % of the summer water flow through the year. The affected rivers are of reduced ecological quality and even the natural continuum is interrupted.

5.1.5 Hydropower

Surface water abstraction for generating hydropower was reported from mountainous areas and is described in chapter 4.1.3 (damming for hydropower) and chapter 4.5.3 (lake regulation for hydropower).

5.1.6 Inter-basin Transfer

Inter-basin transfer is often enforced in connection with hydropower purposes in mountainous areas. See section 4.1.3 (damming for hydropower). It is also important on the Iberian Peninsula (water supply, irrigation).

5.2 Groundwater Abstraction

The major reasons for groundwater abstraction and usage are for public and industrial water supply and for irrigation purposes. Information has been provided for the Atlantic and Continental region.

5.2.1 Public Water Supply

This intervention was reported for the Atlantic, Continental and Mediterranean regions.

Groundwater in Denmark makes up to 99 % of the total public water supply. It secures a high quality and stable supply of drinking water to large populations.

In France this intervention is required because of a lack of surface water of sufficient quality in the certain areas (e.g. Lille and Paris). Nationally, groundwater abstractions represent 57 % of total public water supply abstractions, but in some parts of northern Atlantic France, this figure is much higher (88 % in Artois-Picardie water agency area which includes Lille).

In Portugal 70 % of total water supply is met by groundwater. Groundwater quality will deteriorate because of deficiencies in waste water collection systems and treatment, and in industrial waste disposals.

Problems from groundwater abstractions may occur by reducing groundwater levels which in turn may reduce river base levels, too. As a result wetlands disappear and river ecosystems get disturbed.

Particularly for groundwater abstractions in coastal areas there is a risk of salt water intrusion into groundwater. For example this occurs in Denmark and Portugal. As a result, for example, in Denmark groundwater has to be abstracted some distance away from the larger coastal cities.

5.2.2 Irrigation

The contributions to this report show that groundwater abstraction for irrigation purposes is one of the major interventions in the hydrological cycle especially in the Atlantic, Continental and Mediterranean regions. For example, the water cycle can be massively affected by the high consumption rate of the water (differences between abstraction and recharge can be around 70-80 %).

Irrigation increases agricultural productivity, secures a highly stable agricultural production and permits agricultural development in climatically disadvantageous areas. High amounts of groundwater are abstracted for irrigation and the demand is still increasing.

Groundwater abstraction for irrigation is in some regions a significant problem, especially in dry summers. Groundwater abstraction contributes significantly to the fact that the rivers cannot meet the politically decided quality objectives. If the groundwater renewal rate is low and the total water demand is higher, groundwater level drops, river levels decrease and aquatic and riparian ecosystems will massively be influenced.

6. OVERVIEW OF CATEGORY C INTERVENTIONS: ACTIVITIES IN THE CATCHMENT

6.1 Land Drainage for Cultivation

This intervention was reported for all regions.

In Austria and Denmark, for example, land drainage, either for flood control or land reclamation, is probably the single most important measure which has adversely affected the landscape (loss of wetlands, small scale structures in the landscape), the biodiversity and the hydrological cycle.

Between 1980 and 1990 more than 37 % of wetlands of Austria have been destroyed. In Denmark it is estimated that about 49 % of the agricultural land has been drained, mainly in the 19th century.

The main benefits of this intervention are reclaimed land for cultivation, increase agricultural production (economical benefits) and a reduction in the risk of floods.

Land drainage causes the loss of important wetlands with their biodiversity and nutrient retention capacity as well as the loss of important water retention areas. Because of the removal of water from drained areas, runoff and high-flow peaks will increase as well as the risk of downstream floods which may lead to river channelisation. The groundwater table and renewal rate will then further decrease in the drained area/catchment.

Nowadays in Austria the drainage of land is no longer supported by government and programmes to recover drained land and restore rivers, including riparian wetlands, have been started to re-establish their natural hydrological features. Thus it is expected, that land drainage will decrease.

6.2 Land Sealing

This intervention refers to chapter 6.1 (land drainage due to cultivation) and was reported in all biogeographic regions. It is caused by urbanisation, infrastructure for traffic and tourist facilities such as skiing grounds in mountainous areas.

6.2.1 Urbanisation and Infrastructure

This intervention is closely connected to, and illustrated by, demographic trends and the increasing mobility of the population by individual transport.

Land sealing causes an increased and accelerated runoff, which causes problems in local flood control. In addition, sealed land prevents groundwater recharge by preventing the slow infiltration of water in particular during snow/frost thaw. Runoff water from sealed housing and traffic areas is normally unfiltered and contaminated with chemicals. This does not include major pollution caused by accidents.

Intimately related to this urbanisation and construction of buildings in zones former flood plains is the extensive flood control and sealing of river banks.

6.2.2 Tourism - Skiing Grounds

Land sealing for tourism purposes is reported in mountainous regions and especially concerns skiing grounds. Skiing tourism is one of Austria’s most important economic factors. Skiing pistes cover about 250 km^2 (0.28 %) of the Austrian territory.

The more severe environmental impacts are normally associated with downhill skiing. Forest clearance, construction of infrastructure (access roads, parking, hotels, lifts) and increased incidence of avalanches (mudslides) are major negative effects as well as water pollution due to sewage and chemicals caused by tourists outnumbering the local population many times over short periods. In some areas an extensive use of water due to snow cannons is a further impact in the water cycle (Stanners and Bourdeau, 1995).

6.3 Wet Cuts - Mining of Alluvial Gravel

Especially in the French Atlantic and Continental regions wet cuts in floodplains for mining of alluvial gravel as well as dredging in river beds has been reported as an important and economically useful source of high quality aggregates. It causes a massive intervention in the hydrological cycle. Also lakes will be created which sometimes may have better water quality for fish production than the rivers.

This intervention may affect groundwater quality as a result of the decreased filtering capacity and the frequent use of the created quarries as waste dumping grounds (especially illegal operations). It was also reported that the concentration of nitrate or pesticides increases due to pumping during quarry operations.

6.4 Agricultural Activities - Increase in Intensity of Agriculture

An increase in the intensity of agriculture is a pan-European problem and was reported for the northern and south-western part of the Atlantic region of France and the Continental region of Austria. As a result and benefit, for example, Austria has reached a high degree of self-sufficiency in agriculture.

Such activities include land improvement, land consolidation, land drainage, merging of small areas, removing of hedgerows as well as the type of tillage, type of crop cultivated, simplification of crop rotation, single-crop farming, etc. It disturbs the water balance of rural areas (decrease in the groundwater renewal rate, decrease in the groundwater table, increase of water discharge, etc.) and increases the risk of erosion (erosion caused by precipitation, wind-erosion, mudflow, flooding (inundation), slumping).

The main causes of increased erosion are seen as single-crop farming, simplification of crop rotation, soil compaction (caused by wheel tracks), deterioration of the soil structure, changing from grassland to arable land and land drainage. This will reduce the water storage capacity and the filtration capability of the soil, and the surrounding surface waters may become eutrophic. Soil compaction and deterioration of the soil structure increases the surface runoff and, therefore, will reduce the groundwater renewal rate of this area. The increase of biomass of the crops increases the water consumption and as a consequence reduces the soil moisture and the groundwater renewal rate. In some regions often the associated irrigation completes the increased water demand.

6.5 Forestry

Forestry activities in catchments were reported as significant in Norway and Portugal. In Norway deforestation was a drastic intervention during the 17th until the middle of the 19th century. The last century was characterised by afforestation which has strongly influenced the runoff regime in Norwegian rivers.

In Portugal deforestation is still a serious problem especially caused by urban development, agriculture, tourism and fires.

7. CONCLUSIONS

1. Major human interventions with significant ecological impact have been identified in all participating countries.

2. The most significant human interventions in the hydrological cycle have been made over the last decades. Today the negative effects of these interventions are recognised and analysed, and restoration activities are initiated. The perception of the importance of an intervention changes over time, as the understanding of the aquatic environment evolves.

3. Key figures and statistics concerning freshwater resources, freshwater abstractions, and major uses by countries are not readily comparable because of the different methods of assessment and calculation in each country. However, comparable data characterising the hydrological cycle, the water balance and water demand are necessary to quantify and judge the human interventions identified in this report, and on the basis of figures which characterise the extent of the impacts (quantity measures), to identify key issues relevant for the EEA.

4. One of the main difficulties in determining the significance of human interventions in the hydrological cycle on a pan-European scale appears to be the lack of appropriate criteria or regional scale for comparison. To that end the use of the regionalisation of the continent by the Biogeographic Regions used for the Natura 2000 process would be inappropriate. From the hydrological standpoint this division of Europe does not seem to be optimal due to the fact that hydrological characteristics vary strongly within a biogeographic region. Interventions in the hydrological cycle are not mainly based on the biogeographic regions itself but rather caused by human pressure (population density etc.) and cultural development. Further, distance between supply and demand, the pressure and the intervention, becomes relevant (e.g. upstream flood control of cities, distant hydropower generation etc.).

5. The report and the selection of the most significant interventions in the hydrological cycle is based on a consultation of experts at AWW (Austria), INAG (Portugal), IOW (France), NERI (Denmark) and NIVA (Norway). Therefore some aspects concerning other countries or regions may have been missed at this stage and will become evident in the further process.

8. RECOMMENDATIONS

1. There is a need to increase the comparability of data with regard to human interventions and to extend data collection to all EEA countries.

2. The regionalisation of the continent should, if required for the comparison of human interventions, be based on hydrological characteristics and/or on human pressures and demand.

3. The investigation on significant human interventions in the hydrological cycle should be extended to all EEA countries to give a representative overview of the situation across Europe. The reasons for an intervention should, in particular, be outlined in a detailed way, which may help in defining the most appropriate comparative regions. The importance of interventions nationally, regionally and across Europe should then be able to be assessed.

4. Single interventions should be investigated separately with more detailed assessments on the impacts on water quality.

5. At this stage of the Project the different human activities have not been fully quantified at a national or European level. For example, there appears to be no real information on the extent/intensity of different activities affecting the hydrological cycle. Information such as on the number of dams in a Member State and the catchment area affected, or the approximate length/% of river channelised or under flow regulation might be feasible to obtain in the near future. Indeed work undertaken by the ETC/IW on developing a reservoirs database has begun to quantify the number of dams, reservoirs and lakes across the EEA area. The next phase of this study must address these issues and should suggest a list of data/information which each Member State could supply in the medium term (next two or three years).

6. It is recommended that the methodology and definitions used in this scoping study are further refined and developed in light of the experience obtained. Information gathering should then be extended to other EEA Member States. It should be noted that the work on human interventions affecting groundwater quality and quantity will be addressed in the Groundwater Quality and Quantity Monograph to be produced by the ETC/IW in 1997 under the 1996 subvention.

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APPENDIX A LIST OF HUMAN INTERVENTIONS IN THE HYDROLOGICAL CYCLE

"HUMAN INTERVENTIONS IN THE HYDROLOGICAL CYCLE"

Three main categories have been identified - human interventions in the hydrological cycle (quantity aspects) are caused by:

1. RIVER, LAKE AND ESTUARY REGULATION
2. WATER ABSTRACTION
3. ACTIVITIES IN THE CATCHMENT (mainly changes in land use)

Please fill in and select the most important activities:

COUNTRY:____

BIO-GEOGRAPHIC REGION: _______________________

1. RIVER, LAKE AND ESTUARY REGULATION

*(The term **River Regulation** is used in this context as a general term describing the physical changes that people impose on water courses)*

<u>1.1 Damming, building and management of river reservoirs</u>

1.1.1 **[ ]** **Public water supply** *(drinking water supply)*

( ) of surrounding areas

of far regions *(interbasin water transfer, interregional water transfer)*

( ) due to a lack of freshwater resources in the receiving area

( ) due to a lack of water quality in the receiving area

1.1.2 **[ ]** **Industrial water supply** *(for cooling purpose, water for production, water use for mining,…)*

( ) of surrounding areas

of far regions *(interbasin water transfer, interregional water transfer)*

( ) due to a lack of freshwater resources in the receiving area

( ) due to a lack of water quality in the receiving area

1.1.3 **[ ]** **Cooling water for power plant**

( ) Closed circuit

( ) Open circuit

1.1.4 **[ ]** **Irrigation**

( ) of surrounding areas

of far regions *(interbasin water transfer, interregional water transfer)*

( ) due to a lack of freshwater resources in the receiving area

( ) due to a lack of water quality in the receiving area

1.1.5 **[ ]** **Hydropower**

Type of power stations

( ) Intermittent power generation plant *(peak-, seasonal- or base production)*

( ) Runoff-river power plant
( ) Pumped-storage plant
( ) Diversion type power plant
( ) Other

1.1.6 [ ] Navigation / Transport

( ) Diversion function *(where the dam diverts water into a channel or canal)*
( ) Weir function *(where the dam controls water levels in the river to permit navigation)*
( ) Storage function *(where the dam stores water in order to operate sluice gates)*
( ) Other

1.1.7 [ ] Flood control

( ) Basin where percolation takes place
( ) Dams acting as dikes to prevent the flooding of specific areas
Laying-up basin
( ) Dam in long and narrow valleys *(´dynamic´ capacity)*
( ) Large reservoirs situated in plains *(´static´ capacity)*

1.1.8 [ ] Low flow enhancement

( ) To provide a reliable downstream water supply
( ) To protect the downstream river habitat
( ) To maintain alluvial groundwater tables
( ) To enhance flows in the event of a pollution accident

1.1.9 [ ] Fish farming and fishing

1.1.10 [ ] Recreation

1.2 River channelisation *(straightening of water courses)* **due to**

1.2.1 [ ] Flood control *(torrent damming, breaking-up of avalanches, ...)*
1.2.2 [ ] Flooding for irrigation purpose
1.2.3 [ ] Drainage of surrounding land
1.2.4 [ ] Navigation
1.2.5 [ ] Others uses

1.3 Building of weirs

1.3.1 [ ] Flow regulation
1.3.2 [ ] Level regulation
1.3.3 [ ] Improving fish habitats, fish production, fishing possibilities
1.3.4 [ ] Improve aesthetic impression of the river

1.4 Dredging of river channels due to

1.4.1 [ ] Navigation
1.4.2 [ ] Drainage of the surrounding land
1.4.3 [ ] Mining of river bed gravel
1.4.4 [ ] Other uses

1.5 Lake regulation

(Natural lakes *are formed essentially by natural processes.* ***Semi-artificial lakes*** *have been formed or transformed by man. Unlike natural lakes they often have important ´artificial´ aspects like weirs and dykes.)*

1.5.1 **[ ]** **Lake shore modification**

( ) Natural lakes

( ) Semi-artificial lakes

1.5.2 **[ ]** **Fishing**

( ) Natural lakes

( ) Semi-artificial lakes

1.5.3 **[ ]** **Marinas, tourism, recreation purposes**

( ) Natural lakes

( ) Semi-artificial lakes

1.5.4 **[ ]** **Reduce flooding / flood defence** *(of adjacent agricultural land,…)*

1.5.5 **[ ]** **Water storage** *(public supply, hydroenergy, to supply canals/mills,…)*

( ) Natural lakes

( ) Semi-artificial lakes

1.5.6 **[ ]** **Others**

( ) Natural lakes

( ) Semi-artificial lakes

1.5.7 **[ ]** **Semi-artificial lakes formed by or for drainage of surrounding land**

1.6 Estuary regulation

1.6.1 **Estuary barrages which span the whole estuary** *(or nearly the whole estuary)*

1.6.1.1 **[ ]** Hydropower generation

1.6.1.2 **[ ]** Flood defence

1.6.1.3 **[ ]** Land reclamation

1.6.1.4 **[ ]** Navigation, industrial development of port areas

1.6.1.5 **[ ]** Tourist-oriented development of port areas *(raising water levels, covering ´unsightly´ mudflat zones)*

1.6.2 **Estuary barrages which cover part of an estuary** *(reservoirs)*

1.6.2.1 **[ ]** Water storage

1.6.2.2 **[ ]** Land reclamation

1.6.3 **Upstream modifications of tidally-influenced river reaches**

1.6.3.1 **[ ]** Upstream tidal control *(modifies tidal effects in river)*

1.6.3.2 **[ ]** Upstream flood control *(modifies flood effects on estuary areas)*

1.7 [ ] Lagoon regulation

*(**Lagoons** are lakes or ponds with continual/intermittent connections to the sea. Interventions could be modifications of marine water exchanges for purposes like tourism, flood control, sea defence, beach development,…)*

2. WATER ABSTRACTION / RELEASE

*(**Water abstraction** or water withdrawal means water physically moved from its natural site of occurrence) This part doesn't including water abstraction from impounded rivers (river reservoirs see 1.1)*

2.1 Surface water abstraction / release *(river, lake)*

2.1.1 [ ] Public water supply *(drinking water supply)*

( ) of surrounding areas

of far regions *(interbasin water transfer, interregional water transfer)*

( ) due to a lack of freshwater resources in the receiving area

( ) due to a lack of water quality in the receiving area

2.1.2 [ ] Industrial water supply *(for cooling purpose, water for production, water use for mining,…)*

( ) of surrounding areas

of far regions *(interbasin water transfer, interregional water transfer)*

( ) due to a lack of freshwater resources in the receiving area

( ) due to a lack of water quality in the receiving area

2.1.3 [ ] Cooling water for power plants

( ) Closed circuit

( ) Open circuit

2.1.4 [ ] Irrigation

( ) of surrounding areas

of far regions *(interbasin water transfer, interregional water transfer)*

( ) due to a lack of freshwater resources in the receiving area

( ) due to a lack of water quality in the receiving area

2.1.5 [ ] Fish farms

2.1.6 [ ] Other agricultural water abstraction

2.1.7 [ ] For the generation of hydroelectric power

Type of power stations

( ) Diversion type power station

( ) Storage power plant

( ) Others

2.1.8 [ ] To store water in reservoirs *(mainly for drinking water supply)*

Pumped intake reservoirs

2.1.9 [ ] Interbasin transfer *(hydropower or agricultural purposes)*

2.1.10 [ ] To maintain groundwater tables / recharge groundwater bodies

( ) of surrounding areas

of far regions *(interbasin water transfer, interregional water transfer)*

( ) due to a lack of freshwater resources in the receiving area

( ) due to a lack of water quality in the receiving area

2.1.11 [ ] Lowering the lake surface

2.1.12 [ ] Other uses *(tourism e.g. snow making for skiing grounds, ...)*

2.1.13 [ ] Major discharges to the river

<u>2.2 Groundwater abstraction / release</u>

2.2.1 [ ] Public water supply *(drinking water supply)*

( ) of surrounding areas

of far regions *(interbasin water transfer, interregional water transfer)*

( ) due to a lack of freshwater resources in the receiving area

( ) due to a lack of water quality in the receiving area

2.2.2 [ ] Industrial water supply *(for cooling purpose, water for production, water use for mining,…)*

( ) of surrounding areas

of far regions *(interbasin water transfer, interregional water transfer)*

( ) due to a lack of freshwater resources in the receiving area

( ) due to a lack of water quality in the receiving area

2.2.3 [ ] Cooling water for power plants

( ) Closed circuit

( ) Open circuit

2.2.4 [ ] Irrigation

( ) of surrounding areas

of far regions *(interbasin water transfer, interregional water transfer)*

( ) due to a lack of freshwater resources in the receiving area

( ) due to a lack of water quality in the receiving area

2.2.5 [ ] Fish farming

2.2.6 [ ] Due to artificial buildings

( ) Operating of dumping grounds

( ) Tunnelwork, mining,…

2.2.7 [ ] For other purposes *(e.g. snow making, …)*

2.2.8 [ ] Groundwater recharge

( ) Groundwater recharge schemes

( ) Cessation of long-term groundwater abstraction pumping *(closure of factories, mines)*

3. ACTIVITIES IN THE CATCHMENTS

<u>3.1 Land drainage due to</u>

3.1.1 [ ] Cultivation

3.1.2 [ ] Flood control *(loss of percolation area)*

3.1.3 [ ] Urbanisation *(including industrial areas)*

3.1.4 [ ] Infrastructure for traffic *(road, rail,…)*

3.1.5 [ ] Other use

3.2 Land sealing *(changes in land use)* due to

3.2.1 **[ ]** **Urbanisation** *(including industrial areas)*

3.2.2 **[ ]** **Infrastructure for traffic** *(road, rail, …)*

3.2.3 **[ ]** **Other use** *(e.g. skiing grounds)*

3.3 [ ] Dredging

*(**Dredging** in groundwater bodies - under groundwater table - for mining blocks of stone or gravel,…)*

3.4 Agricultural activities *(including changes in land use)*

3.4.1 **[ ]** **Intensification of agriculture**

- ( ) Cultivation of crops with general high water *requirements (maize, sugar-beet, vegetables, ...)*
- ( ) Cultivation of crops depending on irrigation systems *(e.g. vegetables in arid areas)*
- ( ) Long-term changes of grassland to arable land
- ( ) Drainage of wetlands *(see 3.1.1)*
- ( ) Water regulation in cultivation areas

3.4.2 **[ ]** **Irrigation management** *(e.g. inefficient irrigation systems)*

3.4.3 **[ ]** **Cultivation management** *(crop rotation, setaside, …)*

3.4.4. **[ ]** **Type of tillage**

- ( ) Cultivation on terrace shaped flats
- ( ) Plough *(no contour farming, ...)*
- ( ) Soil sealing, soil compaction

3.5 Forestry

3.5.1 **[ ]** **Deforestation due to**

- ( ) Cultivation *(arable land, grassland)*
- ( ) Urbanisation *(including industrial areas)*
- ( ) Tourist reasons *(areas for golfing, hotel accommodation, skiing grounds, ..)*
- ( ) Others *(torrent damming, breaking-up of avalanches, infrastructure, ...)*

3.5.2 **[ ]** **Afforestation in order for**

- ( ) Extensification of land use
- ( ) Erosion prevention
- ( ) Production of raw material *(pulp and paper, energy,…)*