Hydropower and the Environment: Survey of the environmental and social impacts and the effectiveness of mitigation measures in hydropower development

IEA Technical Report

Volume I

Report

IEA Hydropower Agreement

CANADA CHINA FINLAND FRANCE JAPAN NORWAY SPAIN SWEDEN UNITED KINGDOM

OVERVIEW OF THE IEA IMPLEMENTING AGREEMENT FOR HYDROPOWER TECHNOLOGIES AND PROGRAMMES

The Hydropower Implementing Agreement is a collaborative programme among nine countries: Canada, China, Finland, France, Japan, Norway, Spain, Sweden and the United Kingdom. These countries are represented by various organizations including electric utilities, government departments and regulatory organizations, electricity research organizations, and universities. The overall objective is to improve both technical and institutional aspects of the existing hydropower industry, and to increase the future deployment of hydropower in an environmentally and socially responsible manner.

HYDROPOWER

Hydropower is the only renewable energy technology which is presently commercially viable on a large scale. It has four major advantages: it is renewable, it produces negligible amounts of greenhouse gases, it is the least costly way of storing large amounts of electricity, and it can easily adjust the amount of electricity produced to the amount demanded by consumers. Hydropower accounts for about 17 % of global generating capacity, and about 20 % of the energy produced each year.

ACTIVITIES

Four tasks are operational, they are: 1. upgrading of hydropower installations, 2. small scale hydropower, 3. environmental and social impacts of hydropower, and 4. training in hydropower. Most tasks have taken about five years to complete, they started in March 1994 and the results will be available in May 2000. To date, the work and publications of the Agreement have been aimed at professionals in the respective fields.

UPGRADING

The upgrading of existing hydropower installations is by far the lowest cost renewable energy available today. It can sometimes provide additional energy at less than one tenth the cost of a new project. One task force of the Agreement is studying certain technical issues related to upgrading projects.

SMALL SCALE HYDROPOWER

Advances in fully automated hydropower installations and reductions in manufacturing costs have made small scale hydropower increasingly attractive. The small scale hydropower task force will provide supporting information to facilitate the development of new projects.

ENVIRONMENTAL AND SOCIAL ISSUES

For some hydropower projects the environmental and social impacts have been the subject of vigorous debate. There is a need to communicate objective information to the public, so that countries can make good decisions with respect to hydropower projects. The environmental task force will provide such information on possible social and environmental impacts and on mitigation measures.

TRAINING

The availability of well-trained personnel is a key requirement in the hydropower sector. The training task force is concentrating on training in operations and maintenance, and planning of hydro power projects.

THE INTERNATIONAL ENERGY AGENCY – IMPLEMENTING AGREEMENT FOR HYDROPOWER TECHNOLOGIES AND PROGRAMMES

Annex III
Hydropower and the Environment

Subtask 1

SURVEY OF THE ENVIRONMENTAL AND SOCIAL IMPACTS AND THE EFFECTIVENESS OF MITIGATION MEASURES IN HYDROPOWER DEVELOPMENT

Volume I

Report

The views presented in this report do not necessarily represent the views of the International Energy Agency, nor the government represented therein.

May 2000

OTHER TECHNICAL REPORTS IN THIS SERIES

HYDRO POWER UPGRADING TASK FORCE (ANNEX 1)

Guidelines on Methodology for Hydroelectric Turbine Upgrading by Runner Replacement – 1998 (available to non-participants at a cost of US $ 1,000 per copy)

Guidelines on Methodology for the Upgrading of Hydroelectric Generators – to be completed in May 2000.

Guidelines on Methodology for the Upgrading of Hydropower Control Systems – to be completed in 2000.

SMALL SCALE HYDRO POWER TASK FORCE (ANNEX 2)

Small Scale Hydro Assessment Methodologies – to be completed in May 2000 (available to non-participants on request)

Research and Development Priorities for Small Scale Hydro Projects – to be completed in May 2000 (available to non-participants on request)

Financing Options for Small Scale Hydro Projects – to be completed in May 2000 (available to non-participants on request)

Global database on small hydro sites available on the Internet at:
www.small-hydro.com

ENVIRONMENT TASK FORCE (ANNEX 3)

Survey of the environmental and social impacts and the effectiveness of mitigation measures in hydropower development – 2000 (available to non-participants on request)

Environmental comparison between hydropower and other energy sources for electricity generation – 2000 (available to non-participants on request)

Survey of existing guidelines, legislative framework and standard procedures for environmental impact assessment related to hydropower development – 2000 (available to non-participants on request)

Present Context and Guidlines for Future Action
Volume 1: Summary and Recommendations
Volume 2 : Main Report
Volume 3 : Appendices
– 2000 (available to non-participants on request)

Effectiveness of Mitigation Measures – 2000 (available to non-participants on request)

EDUCATION AND TRAINING TASK FORCE (ANNEX 5)

(All of the following reports are available on the Internet at www.annexv.iea.org Some reports may consist of more than one volume.)

Summary of Results of the Survey of Current Education and Training Practices in Operation and Maintenance – 1998 (available to non-participants on request)

Development of Recommendations and Methods for Education and Training in Hydropower Operation and Maintenance - 2000 (available to non-participants on request)

Survey of Current Education and Training Practice in Hydropower Planning – 1998 (available to non-participants on request)

Structuring of Education and Training Programmes in Hydropower Planning, and Recommendations on Teaching Material and Reference Literature - 2000 (available to non-participants on request)

Guidelines for Creation of Digital Lectures – 2000 (available to non-participants on request)

Evaluation of tests – Internet Based Distance Learning – 2000 – (available to non-participants on request)

BROCHURE

A brochure for the general public is available. It is entitled "Hydropower – a Key to Prosperity in the Growing World", and can be found on the Internet (www.usbr.gov/power/data/data.htm) or it can be obtained from the Secretary (address on the inside back cover).

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PREFACE

The International Energy Agency (IEA) is an autonomous body, established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD). The IEA carries out a comprehensive programme of energy co-operation among 24 of the OECD's 29 member countries. The basic aims of the IEA, which are stated in the *Agreement on an International Energy Programme*, are the following:

- Co-operation among IEA participating countries to reduce excessive dependence on oil through energy conservation, development of alternative energy sources, and energy research and development
- An information system on the international oil market as well as consultation with oil companies
- Co-operation with oil producing and oil consuming countries with a view to supporting stable international energy trade, as well as the rational management and use of world energy resources in the interest of all countries
- A plan to prepare participating countries against the risk of a major disruption of oil supplies and to share available oil in case of an emergency.

At its inception, the IEA concentrated on issues related to oil. Since that time the Agency has broadened its work to include all forms of energy. More than forty «Implementing Agreements» have been set up to deal with specific energy technology issues. Such Agreements comprise a number of task forces, called "Annexes", which implement specific activities such as collection of data or statistics, assessment of environmental impacts, joint development of technology etc. The work of these Annexes is directed by an «Executive Committee» consisting of representatives of the participating Governments.

In 1995, seven IEA member countries agreed to co-operate in a five-year research program focused on hydroelectric power formally called the *Implementing Agreement for Hydropower Technologies and Programmes*. Italy withdrew, but France, United Kingdom and People's Republic of China subsequently joined the remaining countries. This Agreement proposed that four distinct Task Forces ("Annexes") should be set up to address the following topics:

Annex I:	Upgrading of Existing Hydropower Facilities
Annex II:	Small-Scale Hydropower
Annex III:	Hydropower and the Environment
Annex V:	Education and Training

Annex III "Hydropower and the Environment" entered into force in February 1995 with the following principal objectives:

- To arrive at a set of international recommendations for environmental impact assessment of hydropower projects, and criteria for the application of mitigation measures
- To improve the understanding of hydropower's environmental advantages and suggest ways to ameliorate its environmental drawbacks
- To forward national experiences regarding environmental effects of hydropower development at a project level and the legislation and decision making process at a national level
- To provide an environmental comparison between hydropower and other sources for electricity production

To achieve these goals the following Subtasks have been implemented:

Subtask 1:	Survey of the environmental and social impacts and the effectiveness of mitigation measures in hydropower development *(Subtask leader: NVE, Norway)*
Subtask 2:	Data base (included in Subtask 1)
Subtask 3:	Environmental comparison between hydropower and other energy sources for electricity generation *(Subtask leader: Vattenfall, Sweden)*
Subtask 4:	Survey of existing guidelines, legislative framework and standard procedures for environmental impact assessment related to hydropower development *(Subtask leader: UNESA, Spain)*
Subtask 5	Present context and guidelines for future action *(Subtask leader: Hydro-Québec, Canada)*
Subtask 6	Effectiveness of mitigation measures *(Subtask leader: Hydro-Québec, Canada)*

From a scientific perspective, environmental studies are complex because of the many interactions in the ecosystem. In a subject area as wide as hydropower and the environment, it has been important to maintain the scope of the work within the limits imposed by the five-year time schedule and the available financial and human resources. However, several of the topics discussed are very extensive and complex, and as such, ought to have been handled with resources equivalent to an Annex. The main Annex III challenges have been to define the context and focus on the most important environmental and social issues. Two guiding themes have been the relation to government decision-making processes, and the need to ensure the highest possible level of credibility of the work.

Annex III is based on a case study approach combined with experience from a wide range of international experts representing private companies, governmental institutions, universities, research institutions, and international organizations with relevance to the subject. In all 112 experts from 16 countries, the World Bank (WB) and the World Commission of Dams (WCD) have participated in meetings and workshops. Additionally, 29 professional papers have been presented at the meetings. The participating countries are responsible for the quality control of the information given at the national level. Reference groups have been consulted in some countries.

Like all extraction of natural resources, the harnessing of rivers affects the natural and social environment. Some of the impacts may be regarded as positive; others are negative and severe. Some impacts are immediate, whereas others are lingering, perhaps appearing after several years. The important question, however, is the severity of the negative impacts and how these can be reduced or mitigated. The aspect of ecological succession is also of great interest. Through history, the ecosystems have changed, as a result of sudden disasters or more gradual adjustments to the prevailing weather conditions. Any change in the physico-chemical conditions seems to trigger processes that establish a new ecological equilibrium that matches the new ambient situation. Under natural conditions environmental change is probably more common than constancy. Ecological winners and losers, therefore, are found in natural systems as well as those created by man.

Even if the "fuel" of a hydropower project is water and as such renewable, the projects are often quite controversial since the construction and operation directly influences the river systems, whereby the adverse impacts become direct and visible. The benefits, like avoidance of polluting emissions that would have been the unavoidable outcome of other electricity generating options is, however, less easily observed.

Access to water and water resources management will be a very important environmental and social global challenge in the new century, because water is unevenly distributed and there are regional deficits. Dam construction and transfer of rivers and water abstraction are elements in most water management systems. The lessons learned from past hydropower projects may be of great value in future water resources management systems. If a regional water resources master plan or management system is available, then the development of hydropower resources could also contribute to an improved water supply for other uses.

It is necessary to underline that the Annex III reports discuss the role and effects of hydropower projects and how to improve their sustainability. They do not consider the increased energy consumption *per se* since this aspect is a national and political issue. Annex III has developed a set of international recommendations and guidelines for improving environmental practices in existing and future hydropower projects. One main conclusion is the necessity of an environmental impact assessment undertaken by competent experts and forming an integrated part of the project planning.

The Annex III reports have been accomplished based on a cost and task sharing principle. The total costs amount to USD 805 305, while the task sharing part had a budget of 93 man months. The reports which have been completed include 4 Technical reports (Subtasks 1, 3, 4, 6) with Appendices, one Synthesis report (Subtask 5) with Appendices and one Summary report presenting the recommendations and guidelines.

Annex III comprises the following countries and organizations: Canada (Ontario Hydro, 1995-98, Hydro-Québec 1995-2000), Finland (Kemijoki OY 1996-2000); Italy (ENEL 1995-98); Japan (CRIEPI 1995-2000); Norway (NVE 1995-2000); Spain (UNESA 1995-2000) and Sweden (Vattenfall AB 1995-2000).

Oslo 30 March 2000

Sverre Husebye
Operating Agent
IEA-Annex III

ANNEX III ACKNOWLEDGEMENTS

I wish to thank the Annex III team, their companies and experts for the support and constructive and professional participation during all these 5 years. The Expert Meetings and Workshops have been characterized by an open, friendly and informal atmosphere, which have ensured common understanding with regard to professional content and the decisions made. During the 11 meetings the work has progressed steadily, with no steps back caused by misunderstandings or unclear decisions. Special thanks go to the National Representatives, Subtask Leaders and the Annex III Secretary for their enthusiasm, co-operation and achievement. On behalf of all the participants in our meetings and workshops, I would like to express our appreciation to the companies which were our hosts: Vattenfall, ENEL, UNESA, CRIEPI, NEF, Kemijoki OY and Hydro-Québec..

The credibility of the Annex III work has been greatly enhanced by the contributions from the participating experts representing: Ethiopia, Indonesia, Laos, Nepal, Philippines and Vietnam. Japan and Norway supported their participation. All Annex III countries and companies are thanked for financing additional internationally renowned experts in specialized subject areas. This ensured that progress was maintained and credibility was enhanced.

I also wish to thank the professionals who have filled in the comprehensive questionnaires. The participation from the World Bank and WCD has inspired the Annex III team and contributed to the actuality of our results.

The Executive Committee members are thanked for their guidance, support and co-operation.

Even if all names are given in the review of the IEA-Annex III Organization below, I would like to draw special attention to the following persons due to their active participation and support over the years: Mr. Jens Petter Taasen (Annex III secretary and STL 1), Ms. Kirsti Hind Fagerlund (Annex III secretary and STL 1), Mr.Björn Svensson (STL 3), Mr. José M. del Corral Beltrán (STL 4), Ms. Cristina Rivero (STL 4), Mr. Jean-Étienne Klimpt (STL 5), Mr. Gaétan Hayeur (STL 6), Mr. Serge Trussart (STL 6), Mr. Joseph Milewski, Mr. Frans Koch (Executive Committee secretary), Mr. Luc Gagnon, Mr. Raimo Kaikkonen, Mr. Hannu Puranen, Mr. Mario Tomasino, Mr. Shuichi Aki, Mr. Jun Hashimoto, Mr. Tsuyoshi Nakahata, Mr. Kiyoaki Uchikawa, Mr. Yohji Uchiyama, Mr. Svein T. Båtvik, Mr. Rune Flatby, Mr. Geir Y. Hermansen, Mr. David Corregidor Sanz ,and Mr. Magnus Brandel.

Oslo 30 March 2000

Sverre Husebye
Operating Agent
IEA-Annex III

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IEA - Annex III Organisation

Operating Agent:

Husebye, Sverre	1995-2000	Norwegian Water Resources and Energy Directorate (NVE), Norway

Secretary:

Taasen, Jens Petter	1997-2000	Norwegian Water Resources and Energy Directorate (NVE), Norway
Fagerlund, Kirsti H.	1995-1997	Norwegian Water Resources and Energy Directorate (NVE), Norway

National representatives:

Hayeur, Gaëtan	1995-1997	Hydro-Québec, Canada
Klimpt, Jean-Etienne	1997-2000	Hydro-Québec, Canada
Kaikkonen, Raimo	1996-2000	Kemijoki Oy, Finland
Aki, Shuichi	1995-2000	Central Research Institute for Electric Power Industry (CRIEPI), Japan
Husebye, Sverre	1995-2000	Norwegian Water Resources and Energy Directorate (NVE), Norway
Corral, Jose del	1995-1998	Hidroelectrica Catalunia, Spain
Rivero, Cristina	1998-2000	UNESA, Spain
Svensson, Björn	1995-2000	Vattenfall Hydropower AB, Sweden
Young, Christopher	1995-1997	Ontario Hydro, Canada
Tomasino, Mario	1995-1998	ENEL, Italy

Subtask leaders:

ST1 Survey of the Environmental and Social Impacts and the Effectiveness of Mitigation Measures in Hydropower Development

Taasen, Jens Petter	1997-2000	Norway
Fagerlund, Kirsti H.	1995-1997	Norway

ST2 Creation of an International Information Data Base Comprising Environmental and Social Impacts, the Effect of Mitigation Measures and the Licensing Procedures Related to World Wide Experience of Hydropower Development
(Closed down in 1997, database included in ST1)

Young, Christopher	1995-1997	Canada
Yu, Margaret S.	1997	Canada

ST3 Environmental and Health Impacts of Electricity Generation

Svensson, Björn — Sweden

ST4 Survey of Exisitng Guidelines, Legislative framework and Standard Procedures for EA of Hydropower Projects

Rivero, Cristina	Spain
Corral, Jose del	Spain

ST5 Hydropower and the Environment: Present Context and Guidelines for Future Action

Klimpt, Jean-Etienne — Canada

ST6 Hydropower and the Environment: Effectiveness of Mitigating Mesures

Trussart, Serge — Canada

Activity list Annex III:

Expert meetings and workshops

March 1995 - Montreal, Canada: : — 18 participants

October 1995 - Rome, Italy: — 18 participants
Case-study presentations

February 1996 - Stockholm , Sweden: — 16 participants

October 1996 - Madrid, Spain: — 19 participants
Presentations

Review of the national/provincial legislation in:

Canada	Young, Christopher	Ontario Hydro
Finland	Kaikkonen, Raimo	Kemijoki Oy
Italy	Tomasino, Mario	ENEL

Japan	Aki, Shuichi	Central Research Institute for Electric Power Industry
Nepal	Sudesh, Kumar Malla	Energy Development Centre
Norway	Flatby, Rune	Norwegian Water Resources and Energy Directorate
Spain	Rivero, Cristina	UNESA
Sweden	Svennson, Björn	Vattenfall Hydropower AB

General papers:

Kjørven, Olav, World Bank :Environmental Assessment at the World Bank: Requirements, Experience and Future Directions
Haagensen, Kjell, Statkraft: IEA program: Hydro Power and the Environment

April 1997 - Tokyo, Japan: 21 participants

Presentations

Sumitro, Sasmito, Indonesia: The Saguling Hydro Power Electric and Environment Aspects
Manolom, Somboune, Laos: Hydropower and the Environment Lao PDR
Benito, Francisco A., Phillipines: Hydropower Development and the Environmental Impact System in the Philippines
Xayen, Nguyen, K. X., Vietnam: Brief Review on Hydropwer situations in Vietnam

October 1997 - Venice, Italy: 21 participants

March 1998 - Rovaniemi, Finland: 20 participants

October 1998 - Manila, Philippines: 28 participants

Presentations

Merdeka, Sebayang, Indonesia: Environmetnal Aspects on Hydropower Development in Indonesia
Boungnong, Chanchaveng, Laos PDR: Socio-Environmental Impact Assessment of the Nam Ngiep 1Hydroelectric Project
Marasigan, Mario C., Philippines: Status of Mini-Hydropower Development in the Phillippines
Delizo, Tito D., Philippines: Tapping Private Sector for Small and Medium hydroelectricpower Plants in the Phillipines

March 1999 - Madrid, Spain: 25 participants
November 1999 - Paris, France: 19 participants

Technical Seminar

Escorial - Madrid, Spain 15-17 March 1999 55 participants

Presentations

Gagnon, Luc & Bélanger, Camille, Canada: Windpower: More Renewable than Hydropower?
Goddland, Robert, World Bank: What Factors Indicate the Future Role of Hydro in the Power Sector Mix? Environmental Sustainability in hydroprojects.
Henderson, Judy, South Africa: WCD-Strategy and Objectives
Husebye, Sverre, Norway: Status and Progress of the IEA-Annex III Work
Marasigan, Mario C., Philippines: Philippine Perspective: Hydropower and Rural Electrification
Nakamura, Shunroko, Japan: Recent River Ecosystem Conservation Efforts Downstream of Power Dams in a Densely Populated and Highly Industrialized Country: Japan
Oud, Engelebert, Germany: Planning of Hydro Projects
Roy, Louise, Canada: Ethical Issues and Dilemmas
Svensson, Björn, Sweden: A Life Cycle Perspective on Hydroelectric and Other Power Plants
Uchiyama, Yohji, Japan:Life Cycle Assessment For Comparison of Different Power Generating Systems
Pineiro, S.J.L., Spain: El libro blanco del agua en España

Subtask Leader meetings

July 1998 - Montreal, Canada
September 1999 - Montreal, Canada

Participants at the Annex III Expert meetings, Workshops and Technical Seminar (1995-2000):

Canada	Adams, Ken	Manitoba Hydro
Canada	Baillard, Dominique	Hydro-Québec
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Canada	Hayeur, Gaëtan	Hydro-Québec
Canada	Howard, M. Charles D.D.	Charles Howard and Associates Ltd
Canada	Kingsley, Tony	Canadian Electrical Association
Canada	Klimpt, Jéan-Étienne	Hydro-Québec
Canada	Koch, Frans	IEA-Hydropower Agreement
Canada	Lee, Walter	Engineering & Technical Support
Canada	Messier, Danielle	Hydro-Québec
Canada	Milewski, Joseph	Hydro-Québéc
Canada	Oud, Engelbert	Lahmeyer
Canada	Roquet, Vincent	VR Associates Inc.
Canada	Rowsell, Jim	Ontario Hydro
Canada	Roy, Louise	Consensus Inc.
Canada	Trussart, Serge	Hydro-Québéc
Canada	Young, Chris	Ontario Hydro
Canada	Yu, Margaret S.	Ontario Hydro
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Ethiopia	Shenkut, Gebresemayat	Ministry of Mines and Energy
Finland	Aula, Antti	Kemijoki Oy
Finland	Huttunen, Arja	Arctic Centre (Rovaniemi)
Finland	Hyvönen, Matti	Lapland Regional Environment Centre
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Norway	Østhagen, Håvard	Norwegian Water Resources and Energy Directorate
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Philippines	Delizo, Tito D.	National Power Corporation
Philippines	Marasigan, Mario, C.	Department of Energy
Philippines	Morante, Jennifer L.	Department of Energy
Philippines	Rayos, Alex H.	Department of Energy
Philippines	Salvania, Rey V.	Department of Energy
Philippines	Sargento, Ronnie, N.	Department of Energy
Philippines	Zabala, Arnulfo M.	Department of Energy
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Spain	Bailly-Bailliere, Enrique	Ministerio de Medio Ambiente
Spain	Borrego, Margarita	UNESA
Spain	Corregidor, David	UNESA
Spain	Cortés, Hernán	ENDESA
Spain	Del Corral, J. Miguel	Hidroélectrica de Cataluna-1, S.A.
Spain	Diaz Pineda, Francisco	University Complutense of Madrid
Spain	Lopez Marinez, Javier	Minstry of Industry and Energy
Spain	Palau, Antonio	University of Lérida
Spain	Piñeiro, Santiago J.L.	Ministerio de Medio Ambiente
Spain	Plaza, Vicente	UNESA
Spain	Rivero, Cristina	UNESA
Spain	Sabater, Juan	ENDESA
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Sweden	Brink, Björn	Svenska Kommunforbundet
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Sweden	Malmkvist, Maria	Swedish National Energy Administration
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Sweden	Svensson, Björn	Vattenfall Hydropower AB
UK	Taylor, Richard M.	International Hydropower Association
USA	Galbreth, Tim	Tennessee Valley Authority
USA	Sullivan, Charles	Electric Power Research Institute, California
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	Kjørven, Olav	World Bank
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EXECUTIVE SUMMARY

To collect information about hydropower and the environment, the questionnaire approach was chosen. The objective of the questionnaire is to develop a tool whereby the actual effects of hydropower in terms of environmental and social impacts and the efficiency of applied mitigation measures can be compared and assessed in a global perspective.

28 questionnaires have been received and are included in the database. These questionnaires describe 46 projects, 39 of which are new projects and seven are upgrading projects. The database programme in use is Microsoft's Access 97.

Sources of environmental and social impacts
Main physical impacts: Air and water temperature, drainage from construction work, eutrophication, flood frequency, flow regime, groundwater level, heavy metals, oxygen content, sedimentation, transport of elements and matter, and turbidity or suspended solids.
Main biological impacts: Fauna (aquatic and terrestrial - birds, insects, mammals), fish communities, fish migration, fisheries (fish stocking), flora (aquatic and terrestrial), mercury (in fish), and red-listed species (both aquatic and terrestrial).
Main socio-economic impacts: Access roads, agriculture, fisheries (fish stocking), forestry, indigenous people, landscape appreciation, recreational areas, resettlement, rock tips, schools, social intrusion, tourism employment, transportation, and water supply.

Activities commonly associated with mitigation measures

Activity	Mitigation measures
Altering long-term river flow	Water quality protection and adjustments
”	Water quantity control
”	Economic impact management
”	Protection, replacement and control of vegetation
”	Fish protection
”	Protecting or mitigating changes to landscape
”	Social impact management
”	Protection of valued ecosystem components
”	Erosion prevention and control
”	Sedimentation prevention and control
Dewatering and draining	Water quality protection and adjustments
Impounding (reservoir filling)	Water quality protection and adjustments
Operating at peak efficiency	Water quantity control
”	Mitigating effects on resource use

Most of the mitigation measures are implemented in connection to the impact group ”Change in biota habitat” and are connected to fish protection, landscape, protection of valued ecosystem components and protection of vegetation. The other most important impact groups where mitigation measures are carried out are ”Change in water quality” (water quality protection), ”Change in local economy” (economic and social management), ”Change in ecosystem community populations” (fish protection), and ”Change in water quantity” (control of water flow, water level and velocity).

Mitigation measures: Characterisation of success

Mitigation group	Sum of projects	High	Indif-ferent	Low
Water quality protection and adjustments	44	40	1	3
Water quantity control (flow, velocity, level; including ice formation and movements)	43	36	4	3
Fish protection	42	33	4	5
Protection, replacement and control of vegetation	42	35	2	5
Economic impact management	35	26	1	8
Other (see questionnaire)	33	29		4
Social impact management	31	24	1	6
Protecting or mitigating changes to landscape	17	13		4
Erosion prevention and control	11	8	1	2
Mitigating effects on resource use	11	8		3
Human health and safety risk management	9	7	2	
Sedimentation prevention and control	5	4		1
Climatic and local air quality controls	4		4	
Protecting or mitigating changes to aboriginal land use, cultural heritage, archaeological resources	4	2		2
Protection of valued ecosystem components (aquatic and terrestrial habitats, communities, rare, threatened species and spaces, and particular species other than fish)	3	1		2
Minimising soil contamination and loss of soil due to inundation	2	2		
Mitigating cumulative effects of multiple hydroelectric facilities	2	1		1
Protecting or minimising changes in channel morphology	1	1		

1. INTRODUCTION – ANNEX III AND SUBTASK III/1

1.1 The background and objective of Annex III

From a scientific perspective, environmental studies are complex because of the many interactions in the ecosystem. When human societies interact with the environment, the complexity increases because different groups attach different values to environmental costs and benefits. The task force of Annex III has been working to bring together objective facts and accumulated experience to assist decision-makers in reaching wise compromises within this complex field of environmental and social interactions.

The main objective of Annex III will then be to develop a set of international recommendations and standards for environmental impact assessments, which are based on a very wide range of experience in different countries.

1.2 The background and objective of Subtask 1 - Survey of the environmental and social impacts and the effectiveness of mitigation measures in hydropower development

The objective of Subtask 1 is to develop a method to make it possible to collect the information and data needed in order to document the positive and negative effects of hydropower development as well as the effect of mitigation measures. The main elements of this method include:

- Development and promotion of a word wide study of hydropower based on a "Case study approach", focusing on main environmental issues, impacts and the documented effect of mitigation measures
- This collected information should be based on a wide range of hydropower projects representing different climatic and geographical regions as well as countries with different social and economic backgrounds
- Forwarding the combined experience of hydropower development, environmental impacts, effects of mitigation measures etc. in order to make the experiences available at an international level.

For technical reasons the report of the Subtask I work is divided into two parts:
- Volume I consists of the main text, the references to mitigation measures and impacts as given in the questionnaires, and a glossary relevant for this report. In addition, as there are frequent references to the Appendices 1-5 in the text, giving definitions and categories used in the questionnaire, these Appendices are included in volume I in order to make it easy for the reader to check these definitions and categories.
- Volume II consists of the remaining Appendices 6-18.

1.3 The duration and financing of the programme

For such a comprehensive issue as hydropower and the environment, it is important to maintain the scope of the work so that results could be obtained within a reasonable time scale, in this case five years, and with a reasonable amount of resources.

Financially, the participating countries found it preferable to invoice a fixed amount every year. This implies an annual total payment divided between the participating countries.

2. SURVEY ON ENVIRONMENTAL IMPACTS OF HYDROPOWER AND MITIGATION MEASURES – THE METHOD

2.1 Method selected

During the century-long history of hydropower development, this activity has changed from being primarily a challenge for engineers to become a rather complex undertaking also involving economists, biologists, sociologists and a wide array of NGOs, affected people, pressure groups and lobbyists. Today, at least in most democratic and industrialised countries, there is a whole range of stakeholders linked to the process of hydropower development offering their view of the "reality" of any proposed or implemented project. A bewildering array of evaluation reports on process efficiency, EIAs and mitigation measures have in more recent years been produced for particular hydropower projects, or for a group of projects, or for whole regions or countries. Most of these reports claim to give the "real picture" of the issue, or at least a part of the issue. However, the conclusions and recommendations that can be found in such reports have a tendency to vary rather widely, or even be completely contradictory, depending on the interests, ethical values and the different importance being given to various issues inherent in the complex process of hydropower development.

To our knowledge, there has never been any international effort made to try to organise and systematise this very comprehensive, but heterogeneous and piecemeal information through the application of an international questionnaire approach. The great advantage of this approach is to make it possible to obtain factual information on a wide selection of different hydropower projects in a systematic way, and where all types of relevant information are asked for. Ideally, the questionnaire approach can also make it possible to be able to compare hydropower development in different geographical, climatic, political, social, legislative, and economical contexts. Some of the possible drawbacks will of course be related to the difficulty of obtaining a fair distribution of representative projects worldwide, as well as the inherent problem of obtaining qualitatively relevant, correct and objective data.

2.2 Preparation of the questionnaire

The questionnaire is mainly based on the ideas from two workshops within the Annex work. National representatives and experts attended these workshops and agreed on which parameters and issues the questionnaire should concentrate on. Subsequent meetings with different subtask leaders were also arranged to assure that the questionnaire would fulfil the requirements. During this process the preliminary questionnaire was distributed twice for comments from the participating countries.

To make the questionnaire available also in an electronic form, both for simplifying the distribution of the questionnaire as well as facilitating a computer-based treatment of the material, the development of an electronic version was made in parallel to the paper version.

Norway has been in charge of the paper version of the questionnaire and Canada (Ontario Hydro) started with the development of the electronic version, - the latter was the main activity within "Subtask III/2". As Ontario Hydro withdrew from Annex III and Subtask III/2 in October 1997, Norway took over the responsibility of the electronic version within a broadened Subtask III/1. There was a close co-operation between Subtask I and Subtask II until the withdrawal of Ontario Hydro in order to obtain the best possible result.

A fairly detailed "User Guide" is distributed together with the electronic version of the questionnaire and is included as Appendix 17. A paper version of the questionnaire is included as Appendix 18.

2.2.1 Scope and objective

The IEA questionnaire developed for Annex III is called "Environmental Impacts and Hydropower". The scope of the questionnaire covers the actual environmental and social impacts and the various mitigation measures related to hydropower development worldwide, as well as the legislative, geographical and climatic setting in which the projects were implemented.

The objective of the questionnaire is to develop a tool whereby the actual effects of hydropower development, in terms of real environmental and social impacts, and the efficiency of applied mitigation measures can be systematically compared and assessed within a global perspective. Furthermore, provided there is an adequate number of qualitatively relevant hydropower projects from a wide range of different settings globally, this method will furnish decision-makers and all involved stakeholders with factual data for hydropower development in the future.

It is the hope of the Annex III collaborating countries that this approach will contribute to bringing the issue of hydropower development from a state of conflict towards an atmosphere of co-operation and constructiveness whereby the different stakeholders will have a common and "objective" platform based on which all parties can reach acceptable solutions.

2.2.2 Content of the questionnaire

The questionnaire has several parts, which are linked together. It is of importance to start with Part 1 in the questionnaire, but then it is possible to move around from one part to another. Some parts contain sections that may have to be filled in several times to create more than one record. After completing some of the entries in the forms, it is possible to go back and make corrections if needed (see also Appendix 18).

<u>Part 0: Introduction.</u> This part of the questionnaire asks for the name of the project and the name of the company/institution/department being responsible for the project. To ensure responsibility and quality control as well as to be able to get more information from each project, the name of the people that have filled in the data as well as the name of a superior person in charge are asked for.

<u>Part 1: Project data.</u> Part 1.1 and 1.2 ask for information about locality and geographical position, possible associated projects, the rationale and the project history (planning phase, approval phase, construction phase and operation).

Part 1.3 and 1.4 ask for quality management systems applied (if any; e.g. ISO systems), the possible purposes of the project in addition to power generation, and maps for the project area.
Part 1.5 is dealing with power station(s) specifications (type of project, reservoirs and diversions, technical power plant data, and the general production strategy.)
Part 1.6 is dealing with reservoir(s) specifications (catchment area, volume, hydrology, size, etc.) as well as dam(s) and spillway(s) specifications.
Part 1.7: This part of the questionnaire has several sections where various climatic, environmental and hydrological data should be filled in. Data on the catchment area and natural landscape and/or cultural amenities in the project area are also asked for here.
Part 1.8 asks for social data. This part includes questions about population, possible resettlement and compensation issues, as well as the actual information flow during the planning and implementation phases of the project. This part also asks for the perception of the project among the local or affected population, and the actual land-use in the area before and after the project. Relevant project spin-offs are also included here.

Part 2: Identification of key issues. This part of the questionnaire asks for the key issues that where identified in the project-planning phase, including issues related to the environment, economy, geophysics, hydrology, landscape, climate and various social issues. Information on how and why the key issues were identified as well as which stakeholders were consulted in this identification process should also be submitted here.

Part 3: Verification of impacts. This part of the questionnaire is particularly important for the selected method. To try to assure that relevant, high quality and "objective" data are submitted, this part must be equipped with published references (or by references to unpublished reports) to substantiate the information given.
Part 3.1 asks for the actual studies undertaken to determine the impacts of the hydropower development. The various impacts might be sorted into different defined locations within the catchment and construction area (five different entries in the questionnaire, see Appendix 1), activities (49 different entries in the questionnaire, see Appendix 2), impacts (32 different entries in the questionnaire, see Appendix 3), environmental component types (13 different entries in the questionnaire, see Appendix 5) and environmental components (72 different entries in the questionnaire, see Appendix 5). A comparison should be given between the expected and the documented impacts.
Part 3.2 deals with the documentation of the impacts, and asks for published or unpublished references. These might include everything from peer-reviewed journals, official reports and publications via mimeographed reports to confidential, internal or publicly unavailable reports. It is also interesting here to give information about by whom the reports are made.
Part 3.3 and 3.4 are dealing with the main environmental impacts of the project that turned out to be the most important after the project was implemented, based on the identified issues in part 3.1, and also what kind of studies were undertaken to verify these.

Part 4: Mitigation measures. Part 4.1 and 4.3 are dealing with an outline of mitigation measures undertaken in the project, and the reason for success (or lack of success), respectively. The general characterisation of success might be complemented by suggested improvements, and information relating to the cost of the mitigation measures (e.g. in percentage of the total project cost) is also asked for. The questionnaire again includes entries for location, activity, impact, environmental component type and environmental component (see under part 3.1), and it also lists a total of 129 common mitigation measures related to 19 main mitigation groups (see Appendix 4).
Part 4.2 and 4.4 are dealing with the documentation of the mitigation measures, including their effectiveness (see part 3.2). The whole issue of mitigation measures related to hydropower development has been the main topic for a separate subtask (ST III/6) within this annex work.

Part 5: Regulatory approval process. Part 5.1 is asking for a description of the regulatory approval process for the project. This information should include a listing of the regulatory authorities that were involved and a brief description of the type of involvement, the time spent to issue an approval, what kinds of mitigation measures were imposed by the regulatory authorities, and also a description of changes in project design imposed as a consequence of the assessments of plans. The whole issue of surveying existing guidelines, legislative framework and standard procedures for EIA of hydropower projects has been the main topic for a separate subtask (ST III/4) within this annex work.

2.2.3 Selection of the projects

For each participating country of this undertaking some criteria were listed to ensure that as much as possible of the relevant information was submitted to the database: Each country should present a number of case studies reflecting the different climatic and topographic regions as well as the variety of project types. Additionally, the projects should be fairly recent so as to make sure that the projects involved a real planning phase with environmental and social impact assessments and implemented mitigation measures in a defined, legal regulatory context.

2.2.4 Data collection

The data collection is based on the response of the questionnaire, which has been distributed by the representatives of the participating countries. The representatives of each country have also been responsible for the feedback and the quality control of the received material.

As mentioned under chapter 2.1 this method has as a prerequisite that a fairly large and representative number of project cases are submitted to the total database to be able to draw tentative conclusions from the material. Representativity at the global level should therefore include project cases from various climatic, geographical, economical and social settings. As the participating countries are all industrialised, predominantly temperate and "modern" democracies, project cases from only these countries would not fulfil any requirement of global representativity.

Operating Agents and Subtask Leaders within IEA recommended that some non-participating countries were asked to answer the questionnaire. To try to achieve a better global coverage of project cases, each participating country has made an effort to contact other interested parties, institutions and countries, especially in the tropics. Hoping that some recent hydropower projects in other parts of the world could be submitted to the database, the questionnaire was distributed to a selected number of non-participating countries and institutions. However, in such a fairly short time, and bearing in mind that the filling in of the questionnaire is a quite time-consuming undertaking, it was unrealistic to expect that the database would be loaded with an adequate number of high quality project cases from most parts of the world so as to make it possible to give statistically significant conclusions and recommendations based on an analysis of the total material. Still, in just a couple of years' time after the electronic version of the questionnaire was completed, the database has been loaded with some relevant project cases from East Asia and Africa, and more project cases are still expected from other countries and regions, including South America.

It remains to be decided whether the database will be developed further after the lifespan of the present Annex III undertaking. If it will, and if there will eventually be a fair coverage of various hydropower projects submitted to the database, it will be possible to test if this approach might serve as a better and more objective international tool for hydropower decision-makers and other stakeholders than what the present situation represents. At the present level, however, where there are less than 30 project cases loaded into the database, and the large majority of these represents projects in northern temperate and industrialised countries, the information might best be used to serve as an illustration of how the method can be used, and also as examples of good (or bad) practice regarding regulatory regimes, impact assessments, mitigation measures and stakeholder involvement in the process.

Both the filled-in paper questionnaires and the filled-in electronic questionnaires have been sent to the Operating Agent of Annex III, the Norwegian Water Resources and Energy Directorate (NVE). The paper versions were systematised and converted into the electronic form in NVE to be able to analyse the material in appropriate database software. The database programme selected has been Microsoft's "Access 97".

Originally, the subtask dealing with the development of the questionnaire had the ambition to combine the questionnaire/database approach with other available and published sum-up studies on various hydropower related subjects, and include these studies fully in the report's discussion. However, as the subtask also took over the responsibility of developing the questionnaire in an electronic form, and as the subtasks dealing with general guidelines for future action (ST III/5) and specifically on mitigation measures (ST III/6) both have put substantial efforts in presenting results and experience from such studies, it was decided to avoid overlapping their work. Instead, Subtask III/1 concentrated on making the electronic questionnaire and the database fully operative, and on presenting this approach as a method and potentially an attractive tool for future decision-making in hydropower development.

2.2.5 Quality control of the data

Data collected and entered into the questionnaire (paper version or electronic version) have been the responsibility of the different countries. The quality control of the data returned to the database has been the responsibility of each country's National Representative or, for the non-participating countries that do not have a National Representative, the person who has signed as superior of the project.

Misunderstandings and contradictions discovered by the Subtask III/1 Leader during the process of making comparisons between different projects were discussed and settled by direct communication with the people responsible for the filling in of the questionnaire.

Even if a major advantage of this method is objectivity, factual and quality-controlled data, there will always be some elements of judgement and interpretation of the data. It would have been an interesting exercise to let different groups of stakeholders with different interests (e.g. a utility and an NGO), answer the same questionnaire for the same project, and then compare the outcome. Ideally, the answered questionnaires should basically look similar, as long as the actual project had been studied, planned, implemented and evaluated in a transparent and democratic way.

However, even this approach to such a complex issue can not overcome the intrinsic problem of the variable quality of basic data and various types of value judgements. Basic data may not be fully coherent, and different reports on e.g. the planning process, or implementation phase, or the economical performance, or the environmental impact assessment, or the mitigation measures on the same project, may deviate from each other, or may even be contradictory to each other. The problem is related to the various points of view that are attached to the whole issue of hydropower development, based on people's perceptions of development, ethics, relative importance attached to different aspects of the issue, etc. This will easily result in a wide range of opinions regarding the degree of success each project is perceived to have. What are considered to be the most important issues in a particular project by one group may be regarded as of minor interest to other parties in hydropower development, and vice versa.

Nevertheless, major strengths of this approach are that there is a responsible person identified and attached to the project evaluation, the projects are evaluated in the same systematic and standardised way, and the judgements given should be based on firm and published/written knowledge of the project with actual references given. In this way purely subjective evaluations of only selected aspects of the projects as a basis for decision-making are avoided to the largest possible degree.

3. SURVEY ON ENVIRONMENTAL IMPACTS OF HYDROPOWER AND MITIGATION MEASURES - RESULTS

This chapter is giving a brief description of the projects in the current database, with some information on the data frequency of important parameters. The database information here includes a total of 28 project cases, of which eight are from Norway, five from Finland, four from Japan, three from Canada, three from Spain, two from the Province of Taiwan, and one each from Italy, Malaysia and Tanzania. Information on these 28 projects is given in Table 1.

The current project cases entered into the database include a few projects from before any modern EIA legislation was in place (like the **Mis Dam-Sospirolo** in Italy which started operation already in 1963), via some early examples of hydropower projects with EIA studies (like the **Great Ruaha** Project in Tanzania were planning started in 1969), to the majority of cases developed under a regime with various EIA legislation in place (like the **Shin-Takanosu** Project in Japan that is projected to be operative in 2001).
In the "pre-EIA" **Mis Dam-Sospirolo** Project in Italy, with planning undertaken in the 1950s, the information on the project was typically covering only technical solutions distributed by the proponent, local people had no influence during the planning, construction and operation phase, and there were no particular interest in environmental matters from the proponent's side. For a long period after construction there was no flow downstream the dam.

3.1 Sources of environmental and social impacts

A source of environmental or social impact is a human intervention that directly or indirectly affects the environment or the social structure of an area.

3.1.1 Construction activities

A list of the main construction activities related to hydropower development is given in the questionnaire (see Appendix 2). The questionnaire is constructed in such a way as to link the various construction activities both to locations and to environmental component types (see below).

The main sources of impacts generated by the construction activities in a project are components like dam constructions, embankments, power plants, and various spin-offs during the operating phase (like new industry, changes in local economy, etc.). Transmission lines are not considered here, as such equipment is not specific to hydropower generation.

The questionnaire has defined five kinds of locations in relation to the watershed (for detailed definitions of these locations, see Appendix 1):
1. Construction disturbance area (the entire project area were direct construction activities are taking place)
2. Downstream area (regulated river basins)
3. Other broad areas (areas outside the construction area, the downstream area or the reservoir where impacts may occur during or after construction)
4. Other specific areas in the catchment (areas within the catchment, but outside the directly affected parts of the catchment where impacts may occur during or after construction)

5. Reservoir area (areas converted from land, wetland or watercourses to an impoundment for storage of water).

Furthermore, the questionnaire lists 11 ”environmental component types” in addition to entries for ”others” and ”unspecified” (see Appendix 5 for details).

1. Construction disturbance area:
The main activities (see list of activities in Appendix 2) reported in the questionnaires with respect to this location are activities having an effect on the following environmental component types (see also Appendix 6):
Economy, Aquatic biology, Terrestrial biology, Landscape, Water quality, Social issues, Hydrology, Local climate, and Global effects (greenhouse gases).

2. Downstream Area:
The main activities (see list of activities in Appendix 2) reported in the questionnaires with respect to this location are activities having an effect on the following environmental component types:
Water quality, Economy, Aquatic biology, Hydrology, Terrestrial biology, Local climate, Landscape, Estuarine and coastal habitat, Social issues, Geophysics, and Other.

3. Other broad areas:
The main activities (see list of activities in Appendix 2) reported in the questionnaires with respect to this location are activities having an effect on the following environmental component types:
Economy, Water quality, Terrestrial biology, Aquatic biology, Landscape, Local climate, Social issues, Geophysics, and Hydrology.

4. Other specific areas in the catchment:
The main activities (see list of activities in Appendix 2) reported in the questionnaires with respect to this location are activities having an effect on the following environmental component types:
Aquatic biology, Economy, Terrestrial biology, and Social issues.

5. Reservoir area:
The main activities (see list of activities in Appendix 2) reported in the questionnaires with respect to this location are activities having an effect on the following environmental component types:
Water quality, Aquatic biology, Economy, Hydrology, Landscape, Terrestrial biology, Social issues, Local climate, Geophysics, and Global effects (greenhouse gases).

le 1. A brief description of the projects described in the questionnaires

roject reservoir ames)	Country	Responsible company for filling in question-naire	Biomes						Power plant data									Dam size		Reservoir
			Moun-tain	Sub-arctic	Peat-land/wet-land	Sava-nnah/grass-land	Tem-perate forest	Rain forest	New project or upgra-ding	In opera-tion (year)	Gross head (m)	Instal-led capa-city (MW)	Maxi-mum opera-tion flow (m3/s)	Mean annual energy output (GWh)	Utilisa-tion factor (%)	Regu-lation factor (%)	Has reser-voir	Dam height (m)	Dam length (m)	High-est water level (km2)
anzal	Spain	IBERDROLA S.A.					x		N	1995	36.4	23.0	63.0	64.0	30.0	100.0	Yes(1)	42.5	481.4	3.65
nd I	Norway	NVE	x				x		N	1973	850.0	675.0	92.2	1 955.8	-	90.7	Yes(1)	10.0	23.0	-
nd II H	Norway	NVE	x		x		x		N	1983	500.0	70.0	16.1	204.3	-	108.4	Yes(4)			
rtavatn																		-	-	2.64
lre Millom-/Adams-/Langvatn																		26.0	290.0	-
avatn																		36.0	262.0	-
e Varge-																		18.5	281.0	4.98
nd II L	Norway	NVE	x				x		N	1982	109.0	60.0	62.0	171.0	-	70.0	Yes(2)			
tredals																		-	-	2.19
lebotnvatn																		40.0	128.0	0.76
nd III	Norway	NVE	x				x		N	1979	400.0	270.0	78.0	129.0	-	310.0	Yes(1)	84.0	654.0	16.74
ng Ai	Malaysia	Sarawak Electricity Supply Corp.				x		x	N	1985	75.7	108.0	160.0	300.0	31.0	-	Yes(1)	85.0	649.0	90
t Ruaha, atu	Tanzania	Tanesco Ltd.			x	x			N	1975	175.0	204.0	140.0	1 009.0	-	100.0	Yes(1)	40.0	350.0	9.5
ra		.			x	x			N	1988	105.0	80.0	96.0	303.0	-	100.0	Yes(1)	45.0	260.0	660
lerfossen	Norway	NVE	x		x		x		U	1963	46.4	112.0	320.0	565.0	26.5	-	No			
osniva	Finland	Kemijoki OY		x					N	1990	12.0	25.0	260.0	81.0	37.0	46.0	Yes(1)	-	-	18.0
aska	Finland	Kemijoki OY		x					N	1992	12.5	27.0	260.0	85.0	36.0	48.0	Yes(1)	-	-	6.5
tani	Japan	Electric Power Development Co. Ltd.					x		N	1994	200.7	19.6	12.0	71.6	41.7	-	Yes(3)			
otani																		11.6	52.2	
uzawa																		11.0	39.8	52.5
yuzawa																		12.0	50.0	
rande 2 A	Québec, Canada	Hydro Québec		x					U	1991	175.3	1 998.0	1 620.0	1 700.0	57.0	57.0	Yes(1)	162.0	2 836.0	2 838
emolina -	Spain	ENDESA	x				x		N	1991	85.7	85.0	106.0	140.0	18.8	98.1	Yes(1)	101.0	337.0	22.3
a	Finland	Kemijoki OY		x					N	1967	13.0	0.2	2.0	1.0	80.0	100.0	Yes(1)	18.0	-	417

ble 1. Continued)

roject reservoir ames)	Country	Responsible company for filling in question-naire	Biomes						Power plant data									Dam size		Reservoir	
			Moun-tain	Sub-arctic	Peat-land/ wet-land	Sava-nnah/ grass-land	Tem-perate forest	Rain forest	New project or upgra-ding	In opera-tion (year)	Gross head (m)	Instal-led capa-city (MW)	Maxi-mum opera-tion flow (m3/s)	Mean annual energy output (GWh)	Utilisa-tion factor (%)	Regu-lation factor (%)	Has reser-voir	Dam height (m)	Dam length (m)	High-est water level (km2)	I v I (
ı 1	Taiwan province	Taiwan Power Co.	x						N	1998	106.8	133.5	144.5	410.2	35.1	-	Yes(1)	41.0	239.5	0.18	
ın 2											173.0	90.0	68.0	411.0	52.1	-	No				
ın 3											176.0	105.5	70.0	79.0	8.5	-	No				
tan pum- storage, i	Taiwan province	Taiwan Power Co.	x						N	1992	39.5	12.9	37.2	41.2	36.5	-	Yes(1)	61.5	314.0	-	
tan pum- storage, tan	Taiwan province	Taiwan Power Co.	x						N	1992	380.0	1 600.0	492.0	1 520.0	10.8	-	Yes(2)				
ıishih																		30.3	363.6	8.4	
shih																		19.1	-	-	
Dam - irolo	Italy	ENEL	x						N	1963	77.0	16.0	52.0	130.0	-	-	Yes(1)	91.0	160.0	1.33	
nino	Japan	Chubu Electric Power Co.					x		N	1994	522.0	1 500.0	375.0	-	-	-	Yes(2)				
ıre																		-	-	0.39	
niosu																		98.0	294.5	0.53	
äskoski	Finland	Kemijoki OY		x					U	1996	20.5	135.0	800.0	657.0	-	-	Yes(1)	-	-	26.7	
pahta	Finland	Kemijoki OY		x					N	1981	30.0	35.0	140.0	102.0	33.0	100.0	Yes(1)	38.0	-	214.0	
a	Norway	NVE	x				x		N	1983	395.0	9.0	2.6	23.9	9.5	64.8	Yes(2)				
pvatn																		21.2	82.0	0.11	
klevatn																		10.0	210.0	0.83	
re des e	Québec, Canada	Hydro Québec		x					U	1985	8.0	45.0	784.0	276.0	69.9	-	No				
ert- assa	Québec, Canada	Hydro Québec		x					N	1979	175.2	5 328.0	4 300.0	35 800	80.0	80.0	Yes(1)	162.0	2 836.0	2 838	
-Takanosu	Japan	Tohoku Electric Power Co.					x		U	2001	12.5	15.7	150.0	6 603.0	48.0	0.0	Yes(1)	28.0	177.0	0.35	
dalselva a)	Norway	DN	x		x		x		N	1995	-	140.0	70.0	590.0	-	-	Yes(4)				
rdalssjøen																		-	-	6.00	
gen																		-	-	16.50	
la																		-	-	0.65	
sjøen																		-	-	5.50	

ble 1. Continued)

roject reservoir ames)	Country	Responsible company for filling in question-naire	Biomes						Power plant data									Dam size		Reservoi	
			Moun-tain	Sub-arctic	Peat-land/ wet-land	Sava-nnah/ grass-land	Tem-perate forest	Rain forest	New project or upgra-ding	In opera-tion (year)	Gross head (m)	Instal-led capa-city (MW)	Maxi-mum opera-tion flow (m3/s)	Mean annual energy output (GWh)	Utilisa-tion factor (%)	Regu-lation factor (%)	Has reser-voir	Dam height (m)	Dam length (m)	High-est water level (km2)	I w l (
mi, unai	Japan	Hokkaido Electric Power Co.					x		U	1966/ 1979	46.9	46.0	120.0	84.0	20.8	99.6	Yes(1)	66.0	207.5	1.40	
mi, mi	Japan	Hokkaido Electric Power Co.					x		N	1983/ 1993	112.5	200.0	230.0	244.0	13.9	100.0	Yes(1)	120.0	435.0	6.75	
mi, kawa	Japan	Hokkaido Electric Power Co.					x		N	1979	13.5	7.3	73.0	23.0	36.0	100.0	Yes(1)	30.5	110.0	0.24	
araiso	Spain	IBERDROLA S.A.					x		N	1988	48.0	68.0	160.0	74.5	10.0	100.0	Yes(1)	67.0	540.0	12.23	
jen	Norway	NVE	x				x		U	1980	55.0	35.0	79.0	134.0	-	75.7	No				

3.1.2 Establishment of reservoirs

The main parameters deciding the impacts related to the establishment of a reservoir are the reservoir level, the size and depth of the reservoir, the water-level fluctuations (especially the drawdown zone, the hydrological management regime, and optimum compensation flows, including what is commonly referred to as minimum flows), water turnover time, etc. These parameters will vary greatly in significance related to the climatic and geographical zone in which the reservoir is established. For example will erosion, sedimentation and siltation usually be very important aspects in many tropical areas, while these aspects may often be of less interest to a northern temperate montane project.

Social issues may become very important when large reservoirs are established in densely populated areas where the land areas to be flooded have been extensively used for agriculture, grazing, or human settlements with various infrastructures, or where the areas have other cultural, scientific, aesthetic or emotional values attached to them. In addition to the lost infrastructure and cultural values, this will often involve involuntary resettlement and disruptions of social networks. Another common effect often encountered in a tropical environment is the improved conditions a reservoir creates for a number of waterborne diseases, like malaria, schistosomiasis and Japanese B encephalitis.

On the other hand, a reservoir might also create new habitats for different kinds of game and fish, recreational potential for fishing, tourism and so on. Other potential positive spin-offs, in addition to the extra supplies of electricity, are related to the possible combination of hydropower development with irrigation schemes, water supply, improved navigational possibilities and flood control.

Impounding of reservoirs usually results in a reduction in the downstream water flow for a few months and in some cases up to several years depending on the hydrology and the size of the reservoir. The increase in water level after impounding is usually one of the greatest impacts of a hydropower project as it involves flooding of land and a total change of the ecosystem. This will mainly affect the aquatic life in general, and migrating fish in particular, but also the terrestrial life in the surrounding land areas to be impounded and the ecotone between the terrestrial areas and the running river.

3.1.3 Hydraulic management

Hydraulic management modifies the flow pattern downstream and could be very important for the local ecosystem as well as for the local perceptions of the project. Hydraulic management related to minimum flows, optimum compensation flows, daily fluctuations and periods of flooding are usually the most important.

Usually the hydraulic management will have a profound impact on the ecological characteristics of fauna and flora in the reservoir area as well as downstream, particularly in the reservoir and along the riverbanks. Other human activities can also be directly affected by changes in the downstream water regime, like reductions in the water flow of waterfalls and rapids, security risks for riparian owners and users, restrictions in traditional activities for the local population, limited access to water, etc. Furthermore, the change in hydrology and in sedimentation will often have a profound impact on the rich estuary ecosystems where fresh water meets the sea, including impacts on areas with fish spawning, sea fisheries, fish, clam and shrimp farming, and agriculture on estuarine flood plains.

3.2 Impacts

3.2.1 Description of the main groups of impacts reported in the questionnaires

In connection to the questionnaire a list of keywords regarding important environmental impacts was made (see Appendix 3). This was set up as a tentative list, and could be expanded or changed if necessary. There have been some difficulties in sorting certain impacts into the proposed categories of the list, suggesting that this impact list might be modified in possible future versions of the questionnaire. However, at the present stage the impacts stated in the case studies are sorted into the categories of this impact list. A potential problem here is that impact terms used in the ST III/5 report (Hydropower and the Environment: Present Context and Guidelines for Future Action) may not be completely congruent with the terms used in this context. Anyway, as far as possible, the present report tries to follow the terms used in the ST III/5 report.

An important lesson to be learnt in hydropower development is that the public acceptance for hydropower projects may not only be related to actual environmental or social impacts of the project, but very much also related to the actual **process** of the project's planning and implementation phases. The database includes a part (Part 5) asking for the regulatory approval process of each project. However, as the whole issue of surveying existing guidelines, legislative framework and standard procedures for EIA of hydropower projects has been the main topic for a separate subtask (ST III/4) within this annex work, this issue will not be discussed in any detail in this report.

A few examples of different practices regarding how the main environmental and social issues have been identified, might still be illustrative:

- In the **Agavanzal** and the **Valparaiso** Projects in Spain, the **Kurotani** Project in Japan and the **Mingtan** Project in Taiwan province only the regulatory authorities were consulted in identifying environmental issues
- In the **Aurland I** Project in Norway both the investors, the public, the regulatory authorities and NGOs were consulted
- In the **Batang Ai** Project in Malaysia the bank, the investors and the regulatory authorities were consulted, not the local people or the public in general
- In the **Great Ruaha** Project in Tanzania there were no regulatory approval process developed in the country, and guidelines and requirements were based on the systems used by the investors (donors) and project consultants

3.2.1.1 Physical impacts (see also Appendix 11: "Environmental component type and count of environmental components in each impact group")

The main physical impacts reported in the questionnaires are:

<u>Biotoxicity</u> - connected to: Mercury

Change in biota habitat - connected to: Air humidity, Air temperature, Wind, Earthquakes, Water temperature, and Landslides

Change in water quality - connected to: Eutrophication, Change in water temperature, Changed transport of particles, Changed turbidity or suspended solids, Heavy metals, Drainage from construction work, Change in oxygen content, and Floating peat

Change in water quantity - connected to: Changed flow regime, Change in flooding frequency, Groundwater level, Sedimentation and siltation, Erosion, Evapotranspiration, Recipient, and Fluvial geomorphology

Climatic and local air quality changes - connected to: Change in local air temperature, Greenhouse gas emissions, and Change in local water temperature

Increased erosion - connected to: Erosion and Fluvial geomorphology

Physical impacts - connected to: Earthquakes and Noise and vibration

Sedimentation - connected to: Hydrology/sedimentation

3.2.1.2 Biological impacts (see also Appendix 11: "Environmental component type and count of environmental components in each impact group")

The main biological impacts reported in the questionnaires are:
Change in biota habitat - connected to: Fish communities, Terrestrial fauna (mammals), Terrestrial flora, Aquatic fauna, Aquatic flora, Terrestrial fauna (birds), Fish migration, Terrestrial fauna (insects), Red-listed species (terrestrial), and Red-listed species (aquatic)

Change in ecosystem community populations - connected to: Fish communities, Fish migration, Aquatic fauna, Aquatic flora, Mercury (in fish), Terrestrial flora, Terrestrial fauna (mammals), Red-listed species (aquatic), Red-listed species (terrestrial), Terrestrial fauna (birds), and Terrestrial fauna (insects)

Change in resource use - connected to: Fish communities, Fish migration, Terrestrial fauna (birds), Coastal habitats, and Mercury (in fish)

Change in water quality - connected to: Fish communities and salt intrusion

Change in water quantity - connected to: Salt intrusion, Water circulation, Aquatic fauna, and Fish communities

Noise and human presence effects on biota - connected to: Terrestrial fauna (birds)

Removal of vegetation - connected to: Terrestrial fauna (mammals) and Terrestrial flora

3.2.1.3 Socio-economic impacts (see also Appendix 11: "Environmental component type and count of environmental components in each impact group")

The main socio-economic impacts reported in the questionnaires are:
Change in biota habitat - connected to: Landscape appreciation, Access roads, Rock tips, Recreational areas, Places of religious/historical value, Noise and vibration, Forestry, Fisheries (fish stocking), and Quarries

Change in community and social services - connected to: Commercial activities, Social intrusion (community structure and social networks), Resettlement, Tourism employment, Industry, and Water supply

Change in ecosystem community populations - connected to: Fisheries (fish stocking), Landscape appreciation, and Reindeer husbandry

Change in housing and property values - connected to: Erosion

Change in human safety risk - connected to: Indigenous people

Change in land use and policy plans - connected to: Indigenous people and Agriculture

Change in local economy - connected to: Fisheries (others), Fisheries (fish stocking), Agriculture, Tourism employment, Transportation, Forestry, Water supply, Recreational areas, Schools, Hospitals, Commercial activities, Reindeer husbandry, Industry, Population, and Rock tips

Changes in resource use - connected to: Recreational areas, Social intrusion, Agriculture, Forestry, Fisheries (fish stocking), and Tourism employment

Change in social and community structure - connected to: Indigenous people, Resettlement, Social intrusion, Places of religious/historical value, Waterborne diseases, Commercial activities, and Noise and vibration

Change in transportation and servicing - connected to: Access roads, Indigenous people, and Transportation

Change in water quality - connected to: Agriculture

Change in water quantity - connected to: Resettlement

Increased erosion - connected to: Landscape appreciation

Noise and human presence effects on biota - connected to: Noise and vibration

Physical impacts - connected to: Noise and vibration

Removal of vegetation - connected to: Landscape appreciation, Terrestrial fauna (mammals), and Terrestrial flora

Soil inundation - connected to: Fisheries

3.2.2 Activities commonly connected to the different impact groups

From Table 2 below it can be seen that ”Altering long-term river flow” is the main activity group for the answers given in the questionnaire. Most of the impact is concentrated to the groups ”Change in biota habitat”, ”Change in water quality”, ”Change in local economy”, ”Change in ecosystem community populations”, ”Change in water quantity” and ”Climatic and local air quality changes”. Other important activity groups are: ”Altering river flow route (diversion)”, ”Altering short-term river flow”, ”Dewatering and draining” ”Environmental inventory and sampling”, ”Impounding (reservoir filling)”, ”Operating at maximum power” and ”Operating at peak efficiency”.

3.2.3 Expected and documented effects

The material entered into the database can also be used to check whether there are significant differences between the expected and the documented environmental effects of hydropower development. Appendix 12 gives an overview of the impacts and counts of expected and documented effects taken from the database. Table 3 summarises the information given in Appendix 12, showing the number of impacts within each impact group and the expected and documented effect as entered in the questionnaires.

Appendix 13 lists the documented permanent effect of impacts linked to actual mitigation measures. From this appendix it can be read that for many mitigation measures addressing particular expected impacts, the permanent effect is rather indifferent, while other mitigation measures are documented to be very positive or very negative.

However, the database material is too meagre to allow for firm conclusions to be drawn, or even for important trends to be detected. Again, as the main aim of this report is to illustrate how this database method can be applied, a larger material would allow for certain trends to be detected regarding which mitigation measures are usually experienced or documented to be positive, which are indifferent, and which are even negative. This issue is discussed further in chapter 3.3 (see also Table 6).

Table 2. Activities commonly connected to the different impact groups (see also Appendix 6)

Activity	Impact	Count of impacts in each activity
Aggregate extraction	Change in biota habitat	3
Aggregate extraction	Removal of vegetation	5
Altering long-term river flow	Change in biota habitat	471
Altering long-term river flow	Change in community and social services	24
Altering long-term river flow	Change in ecosystem community populations	157
Altering long-term river flow	Change in human safety risk	1
Altering long-term river flow	Change in local economy	178
Altering long-term river flow	Change in resource use – aquatic biota	14
Altering long-term river flow	Change in resource use – forestry, mining, agriculture	16
Altering long-term river flow	Change in resource use – recreational areas etc.	23
Altering long-term river flow	Change in resource use – terrestrial biota	5
Altering long-term river flow	Change in social and community structure	51
Altering long-term river flow	Change in transportation and servicing	3
Altering long-term river flow	Change in water quality	261
Altering long-term river flow	Change in water quantity	130
Altering long-term river flow	Change in resource use – water	2
Altering long-term river flow	Climatic and local air quality changes	58
Altering long-term river flow	Cumulative effects of hydro and other facilities	1
Altering long-term river flow	Increased erosion	6
Altering long-term river flow	Noise and human presence effects on biota	6
Altering long-term river flow	Physical impacts	4
Altering long-term river flow	Removal of vegetation	4
Altering long-term river flow	Sedimentation	5
Altering river flow route (diversion)	Change in biota habitat	1
Altering river flow route (diversion)	Change in biota mobility	1
Altering river flow route (diversion)	Change in material translocation	1
Altering river flow route (diversion)	Change in resource use – aquatic biota	1
Altering river flow route (diversion)	Change in water quantity	4
Altering river flow route (diversion)	Change in resource use – water	2
Altering short-term river flow	Change in water quality	2
Altering short-term river flow	Change in water quantity	5
Blasting and drilling	Change in biota habitat	2
Blasting and drilling	Noise and human presence effects on biota	6
Chemical spilling	Biotoxicity	1
Constructing onshore installations	Change in biota habitat	2
Constructing onshore installations	Change in local economy	1
Constructing onshore installations	Increased erosion	1
Dewatering and draining	Change in land use and policy plans	3
Dewatering and draining	Change in water quality	10
Environmental inventory and sampling	Change in biota habitat	3
Environmental inventory and sampling	Change in ecosystem community populations	7
Environmental inventory and sampling	Change in land use and policy plans	3
Environmental inventory and sampling	Change in water quality	1
Environmental inventory and sampling	Human health effects of toxins	1

(Table 2. Continued)

Activity	Impact	Count of impacts in each activity
Environmental inventory and sampling	Soil inundation	3
Excavating and fill placement in water	Change in resource use – water	1
Excavating and filling on land	Change in local economy	2
Excavating and filling on land	Removal of vegetation	1
Impounding (reservoir filling)	Biotoxicity	3
Impounding (reservoir filling)	Change in biota habitat	1
Impounding (reservoir filling)	Change in human safety risk	1
Impounding (reservoir filling)	Change in resource use – aquatic biota	1
Impounding (reservoir filling)	Change in water quality	29
Impounding (reservoir filling)	Change in water quantity	4
Impounding (reservoir filling)	Change in resource use – water	1
Information delivery (reporting, meetings, hearings, consultation)	Change in biota habitat	3
Information delivery (reporting, meetings, hearings, consultation)	Change in community and social services	1
Installing and maintaining work camps, laydown areas, parking lots	Change in community and social services	3
Installing and maintaining work camps, laydown areas, parking lots	Change in land use and policy plans	1
Operating at maximum power	Change in biota habitat	6
Operating at maximum power	Change in housing and property values	5
Operating at maximum power	Change in resource use – recreational areas etc.	1
Operating at maximum power	Change in water quality	4
Operating at maximum power	Change in water quantity	1
Operating at maximum power	Increased erosion	1
Operating at peak efficiency	Biotoxicity	2
Operating at peak efficiency	Change in community and social services	2
Operating at peak efficiency	Change in material translocation	1
Operating at peak efficiency	Change in resource use – aquatic biota	4
Operating at peak efficiency	Change in resource use – terrestrial biota	1
Operating at peak efficiency	Change in transportation and servicing	2
Operating at peak efficiency	Change in water quantity	7
Operating at peak efficiency	Change in resource use – water	1
Operating at peak efficiency	Increased erosion	2
Project and maintenance spending	Change in local economy	1
Road maintenance	Change in transportation and servicing	1
Site rehabilitation	Change in channel morphology	5
Site rehabilitation	Removal of vegetation	2
Using local services and amenities	Change in community and social services	1
Using local services and amenities	Change in land use and policy plans	3
Using local services and amenities	Change in social and community structure	2
Vegetation disposal	Change in human safety risk	4
Vehicle movement	Change in transportation and servicing	1
Worker leisure activities	Change in resource use – recreational areas etc.	1

Table 3. Impact groups linked to counts of expected and documented permanent effects (see also Appendices 12 and 13)

Impact group	Count of expected permanent effects	Count of documented permanent effects
Biotoxicity	6	6
Change in biota habitat	179	119
Change in biota mobility	1	1
Change in channel morphology	3	3
Change in community and social services	16	20
Change in ecosystem community populations	114	106
Change in human safety risk	5	5
Change in land use and policy plans	8	8
Change in local economy	77	64
Change in materials translocation	1	1
Change in resource use – aquatic biota	13	14
Change in resource use – forestry, mining, agriculture	5	5
Change in resource use – recreational areas etc.	11	7
Change in resource use – terrestrial biota	1	1
Change in social and community structure	23	23
Change in transportation and servicing	6	6
Change in water quality	161	147
Change in water quantity	62	54
Change in resource use – water	2	2
Climatic and local air quality change	14	18
Increased erosion	6	6
Noise and human presence effects on biota	5	5
Physical impacts	3	2
Removal of vegetation	9	9
Sedimentation	2	2
Soil inundation	3	3

3.2.4 The main environmental impacts after implementation

As could be read from Table 4 reported impacts after implementation are concentrated in 15 main impact groups with very good correspondence to the groups mentioned in chapter 3.2.2 ”Activities commonly connected to different impact groups”.

3.3 Mitigation measures

Mitigation measures is the main topic for a separate task within this IEA undertaking of Hydropower and the Environment, the Subtask III/6; ”Survey of Positive and Negative Environmental and Social Impacts and the Effect of Mitigation Measures in Hydropower Development”. That subtask tries to combine information gathered through this questionnaire approach with various other information sources, including sum-up studies and other relevant reports and publications. To avoid gross overlaps to that subtask, this chapter will concentrate on documenting the questionnaire approach to the issue of mitigation and compensation measures, as well as giving a few examples on how this method may be applied as a tool for decision-makers.

The percentage of the total project costs spent on mitigation and compensation measures will naturally vary according to the nature of each particular project. In e.g. the **La Remolina-Riano** Project in Spain, the cost of relocating 900 people was much higher than the cost of constructing the dam. In the **Valparaiso** Project in Spain, the economic compensation for purchase of land and 45 houses to resettle 150 people amounted to some 10.7 % of the total project cost. Some other examples from the database might indicate this variation further:

	Cost of mitigation measures in percentage of total project costs
Valparaiso, Spain (see comment over)	**0.9**
Agavanzal, Spain	**2.3**
Takami, Japan	**4.8**
La Grande 2A, Québec, Canada	**6.0**

3.3.1 Description of the main groups of mitigation measures marked in the questionnaires

Hydroelectric development involves major modifications of the environment. However, some of these modifications are reversible. The negative effects can be minimised with well-adapted projects and suitable site selections and could make hydroelectricity more attractive as compared to other means of electricity production.

Some types of hydropower structures are more suitable for a given environment than others, and it is therefore important that environmental considerations are incorporated from the very start of the planning phase. Today, certain mitigation measures are known to be effective in reducing various impacts on the environment and on social issues. There are also various ways of compensating for impacts that are not possible to mitigate, or impacts that can be mitigated only to a limited degree. A list of common mitigation measures linked to hydropower development that was worked out for the questionnaire is given in Appendix 4.

3.3.1.1 Physical impacts – mitigation and compensation measures

Some of the main mitigation and compensation measures related to physical impacts of hydropower development may be summarised as follows:

<u>Climatic conditions</u>:
Parameters like temperature, wind, precipitation, evapotranspiration, humidity, fog and greenhouse gas emissions could have effects on the local climate. Some of the changes in such parameters arising as a result of a hydropower project are often difficult to distinguish from annual climatic fluctuations. However, some of the induced modifications to the local climate may be permanent. For example, in cold climates more freshwater released to the sea during the cold season will result in more ice, and a constantly higher water temperature during the cold season, due to a higher release of water as compared to the natural situation, may have profound impacts on the local aquatic ecosystem, etc. In warmer climates, extensive deforestation as a direct or indirect effect of hydropower development, may result in the local climate to become less humid, also impacting the level of precipitation and e.g. agricultural activities. Generally, the most effective mitigation measures in relation to climatic

change involves a careful evaluation of the relevant parameters before site selection and technical solutions are decided upon.

Table 4. Main environmental impacts after implementation

Impact	Count of impacts
Change in biota habitat	492
Change in water quality	307
Change in local economy	182
Change in ecosystem community populations	164
Change in water quantity	151
Climatic and local air quality changes	58
Change in social and community structure	53
Change in community and social services	31
Change in resource use – recreational areas etc.	25
Change in resource use – aquatic biota	20
Change in resource use – forestry, mining, agriculture	16
Noise and human presence effects on biota	12
Removal of vegetation	12
Change in land use and policy plans	10
Increased erosion	10
Change in transportation and servicing	7
Change in resource use – water	7
Biotoxicity	6
Change in resource use – terrestrial biota	6
Change in human safety risk	6
Change in housing and property values	5
Change in channel morphology	5
Sedimentation	5
Physical impacts	4
Soil inundation	3
Change in material translocation	2
Human health effects of toxins	1
Cumulative effects of hydro and other facilities	1
Change in biota mobility	1

Hydrology:

A major part of the more serious impacts connected to hydropower development, regardless of geographical area or climatic zone, is related to changes in the natural hydrology of the actual watershed and watercourses. Mitigation measures can be implemented to ameliorate negative effects on water quality as well as water quantity. Key words in mitigation measures related to impacts on water quantity include the selection of an appropriate type of regulation, adequate minimum flows (”optimum compensation flows”), reservoir management procedures, etc. Reservoirs often have a thermal stratification, which to some extent could be reduced by the placing of intakes. Regarding water quality, main mitigation efforts might include design measures for keeping contaminants away from watercourses, aeration, provisions of weirs or rapids, flushing programmes, reservoir intake position and depth, removal of vegetation and soils in impounded areas, implementation of an effective sewage treatment to avoid eutrophication and aggressive aquatic plant growth, etc. In some cases, special attention must be given to the impacts a changed hydrological cycle might have on the ecology of the rivers' estuaries.

<u>Sedimentation</u>:
Dams will usually retain sediments, resulting in various problems like dam siltation, increased downstream erosion, and profound changes in the physical, chemical and biological characteristics of the estuary. This might indirectly affect groundwater levels and the whole biotic environment of the watershed, with subsequent effects on agriculture and fisheries. Common mitigation measures include flood management programmes, sand traps and silt fences, flushing programmes, upstream reservoirs and cofferdams, intake design to enable sediment bypass, controlled dredging, physical bank stabilisation, revegetation of erosive slopes, watershed land use programmes to prevent reservoir sedimentation, etc.

The main mitigation measures on physical matters reported in the questionnaires are related to the following impacts:
<u>Biotoxicity</u> - connected to: Mercury

<u>Change in water quality</u> - connected to: Changed turbidity or suspended solids, Drainage from construction work, Change in water temperature, Eutrophication, Changed transport of elements and matter, Heavy metals, and Change in oxygen content

<u>Change in water quantity</u> - connected to: Changed flow regime, Change in flooding frequency, Erosion, and Sedimentation and siltation

<u>Increased erosion</u> - connected to: Erosion and Fluvial geomorphology

<u>Sedimentation</u> - connected to: Hydrology/sedimentation

<u>Physical impacts</u> - connected to: Earthquakes and Noise and vibration

3.3.1.2 Biological impacts - mitigation and compensation measures

With respect to hydroelectric power projects, the main potential sources of impacts on biological parameters are considered to be:

- Loss or creation of terrestrial and aquatic habitats
- Modification of water quality
- Regulation of streamflow downstream from dams
- Flood control
- Obstacle of a dam to the migration of fish
- Introduction and dispersal of species

Lots of various mitigation and compensation measures have been developed to ameliorate negative effects on the biotic life. Some important key-words here will include fish ladders and fishways or other by-pass facilities to aid migration, technical designs to minimise aquatic life mortality, minimum flows during critical periods for aquatic life, water level management to mitigate effects of drawdown, protection or re-establishment or improvement of habitats for endangered species, scheduling of work which disturbs wildlife only during non-sensitive time periods, development of forest, wildlife and watershed management and monitoring plans, revegetation programmes, etc.

The main mitigation measures on biological matters reported in the questionnaires are related to the following impacts:
Change in biota habitat - connected to: Fish communities, Terrestrial flora, Terrestrial fauna, Fish migration, Red-listed species (terrestrial), Local climate, Aquatic flora, Aquatic fauna, and Forestry

Change in ecosystem community populations - connected to: Fish communities, Fish migration, Economy (fish stocking), Local climate, Landscape, Aquatic fauna, and Aquatic flora

Changes in resource use - connected to: Fisheries (fish stocking)

Removal of vegetation - connected to: Terrestrial fauna and Terrestrial flora

3.3.1.3 Socio-economic impacts - mitigation and compensation measures

The socio-economic impacts could be addressed under three categories: Land use, economic impacts and social impacts.

Land use:
Changes to land use are generally a consequence of submergence of large areas, permanent modifications to upstream and downstream water levels and water flows, and other types of induced development associated with regulation flows and the creation of large reservoirs. Important mitigation measures here include the establishment of local or regional development plans as well as resource management and monitoring programmes (also to avoid or reduce land use conflicts) emergency preparedness and warning procedures on sudden flow variations, establishment of alternative areas for agriculture and fisheries for local people, clean water supply, irrigation, planning to minimise farm, forest and other resources loss, maximising recovery of valuable resources prior to inundation, etc.

Economic impacts:
Economic impacts may both come as direct effects of induced land use changes, or indirectly by the availability of electricity supply or by altered infrastructure in the area. In a strict economic sense, the area will have no net economic development unless the project's direct and indirect benefits are larger than their direct and indirect costs, including environmental and social benefits and costs. Important mitigation measures within this area include various job opportunities in the construction phase as well as in the operation phase, including indirect spin-offs as a result of changed infrastructure and availability of electricity, establishment of various new job opportunities, relevant training programmes, improvement of municipal infrastructure (medical, social, communication), promotion of tourism, etc.

Social impacts:
The majority of social impacts caused by hydropower projects are often related to forced resettlement, disruption of social infrastructure and networks, and changes in

job opportunities. Of particular concern are the effects on human health, especially in moist tropical areas where waterborne diseases may be significant, as well as the effects on vulnerable ethnic groups, indigenous people or minorities. Impacts on aesthetic, cultural, archaeological or scientific values might also be included here. Important mitigation measures within this area include establishment of local or regional development funds and programmes, careful planning of resettlement in an open, inclusive and transparent way, avoiding a splitting-up of ethnic groups or other vulnerable cultural minorities, establishment of acceptable procedures to solve social problems, monetary compensation or compensations in kind, establishment of health facilities and programmes, control of vectors in waterborne diseases, re-establishment of reserved land or provisions of alternatives, protection or relocation of cultural heritage features, protection of areas with important landscape features, etc.

The main mitigation measures (or compensation measures) on socio-economic matters reported in the questionnaires are related to the following impacts:
Change in biota habitat - connected to: Landscape appreciation, Access roads, Rock tips, Recreational areas, and Noise and vibration

Change in community and social services - connected to: Industry, Commercial activities, Social intrusion (community structure and social networks), and Water supply

Change in local economy - connected to: Fisheries (others), Transportation, Tourism employment, Agriculture, Recreational areas, Reindeer husbandry, Fisheries (fish stocking), Forestry, Hospitals, Rock tips, Schools, and Water supply

Changes in resource use - connected to: Forestry, Recreational areas, and Agriculture

Change in social and community structure - connected to: Resettlement, Indigenous people, and Waterborne diseases

Change in transportation and servicing - connected to: Indigenous people

Increased erosion - connected to: Landscape appreciation

Noise and human presence effects on biota - connected to: Noise and vibration

Removal of vegetation - connected to: Landscape

3.3.2 Activities commonly connected to the different mitigation and compensation measures

The material collected via the questionnaires shows that the majority of mitigation measures are related to activities resulting in an alteration of the long-term river flow (see Table 5 and Appendix 7).

Table 5. Activities commonly connected to mitigation measures (with at least five counts). See also Appendix 7

Activity	Count of mitigation measures	Mitigation measures
Altering long-term river flow	80	Water quality protection and adjustments
Altering long-term river flow	65	Water quantity control (flow, velocity, level; including ice formation and movements)
Altering long-term river flow	64	Economic impact management
Altering long-term river flow	61	Protection, replacement and control of vegetation
Altering long-term river flow	58	Fish protection
Altering long-term river flow	41	Protecting or mitigating changes to landscape
Altering long-term river flow	41	Social impact management
Altering long-term river flow	39	Other
Altering long-term river flow	21	Protection of valued ecosystem components (aquatic and terrestrial habitats, communities, rare, threatened species and spaces, and particular species other than fish)
Altering long-term river flow	10	Erosion prevention and control
Dewatering and draining	10	Water quality protection and adjustments
Impounding (reservoir filling)	10	Water quality protection and adjustments
Altering long-term river flow	7	Sedimentation prevention and control
Operating at peak efficiency	6	Water quantity control (flow, velocity, level; including ice formation and movements)
Operating at maximum	5	Other
Operating at peak efficiency	5	Mitigating effects on resource use

3.3.3 Mitigation measures: General characterisation of success

The material collected in the questionnaires indicates that quite a lot of mitigation and compensation measures have been implemented with a different degree of success, but largely very successful (see Table 6). There might be different explanations as to the domination of “successful mitigation's” in the material. One is that the actual projects in the current database are somewhat biased in the way that mainly positive mitigation measures are given. Another explanation might be that mainly mitigation measures that have proven positive effects have been tried or included. However, in the present material there are also projects where mitigation measures have been considered to have a low degree of success.

Table 6. Number of mitigation measures within each mitigation group with characterisation of success

Mitigation group	Sum of projects	High	Indif-ferent	Low
Water quality protection and adjustments	44	40	1	3
Water quantity control (flow, velocity, level; including ice formation and movements)	43	36	4	3
Fish protection	42	33	4	5
Protection, replacement and control of vegetation	42	35	2	5
Economic impact management	35	26	1	8
Other	33	29		4
Social impact management	31	24	1	6
Protecting or mitigating changes to landscape	17	13		4
Erosion prevention and control	11	8	1	2
Mitigating effects on resource use	11	8		3
Human health and safety risk management	9	7	2	
Sedimentation prevention and control	5	4		1
Climatic and local air quality controls	4		4	
Protecting or mitigating changes to aboriginal land use, cultural heritage, archaeological resources	4	2		2
Protection of valued ecosystem components (aquatic and terrestrial habitats, communities, rare, threatened species and spaces, and particular species other than fish)	3	1		2
Minimising soil contamination and loss of soil due to inundation	2	2		
Mitigating cumulative effects of multiple hydroelectric facilities	2	1		1
Protecting or minimising changes in channel morphology	1	1		

3.4 Quality of the data collected

Referring to the discussion in chapter 2.1 and 2.2.4 all statistical or other information that may be extracted from the database can never be better than the quality of the raw data that originally was entered into the questionnaire. Particularly when it comes to mitigation and compensation efforts, it is essential that firm conclusions and recommendations are based on a broadly representative selection of project types, geographical and climatic regions, and, not least, social settings. Mitigation efforts vary widely from a hydropower project in an uninhabited, montane and temperate area with very limited biotic life as one extreme example, to a hydropower project planned in a densely populated tropical area with very rich biodiversity, human culture and with an extensive land use as the opposite extreme.

Again, the selected method here will only become a valuable tool for planners and decision-makers if the database includes a broad selection of quality-controlled data on impacts and mitigation's from a wide variety of different physical settings, and particularly with data on which types of mitigation and compensation measures that have been shown to be effective under the various circumstances.

4. CHARACTERISTICS OF ENVIRONMENTAL IMPACTS AND EFFICIENCY OF MITIGATION MEASURES

In this chapter an attempt is made to visualise how the selected questionnaire/database approach can be used to serve as a tool for planning and decision-making in hydropower development. Again, it is necessary to stress that the information given here is based on a fairly limited selection of project cases, and of those cases the majority is coming from northern temperate areas.

Quality management systems
Traditionally, the quality management systems related to hydropower development have (if any) been project-specific (like e.g. the **Robert-Bourassa** Project in Québec, Canada) or possibly country-specific. However, there are now international ISO systems in place that are applicable for hydropower development, and e.g. the **Batang Ai** Project in Malaysia (in operation since 1985) followed the ISO 9 000 system, while the **Maan** Project in Taiwan Province (in operation since 1998) followed the ISO 14 000 system.

4.1 Statistical information on the database (see also Table 1)

Received questionnaires: 28 (describing 46 projects)
New projects: 39
Upgrading: 7

Biomes
Subarctic: 8
Mountain: 4
Mountain/Temperate forest: 7
Mountain/Temperate forest/Peatland: 3
Peatland/Savannah: 2
Temperate forest: 8
Rainforest/Savannah: 1

Installed capacity

< 10 MW:	3
10-25 MW:	6
25-50 MW:	5
50-100 MW:	6
100-500 MW:	9
> 500 MW:	5

Reservoirs

With reservoirs:	41
Without reservoirs:	5

Petäjäskoski, Finland
The Petäjäskoski Project in Finland was mainly an upgrading project for a plant constructed in 1953. The official Finnish EIA procedure was not required for such an upgrading project, but anyway a study of environmental impacts was required for the approval process.

4.2 Activities, impacts, main environmental issues and mitigation measures (see also Appendix 8)

Table 7 below presents a synthesis of information taken from the database showing commonly encountered impacts (see Appendix 3) and environmental issues (see Appendix 5) in relation to project activities (see Appendix 2) and relevant mitigation measures (see Appendix 4).

4.3 Main environmental issues and the success of mitigation measures (see Appendices 9 and 10)

With reference to the list of defined mitigation groups in the questionnaire, the Appendices 9 and 10 show that quite a lot of mitigation measures have been done on quite a wide range of environmental issues with different degree of success.

Porttipahta, Finland
In the Finnish approval system the "Water Rights Court" has the power to impose mitigation measures in hydropower projects. In the Porttipahta Project, the Water Rights Court ordered at least the following mitigation and compensation measures to be implemented: - Clearing after the construction activities - Revegetation - Clearing of boat channels - Construction of a bridge suitable for snowmobile traffic - Construction of equipment for floating of timber - Construction of wells - Water quality control - Mercury level control - Construction of embankments - Lengthening of the pasture fence (for reindeer husbandry) - Erosion control - Financial compensations (for lost agricultural land and for reindeer husbandry) - Monitoring of water levels and flows (also for recreational purposes) - Road adjustments

Based on the received questionnaires, it might be concluded that the main environmental groups where mitigation measures have been implemented are:

<u>Aquatic biology</u>: This group is concentrated on aquatic fauna and flora in general and especially on fish community and fish migration. Some risk management programmes for mercury in fish like mercury monitoring and warning on fish consumption limits are also described in the material collected through the questionnaire.

The degree of success (here we have just taken into account numbers of hits >3) shows that the most successful mitigation measures for "Aquatic biology" belong to the mitigation groups "Water quantity control" (flow, velocity etc.), "Fish protection" (fish community and fish migration), "Protection, replacement and control of vegetation", "Human health and safety risk management", and "Mitigating effects on resource use". As may be seen from Appendix 9 the group "Other" is represented with quite a high score. This group includes different types of mitigation, which have been difficult to sort into the defined mitigation groups.

Table 7. Main impacts, environmental issues and mitigation measure groups in relation to hydropower development activity groups

Activity	Main impacts	Main environmental issues	Mitigation measure groups
Aggregate extraction	Change in biota habitat. Removal of vegetation.	Landscape (access roads). Terrestrial biology (fauna, flora).	Erosion prevention and control. Protection, replacement and control of vegetation. Protecting or mitigating changes to landscape. Sedimentation prevention and control.
Altering long-term river flow	Change in biota habitat. Change in community and social services. Change in ecosystem community populations. Change in local economy. Change in resource use – aquatic biota. Change in resource use – forestry, mining etc. Change in resource use – recreational areas etc. Change in social and community structure. Change in water quality. Change in water quantity. Climatic and local air quality changes.	Aquatic biology (fish community, fish migration, fauna, and flora). Economy (agriculture, fisheries, fish stocking, forestry, recreational areas, transportation, tourism employment). Landscape (access roads, landscape appreciation, rock tips). Local climate (water temperature). Sedimentation. Social (noise and vibration, resettlement). Terrestrial biology (fauna, flora, red-listed species). Water quality (drainage from construction work, eutrophication, heavy metals, transport of elements and matter, turbidity or suspended solids, water temperature). Water quantity (flood frequency, flow regime, erosion, groundwater level).	Economic impact management. Erosion prevention and control. Fish protection. Protecting or mitigating changes to landscape. Protection, replacement and control of vegetation. Protection of valued ecosystem components. Sedimentation prevention and control. Social impact management. Water quality protection and adjustment. Water quantity control.
Alter river flow route (diversion)	Change in biota habitat. Change in biota mobility. Change in water quality. Change in water quantity.	Aquatic biology (fish community, fish migration). Economy (forestry, fisheries). Flow regime.	Fish protection. Water quantity control.
Altering short-time river flow	Change in water quantity.	Flow regime.	Water quantity control.
Blasting and drilling	Change in biota habitat. Noise and human presence effects on biota.	Aquatic biology (fish community). Landscape (rock tips). Social (noise and vibration).	Fish protection. Protecting or mitigating changes to landscape.

(Table 7. Continued)

Activity	Main impacts	Main environmental issues	Mitigation measure groups
Chemical spilling	Biotoxicity	Water quality (heavy metals).	Minimising soil contamination and loss of soil due to inundation.
Constructing onshore installations	Change in biota habitat. Change in local economy.	Economy (tourism employment). Landscape (quarries, transmission lines).	Protecting or mitigating changes to landscape. Social impact management.
Dewatering and draining	Change in land use and policy plans. Change in water quality.	Economy (agriculture). Water quality (drainage from construction work).	Economic impact management. Water quality protection and adjustment.
Environmental inventory and sampling	Change in biota habitat. Change in ecosystem community populations. Change in land use and policy plans. Soil inundation.	Aquatic biology (fauna, flora). Economy (fisheries). Local climate (air temperature, fog frequency, water temperature, wind). Social (indigenous people). Water quality (heavy metals).	Climatic and local air quality controls. Human health and safety risk management. Mitigating effects on resource use. Protection, replacement and control of vegetation. Social impact management.
Excavating and filling placement in water	Change in resource use – water.		
Excavating and filling on land	Change in local economy.	Landscape (rock tips).	Protecting or mitigating changes to landscape. Protection, replacement and control of vegetation.
Impounding (reservoir filling)	Biotoxicity. Change in biota habitat. Change in water quality. Change in water quantity.	Aquatic biology (fish community, mercury) Economy (agriculture). Geophysics (earthquakes). Estuarine and coastal habitat (salt intrusion/plume). Water quality (turbidity or suspended solids).	Fish protection. Human health and safety risk management. Economic impact management. Mitigating effects on resource use. Water quality protection and adjustment. Turbidity or suspended solids.
Information delivery (reporting, meetings, hearings, consultation)	Change in biota habitat. Change in community and social services.	Aquatic biology (mercury). Economy (industry). Estuarine and coastal habitat (salt intrusion/plume).	Economic impact management. Human health and safety risk management. Mitigating effects on resource use.

(Table 7. Continued)

Activity	Main impacts	Main environmental issues	Mitigation measure groups
Installing and maintaining work camps, laydown areas, parking lots	Change in community and social services. Change in land use and policy plans.	Economy (commerce, industry).	Economic impact management. Human health and safety risk management. Mitigating cumulative effects on multiple hydroelectric facilities. Social impact management.
Operating at maximum power	Change in housing and property values. Change in land use and policy plans. Change in water quantity.	Hydrology (erosion, flow regime).	Water quantity control.
Operating at peak efficiency	Biotoxicity. Change in community and social services. Change in resource use – aquatic biota. Change in resource use – terrestrial biota. Change in resource use – water. Change in transportation and servicing. Change in water quantity.	Aquatic biology (fish community, fish migration, flora, mercury). Estuarine and coastal habitat (circulation, coastal habitats, salt intrusion/plume, sediment dynamics). Landscape (landscape appreciation). Social (indigenous people, social intrusion). Terrestrial biology (birds).	Erosion prevention and control. Human health and safety risk management. Mitigating effects on resource use. Protection, replacement and control of vegetation. Social impact management. Water quality protection and adjustment. Water quantity control.
Project and maintenance spending	Change in local economy.	Economy (commerce).	Economic impact management.
Road maintenance	Change in transportation and servicing.	Economy (transportation).	Economic impact management.
Site rehabilitation	Change in channel morphology. Removal of vegetation.	Aquatic biology (fish community). Landscape (landscape appreciation). Social (noise and vibration). Terrestrial biology (flora).	Fish protection. Protection, replacement and control of vegetation. Erosion prevention and control.
Using local services and amenities	Change in community and social services. Change in land use and policy plans. Change in social and community structure.	Economy (industry). Social (indigenous people).	Economic impact management. Mitigating effects on resource use. Social impact management.

(Table 7. Continued)

Activity	Main impacts	Main environmental issues	Mitigation measure groups
Vegetation disposal	Change in human safety risk.	Social (indigenous people).	Protecting or mitigating changes to landscape. Human health and safety risk management. Mitigating effects on resource use. Protecting or minimising changes in channel morphology.
Vehicle movement	Change in transportation and servicing.		
Worker leisure activities	Change in resource use – recreational areas etc.		

Economy: Most of the efforts here are apparently concentrated on agriculture, fisheries (fish stocking) and introduction of fish species that could be of commercial use for the local population. Other components of importance are forestry, tourism employment, social and economic management like recreational areas, transportation (e.g. roads) and reindeer husbandry.

For agriculture mitigation measures defined under the groups ”Economic impact management” and ”Water quality protection and adjustments” seem to be quite successful. For fisheries successful mitigations are mainly connected to ”Fish protection” whereas most of the mitigations implemented under the group ”Economic impact management” seem to have had little effect.

As for environmental components like forestry, reindeer husbandry, transportation and water supply mitigation measures seem to be reasonably successful. However, this is not the case for components like recreational areas and tourism employment.

Hydrology: The most important parameters in this category are erosion, flood frequency, flow regime, groundwater level, recipient and sedimentation.

Mitigation measures related to flood frequency, flow regime, groundwater level and sedimentation are apparently successful. However, the results regarding erosion and recipient conditions are more uncertain judged from the answers given in the questionnaires.

Landscape: As could be expected mitigation measures are concentrated to landscape appreciation, especially roads, rock tips and vegetation and mostly under the mitigation groups ”Landscape appreciation”, ”Protecting or mitigating changes to landscape” and ”Protection, replacement and control of vegetation”.

Looking at the Appendices 9 and 10 mitigation measures seem to be fairly successful regarding landscape appreciation and rock tips, but they are not so clearly successful when it comes to roads (access roads) connected to construction work etc.

Local climate: The main environmental component mitigated is water temperature and the reported results are very positive.

Social issues: Mitigation measures are mainly concentrated on indigenous people, resettlement and construction activities (noise and vibration) and could mostly be placed in the mitigation group of ”Social impact management”. The reported results are mainly positive.

Terrestrial biology: The main components here are reported to be fauna (birds, insects, mammals) and flora, mitigated within the mitigation groups ”Protection of valued ecosystem components” and ”Protection, replacement and control of vegetation”.

The experiences with protection of valued ecosystems are reported to be not very successful, while vegetation control and replacement are reported as highly successful.

Water quality: The most important factors mitigated related to water quality are drainage from construction work, eutrophication, heavy metals (e.g. mercury), transport of elements and matter, turbidity or suspended solids, and water temperature.

As to drainage from construction work the effect of mitigation measures is very positive and so is the effort in controlling water temperature, transport of elements and suspended solids.

4.4 Sources of environmental and social impacts

4.4.1. Impacts of construction activities

As mentioned in chapter 3.1 the questionnaire has defined five different types of locations in relation to the watershed and several entries to different activities, environmental component types and environmental components.

Chapter 3.1.1 is summing up which areas (locations) and types of activities that are reported in the questionnaires, and also which types of environmental issues that are influenced by these activities.

As could be expected a power plant/reservoir construction will have influence on almost the whole scale of locations. The activities reported are mainly concentrated to the group defined as ”Altering Long-term River Flow” which usually includes dams, reservoirs and the building of a power plant.

Environmental types and components (parameters):
Aquatic biology: Impacts on aquatic invertebrate fauna and aquatic flora like algae, mosses and higher plants are the most commonly reported groups to be affected by the construction activities together with fish diversity, fish migration and fish stocking. There are also some reports mentioning red-listed species and heavy metals (mercury) as a problem. The issues mentioned are regarded as very important in all the defined locations.

Terrestrial biology: The terrestrial fauna like birds, mammals and insects, and the terrestrial flora especially in the drawdown zone as well as in relation to cutting down trees etc. when cleaning areas for construction purposes are the main groups reported to be affected by the construction activities. Red-listed species are also reported in some of the cases. The issues mentioned are regarded as very important in all the defined locations.

Economy: Agriculture, fisheries, forestry, husbandry (reindeer), and recreational areas, are components that are influenced by hydropower construction activities, with special focus on fisheries and the problem of keeping the traditional fish stocks in an altered habitat. The issues mentioned are regarded as very important in all the defined locations.

Estuarine and coastal habitats: In the downstream areas, changes in the traditional flow system of a river could cause salt intrusion/plume because of changes in the hydrology, water salinity and water temperature. This again could result in profound changes in coastal habitats.

Geophysics: The possibility of earthquakes is an issue to be considered when building power plants and dams in geophysically vulnerable regions. This factor is reported as important in some of the questionnaires. The impacts are mainly related to the "Reservoir area".

Global effects: Greenhouse gas emissions are mentioned as an important issue in some of the questionnaires in relation to the "Reservoir area", but very limited documentation is so far available.

Hydrology: Flood frequency, flow regime, groundwater level, and sedimentation seems to be the most important components to be considered here. These are regarded as important factors in the "Construction disturbance area", the "Downstream area", and the "Reservoir area". Erosion is also mentioned as an important component in a few questionnaires.

Landscape: Access roads, landscape appreciation and rock tips are issues of great importance to be handled when planning construction activities in an area. The issues are considered as very important elements in both environmental and social impacts.

Local climate: Humidity, air temperature, water temperature, wind, and, to a lesser degree, fog frequency are the most important issues related to the local climate, especially in the "Reservoir area" but also in most of the other defined areas influenced by hydropower activity.

Social issues: Indigenous people, noise and vibration, resettlement, social intrusions, places of religious or historical value, and waterborne diseases are factors frequently mentioned in the questionnaires. These impacts seem to be quite important especially in the "Construction disturbance area", the "Downstream area", and the "Reservoir area". Impacts on indigenous people and impacts related to resettlement are considered as the main factors.

Water quality: Impacts like drainage from construction work, eutrophication, water temperature, oxygen content, transport of elements and matter, and turbidity (amount of suspended solid material) seem to be more or less important in all defined areas influenced by construction activities. A few questionnaires are also mentioning issues like floating peat and heavy metals as important.

4.4.2 Frequency of reported impacts and mitigation measures

4.4.2.1 Physical impacts - mitigation and compensation measures

As may be expected most of the reported physical impacts are concentrated to the groups ”Change in water quality”, “Change in water quantity” and “Sedimentation”. The group “Climatic and local air quality changes” is also frequently mentioned, but no reports on mitigation measures related to this group are given. However, some other physical impact groups mentioned in the questionnaires are also included here.

The most important components, which have been reported mitigated within each group, are:

<u>Impact - Biotoxicity</u>

Components

- Mercury

Mitigation groups: Human health and safety risk management.
Mitigating effects on resource use

- Heavy metals

Mitigation group: Minimising soil contamination and loss of soil due to inundation (see mitigation measures list, Appendix 4)

<u>Impact - Change in water quality</u>

Components

- Drainage from construction work
- Eutrophication

Mitigation group: Water quality protection and adjustment

<u>Impact - Change in water quantity</u>

Components

- Change in flow regime
- Change in flooding frequency

Mitigation groups: Water quantity control (flow, velocity, level, including ice formation and movements
Design and construction of intakes, weirs, dikes, riffles, energy dissipators and diffusers for water level and velocity control

- Erosion

Mitigation group: Erosion protection control

<u>Impact - Increased erosion</u>

Components

- Erosion

Mitigation group: Erosion prevention and control

- Fluvial geomorphology

Mitigation groups: Erosion prevention and control
Water quantity control

<u>Impacts - Physical impacts</u>
Components
- Earthquakes

Mitigation group: Social impact management
- Noise and vibration

Mitigation group: Social impact management

<u>Impact - Sedimentation</u>
Component
- Hydrology/sedimentation

Mitigation groups: Sedimentation prevention control
Design intakes to enable sediment bypass and prevent local silting

4.4.2.2 Biological impacts - mitigation and compensation measures
Most of the reported biological impacts are concentrated to the groups ”Change in biota habitat”, “Change in ecosystem community populations”, “Changes in resource use” and “Removal of vegetation”.

<u>Impact - Change in biota habitat</u>
Components
- Aquatic biology (aquatic fauna, aquatic flora, fish communities, fish migration)

Mitigation groups: Fish protection
Human health and safety risk management
Protection, replacement and control of vegetation
Water quantity control
Other (specified under each project)
- Terrestrial biology (fauna and flora)

Mitigation groups: Protection of valued ecosystem components
Protection, replacement and control of vegetation
Water quantity control

<u>Impact - Change in ecosystem community populations</u>
Components
- Aquatic biology (aquatic fauna, aquatic flora, fish communities, fish migration)

Mitigation groups: Fish protection
Protection of valued ecosystem components
Protection, replacement and control of vegetation
Social impact management
Water quality protection and adjustments
Water quantity control
Other (specified under each project)
- Terrestrial biology (fauna, flora, red-listed species)

Mitigation group: Protection of valued ecosystem components

<u>Impact - Change in resource use</u>

Component

- Aquatic biology (fish communities, fish migration, mercury)

Mitigation groups: Mitigating effects on resource use
Other (specified under each project)

<u>Impact - Removal of vegetation</u>

Components

- Terrestrial fauna

Mitigation groups: Erosion prevention control
Protection, replacement and control of vegetation

- Terrestrial flora

Mitigation groups: Protection, replacement and control of vegetation
Sedimentation prevention control

4.4.2.3 Socio-economic impacts - mitigation and compensation measures

Reported impacts on socio-economic matters are concentrated to the groups ”Change in biota habitat”, “Change in channel morphology”, “Change in community and social services”, “Change in local economy”, “Changes in resource use”, “Change in social and community structure” and “Change in transportation and servicing”.

<u>Impact- Change in biota habitat</u>

Components

- Landscape appreciation

Mitigation groups: Minimising soil contamination and loss of soil due to inundation
Protecting or mitigating changes to landscape
Protection, replacement and control of vegetation
Social impact management
Other (specified under each project)

- Access roads

Mitigation groups: Protecting or mitigating changes to landscape
Protection, replacement and control of vegetation
Other (specified under each project)

- Rock tips

Mitigation group: Protecting or mitigating changes to landscape

- Recreational areas

Mitigation groups: Economic impact management
Mitigating cumulative effects of multiple hydroelectric facilities
Protecting or mitigating changes to traditional land use, cultural heritage, archaeological resources
Protecting or mitigating changes to landscape
Water quality protection and adjustments
Water quantity control

- Noise, vibration and other human presence effects on biota

Mitigation group: Social impact management

- Quarries

Mitigation group: Protecting or mitigating changes to landscape

Impact - Changes in community and social services

Components

- Industry

Mitigation groups: Economic impact management
Human health and safety risk management

- Commercial activities

Mitigation groups: Mitigating cumulative effects of multiple hydroelectric facilities
Other (specified under each project)

- Social intrusion

Mitigation groups: Social impact management
Other (specified under each project)

- Water supply

Mitigation group: Social impact management

- Resettlement

Mitigation group: Economic impact management

Impact - Change in local economy

Components

- Fisheries (others)

Mitigation groups: Economic impact management
Fish protection

- Transportation

Mitigation group: Economic impact management

- Tourism employment

Mitigation groups: Economic impact management
Social impact management

- Agriculture

Mitigation groups: Economic impact management
Protection, replacement and control of vegetation
Water quality protection and adjustments

- Recreational areas

Mitigation groups: Economic impact management
Social impact management

- Reindeer husbandry

Mitigation groups: Economic impact management
Protecting or mitigating changes to traditional land use, cultural heritage, archaeological resources
Social impact management

- Fisheries (fish stocking)

Mitigation group: Fish protection

- Forestry

Mitigation group: Protection, replacement and control of vegetation

- Hospitals

Mitigation group: Social impact management

- Rock tips

Mitigation groups: Protecting or mitigating changes to landscape
Protection, replacement and control of vegetation

- Schools

Mitigation group: Social impact management
- Water supply
Mitigation group: Social impact management
- Commercial activities
Mitigation group: Economic impact management

Impact - Changes in resource use
Components
- Forestry
Mitigation group: Economic impact management
- Recreational areas
Mitigation groups: Economic impact management
Social impact management
- Agriculture
Mitigation group: Economic impact management

Impact - Change in social and community structure
Components
- Resettlement
Mitigation group: Social impact management
- Indigenous people
Mitigation groups: Economic impact management
Social impact management
Other (specified under each project)
- Waterborne diseases
Mitigation group: Social impact management
- Places of religious/historical value
Mitigation group: Social impact management
- Social intrusion
Mitigation group: Social impact management

Impact - Change in transportation and servicing
Components
- Indigenous people
Mitigation group: Human health and safety risk management
- Access roads
Mitigation group: Social impact management
- Tourism employment
Mitigation group: Economic impact management
- Transportation
Mitigation group: Economic impact management

Impact - Increased erosion
Component
- Landscape appreciation
Mitigation groups: Erosion prevention and control
Water quantity control

Impact - Noise and human presence effects on biota
Component
- Noise and vibration

Mitigation groups: Social impact management
Other (specified under each project)

Impact - Removal of vegetation
Component
- Landscape appreciation

Mitigation groups: Erosion prevention control
Protection, replacement and control of vegetation
Other (specified under each project)

Impact - Soil inundation
Component
- Fisheries (others)

Mitigation groups: Mitigating effects on resource use
Other (specified under each project)

4.5 *Characteristics of environmental impacts*

4.5.1 Discussion of groups of impacts, based on the case studies

In Table 4 it can be seen that the most common impacts reported in the questionnaires are concentrated in the following impact groups:

	Number of reports
Change in biota habitat	492
Change in water quality	307
Change in local economy	182
Change in ecosystem community populations	164
Change in water quantity	151
Climatic and local air quality changes	58
Change in social and community structure	53
Change in community and social services	31
Change in resource use (recreational areas etc.)	25
Change in resource use (aquatic biota)	20

4.5.1.1 Physical impacts

The frequency of environmental components with physical impacts as reported in the questionnaires is listed in chapter 3.2.1.1. The main physical impacts reported are also presented in Table 7. Table 8 is giving an overview of the main components related to physical impacts with some examples of actual project cases as reported in the questionnaires.

In the following, some selected examples from the database are presented, partly to give an idea of the range of information available in the database, and partly also to illustrate the potential application this database approach might have for future planning and decision-making in hydropower development. The frequency lists may also serve as a first indication of which types of physical, biological and socio-economic impacts are commonly encountered in hydropower development.

Only environmental components mentioned at least five times under each impact group in the current database are included here, and these are listed in descending order of frequency.

Table 8. Physical impacts related to commonly encountered components with some relevant examples taken from the database

Impact group	Environmental component	Examples
Biotoxicity	Mercury	La Grande 2A, Québec, Canada Lokka, Finland
Change in biota habitat	Air humidity	Takami, Japan Stjørdalselva, Norway
	Air temperature	Takami, Japan
	Wind	Stjørdalselva, Norway
	Earthquakes	Takami, Japan
	Water temperature	Takami, Japan
Change in water quality	Eutrophication	Agavanzal, Spain Okumino, Japan
	Change in water temperature	Takami, Japan
	Changed transport of particles	Okumino, Japan
	Changed turbidity or suspended lids	Okumino, Japan Rivière des Prairie, Québec, anada
	Heavy metals	Lokka, Finland
	Drainage from construction work	Takami, Japan
	Change in oxygen content	Agavanzal, Spain Valparaiso, Spain
	Floating peat	Lokka, Finland
Change in water quantity	Changed flow regime	Valparaiso, Spain
	Change in flooding frequency	Kokkosniva, Finland Great Ruaha, Tanzania
	Groundwater level	Stjørdalselva, Norway
	Sedimentation and siltation	Kurotani, Japan Stjørdalselva, Norway
	Estuarine and coastal habitats	La Grande 2A, Québec, Canada
	Erosion	Great Ruaha, Tanzania
Climatic and local air quality anges	Change in local air temperature	Lokka, Finland Stjørdalselva, Norway
	Greenhouse gas emission	Porttipahta, Finland Lokka, Finland
	Change in local water mperature	Great Ruaha, Tanzania Takami, Japan
Sedimentation	Hydrology/sedimentation	Kurotani, Japan

<u>Biotoxicity</u>
Component: Mercury

La Grande 2A, Québec, Canada
In La Grande 2A Project in Québec, Canada, the increased levels of mercury in fish as a result of the establishment of the reservoir was studied. The hydropower development was shown to have negative effects on fisheries and fish migration in general, and the local people do not rely on fishing to the same degree as before the development. The main measures related to the problem of mercury were information to the public as well as

compensation to the most affected communities.
In other hydropower projects, like **Lokka** in Finland, the problem of heavy metals, particularly mercury, was found to be a transitory problem, particularly serious during the construction phase.

<u>Change in biota habitat</u>

Component: Air humidity
Air temperature
Wind
Earthquakes
Water temperature

Takami, Japan
In this project the possibility for increasing risk of earthquakes was quantitatively studied for 10 years. No impact was observed.

<u>Change in water quality</u>

Components: Eutrophication
Change in water temperature
Changed transport of particles
Changed turbidity or suspended solids
Heavy metals
Drainage from construction work
Change in oxygen content
Floating peat

Agavanzal, Spain
In the river Tera fisheries were significant before the Agavanzal project was implemented. The fisheries declined drastically after construction, mainly due to eutrophication and less oxygen content in the water. Creation of a fishery reserve for trout and fish re-stocking were tried as mitigation measures.

Okumino, Japan
In the Okumino Pumped Storage Project in Japan an increased turbidity and eutrophication of the water was mitigated by constructing a by-pass waterway to prevent the long-term persistence of turbid water.

Takami, Japan
Drainage from construction work was studied in this project for two years. Conclusion: As expected, increasing contamination of the water was observed during the construction period but was then decreasing and coming back to normal levels when the construction work ended.

Valparaiso. Spain
In the Valparaiso Project in Spain the problem of lower oxygen content in the downstream water was mitigated by a system of air injection in the turbine, by an aeration weir that was constructed downstream and by the operation of valves. However, the mitigation measures for improving the content of dissolved oxygen in turbinated water were adopted as a consequence of an incident of fish mortality not previously foreseen.

Change in water quantity

Components: Changed flow regime
Change in flooding frequency
Groundwater level
Sedimentation and siltation
Estuarine and coastal habitats
Erosion

Kokkosniva, Finland
The headwater level was lowered one meter from the preliminary plan in the Kokkosniva Project in Finland to save the Suvarto village from being flooded.

La Grande 2A, Québec, Canada
In the La Grande 2A Project in Québec, Canada, an increased water salinity at the estuary was experienced. Establishment of minimum flows to prevent further salt intrusions have had a relatively low success.

Great Ruaha, Tanzania
The erosion control implemented in the Great Ruaha Project in Tanzania included elements of improved land use planning and revegetation. However, the efforts had little success due to lack of funds and lack of a responsible executing agency. No particular agency was identified as responsible to monitor the mitigation measures, including their implementation and assessments of results.

Climatic and local air quality changes

Components: Change in local air temperature
Greenhouse gas emissions
Change in local water temperature

Takami, Japan
In the pumped storage project in Takami a main impact was predicted to be a lower water temperature downstream due to the original design of taking water from the middle or great depths of the pumped reservoir. This might result in colder irrigation water during the summer that again might cause harvest declines. The water intake design was therefore modified, with intake gates for surface water to increase water temperatures downstream. Monitoring of water temperatures upstream, in the reservoir and downstream is ongoing to evaluate the effect of this mitigation measure.

Sedimentation

Component: Hydrology, sedimentation

Kurotani, Japan
Severe sedimentation problems in the Kurotani Project in Japan were not expected, but later on documented. A rubber weir in the main river for automatic sediment flushing was constructed, and this mitigation measure has been shown to be successful.

4.5.1.2 Biological impacts

The frequency of environmental components with biological impacts as reported in the questionnaires is listed in chapter 3.2.1.2. The main biological impacts reported are also presented in Table 7. Table 9 is giving an overview of the main components related to biological impacts with some examples of actual project cases as reported in the questionnaires.

As in the previous section, some selected illustrative examples related to biological impacts are taken from the database.

Table 9. Biological impacts related to commonly encountered components with some relevant examples taken from the database

Impact group	Environmental component	Examples
Change in biota habitat	Fish community	Rivière des Prairie, Québec, Canada
	Terrestrial fauna	Great Ruaha, Tanzania
	Terrestrial flora	Great Ruaha, Tanzania Kurotani, Japan
	Aquatic fauna	Aurland I, Norway Kokkosniva, Finland
	Aquatic flora	Great Ruaha, Tanzania Kokkosniva, Finland
	Fish migration	Shin-Takanosu, Japan Hunderfossen, Norway
	Red-listed species	Great Ruaha, Tanzania Okumino, Japan
Change in ecosystem community populations	Fish communities	La Remolina, Spain Lokka, Finland
	Fish migration	La Grande 2A, Québec, Canada
	Aquatic fauna	La Remolina, Spain
	Aquatic flora	La Remolina, Spain
	Mercury in fish	La Grande 2A, Québec, Canada Lokka, Finland
	Terrestrial fauna	La Remolina, Spain Great Ruaha, Tanzania
	Terrestrial flora	Kurotani, Japan Lokka, Finland
	Red-listed species	Great Ruaha, Tanzania Okumino, Japan
Noise and human presence effects on biota	Fauna (birds)	Aurland I, Norway Mingtan, Taiwan Province

Change in biota habitat

Components: Fish communities
Terrestrial fauna
Terrestrial flora
Aquatic fauna
Aquatic flora
Fish migration

Red-listed species

Rivière des Prairie, Québec, Canada
In the upgrading project of Rivière des Prairie in Québec, Canada, one of the key issues was the expected negative impacts on fish spawning. Creation of new spawning grounds was implemented, and this measure has been documented to be successful.

Kurotani, Japan
In the Kurotani Project in Japan designated reserved forests in the area had to be cancelled due to the hydropower development.

Shin-Takanosu, Japan
In this upgrading of a run-of-river project one of the major impacts was also considered to be negative effects on fish communities and the migration of anadromous fish. A fish ladder was constructed as a mitigation measure, and this solution has here been documented to be successful.

<u>Change in ecosystem community populations</u>

Components: Fish communities
Fish migration
Aquatic fauna
Aquatic flora
Mercury in fish
Terrestrial fauna
Terrestrial flora
Red-listed species

Okumino, Japan
In the Okumino Project in Japan endangered species and protected areas were involved in the development of a daily pump storage. All technical facilities were constructed underground so as not to affect rare plants.

<u>Noise and human presence effects on biota</u>

Component: Fauna (birds)

4.5.1.3 Socio-economic impacts

The frequency of environmental components with socio-economic impacts as reported in the questionnaires is listed in chapter 3.2.1.3. The main socio-economic impacts reported are also presented in Table 7. Table 10 is giving an overview of the main components related to socio-economic impacts with some examples of actual project cases as reported in the questionnaires.

As in the previous sections, some selected illustrative examples related to socio-economic impacts are taken from the database.

Table 10. Socio-economic impacts related to commonly encountered components with some relevant examples taken from the database

Impact group	Environmental component	Examples
Change in biota habitat	Landscape appreciation	Takami, Japan Aurland IIL, Norway
	Access roads	La Remolina-Riano, Spain Stjørdalselva, Norway
	Rock tips	Aurland I, Norway Hunderfossen, Norway
	Recreational areas	Aurland IIL, Norway Porttipahta, Finland
	Places of religious/historical value	Robert-Bourassa, Québec, Canada La Grande 2A, Québec, Canada
	Noise and vibration	Rivière des Prairie, Québec, Canada
Changes in community and social services	Commercial activities	La Grande 2A, Canada Lokka, Finland
	Social intrusion	Rivière des Prairie, Québec, Canada Lokka, Finland
	Resettlement	Batang Ai, Malaysia Robert-Bourassa, Québec, Canada Great Ruaha, Tanzania La Remolina-Riano, Spain
	Tourism employment	La Grande 2A, Canada Stjørdalselva, Norway
Change in housing and property value	Erosion	Great Ruaha, Tanzania Robert-Bourassa, Québec, Canada
Change in land use and policy plans	Indigenous people	Great Ruaha, Tanzania La Grande 2A, Québec, Canada
Change in local economy	Fisheries (others)	Takami, Japan Great Ruaha, Tanzania
	Fisheries (fish stocking)	Hunderfossen, Norway Agavanzal, Spain
	Agriculture	Agavanzal, Spain Lokka, Finland
	Tourism employment	Takami, Japan Great Ruaha, Tanzania
	Transportation	Takami, Japan Kurkiaska, Finland
	Forestry	Great Ruaha, Tanzania Kokkosniva, Finland
	Water supply	La Remolina-Riano, Spain Lokka, Finland
	Recreational areas	Reppa, Norway Porttipahta, Finland
	Schools	Great Ruaha, Tanzania
	Hospitals	Great Ruaha, Tanzania
	Commercial activities	Takami, Japan La Grande 2A, Québec, Canada
	Reindeer husbandry	Porttipahta, Finland Lokka, Finland
	Industry	La Grande 2A, Québec, Canada
Changes in resource use	Recreational areas	Vangen, Norway Porttipahta, Finland

(Table 10. Continued)

Impact group	Environmental component	Examples
	Social intrusion	Rivière des Prairie, Québec, Canada Porttipahta, Finland
	Agriculture	Agavanzal, Spain La Remolina-Riano, Spain
	Forestry	La Grande 2A, Canada Lokka, Finland
	Fisheries (fish stocking)	Agavanzal, Spain Hunderfossen, Norway
Change in social and community structure	Indigenous people	Great Ruaha, Tanzania La Grande 2A, Québec, Canada
	Resettlement	Batang Ai, Malaysia La Remolina-Riano, Spain
	Social intrusion	Rivière des Prairie, Québec, Canada Great Ruaha, Tanzania
	Places of religious/historical value	Robert-Bourassa, Québec, Canada La Grande 2A, Québec, Canada
	Waterborne diseases	Great Ruaha, Tanzania
Noise and human presence effects on biota	Noise and vibration	Rivière des Prairie, Québec, Canada
Removal of vegetation	Landscape appreciation	Mis Dam-Sospirolo, Italy Robert-Bourassa, Québec, Canada

Change in biota habitat

Components: Landscape appreciation
Access roads
Rock tips
Recreational areas
Places of religious/historical value
Noise and vibration

"Landscape appreciation" is a value that is closely linked to cultural values such as the perceived value of recreational areas, aesthetic values, etc., and will often be country specific or even project specific. In the **Aurland II L** project in Norway transmission line routes were set up to avoid recreational areas. A key issue in many recent Norwegian projects, like the **Reppa**, **Stjørdalselva** and **Vangen** projects, has been concern towards technical encroachments in wilderness areas.

Kurkiaska, Finland

In the Kurkiaska Project in Finland the original river landscape was artificially kept by a submerged weir. Furthermore, the power plant was relocated from the scenic Porttikoski canyon and cannot be seen from the river now.

A common way of mitigating negative effects of rock tips is first to cover the rock tips with soil (preferably the top soil that was removed in the construction phase) and then re-vegetate the rock tips. In the **Aurland I** Project in Norway non-local species were used in the revegetation of rock-tips, while in the **Hunderfossen** Project in Norway indigenous species were used for revegetation of rock tips.

<u>Change in community and social services</u>
Components: Commercial activities
Social intrusion
Resettlement
Tourism employment

<u>Change in housing and property values</u>
Component: Erosion

<u>Change in land use and policy plans</u>
Component: Indigenous people

<u>Change in local economy</u>
Components: Fisheries (others)
Fisheries (fish stocking)
Agriculture
Tourism employment
Transportation
Forestry
Water supply
Recreational areas
Schools
Hospitals
Commercial activities
Reindeer husbandry
Industry

Takami, Japan
In the Takami pumped storage project (for daily peaking load) large daily fluctuations of river flow were expected to damage fisheries and the hatching of salmon and trout. To mitigate this problem another dam was constructed immediately downstream of the original plant. This second power plant is operated in such a way as to keep the daily river flow constant via a regulation gate at the dam.

Aurland I, Norway
An expected and documented effect of the Aurland project was a decline in catches of trout and salmon in the river. A common way of mitigating this problem is fish re-stocking, and this was tried both in the river and in the reservoirs. The fish re-stocking in the river had low success due to heavy predation of smolts, while fish re-stocking in reservoirs was more successful.

Dam projects having as the primary aim to produce electricity may also have other positive spin-offs. In the **Aurland II H** Project in Norway, such positive spin-offs included improved local infrastructure and facilities as well as increased local revenues through regulation taxes. In the **La Grande 2A** Project in Québec, Canada, positive spin-offs included better infrastructure, winter passages, new roads, a new bridge, new employment opportunities, a new sewage system, and a new water intake. In the **La Remolina-Riano** Project in Spain, benefits included new irrigation possibilities, flood protection and positive effects on certain fish communities.

Changes in resource use

Components: Recreational areas
Social intrusion
Agriculture
Forestry
Fisheries (fish stocking)

In some dam projects the electricity production is only a part of the aim of the project. Other aspects may be of importance, or even the main rationale, for constructing the dam, like flood control, increased possibilities for irrigating agricultural lands, fish farming, etc. In **Agavanzal** in Spain the irrigated agricultural area expanded from 10 000 ha to 21 000 ha as a result of constructing the Cernadilla dam.

Hunderfossen, Norway
Environmentally, most attention in this project was given to expected changes in fish population and migratory habits. The dam became an effective barrier to migratory and spawning trout. The fish ladder constructed to mitigate this problem was unsuccessful as the reduced river flow below the dam limited fish migration. Even fish restocking (trout) turned out to be less successful than expected. An increase in the minimum flow downstream at certain times to trigger migration improved the situation.

Noise and human presence effects on biota

Component: Noise and vibration

Some negative impacts experienced in hydropower development projects are often temporary and mainly linked to the construction phase of the project, like noise, social intrusion and security problems, turbidity and suspended solids (as in e.g. the **Rivière des Prairies** Project in Québec, Canada).

Change in social and community structure

Components: Indigenous people
Resettlement
Social intrusion
Places of religious/historical value
Waterborne diseases

Robert-Bourassa, Québec, Canada
In the Robert-Bourassa Project in Québec, Canada, some major changes in social and community structure was expected. Some 2 400 people had to be resettled, and many cultural relics, including Indian graves would be drowned by the reservoir. A cooperation committee was set up and this committee was informed about the project throughout the planning and construction phases. Each week, 2-3 days were spent on discussing and commenting upon the project. A long list (with some 43 items) of "main impacts" was set up, and mitigation measures were suggested for most of these impacts. Some mitigation measures turned out to have a rather low success, while others turned out to be rather successful. One of the successful initiatives was indeed the mentioned system of exchange of information to the local population.

La Grande 2A, Québec, Canada

A typical example of an impact of socio-cultural significance was the development of the La Grande 2A project in Québec, Canada, where Cree Indian graves were flooded by the new reservoir.

Resettlement

Involuntary resettlement of people has often been considered to be the most problematic impact following the construction of dams and establishment of reservoirs in populated areas. However, the current database does not include cases with resettlement on a very large scale. Some examples from the database may illustrate this:

Project	**Number of resettled people**
Batang Ai, Malaysia	**3 600**
Robert-Bourassa, Québec, Canada	**2 400**
Great Ruaha, Tanzania	**1 011**
La Remolina-Riano, Spain	**900**
Lokka, Finland	**390**
Porttipahta, Finland	**170**
Valparaiso, Spain	**150**
Kurkiaska, Finland	**6**

The most common ways of mitigating or compensating this impact as reported in the database are e.g.:
- New employment **(Batang Ai, Robert-Bourassa)**
- Lump sum of payment **(Batang Ai, Great Ruaha, Kurkiaska, La Remolina-Riano, Lokka, Porttipahta)**
- New housing **(Batang Ai, Robert-Bourassa)**
- New (agricultural) land **(Batang Ai, Kurkiaska, La Remolina-Riano, Lokka, Porttipahta)**

Removal of vegetation
Component: Landscape appreciation

4.6 Impacts and the efficiency of mitigation measures

As stated in chapter 4.4, most of the mitigation measures are implemented in connection to the impact group ”Change in biota habitat” and are mainly related to fish protection, landscape, protection of valued ecosystem components and protection of vegetation (see also Table 4). The other most important impact groups where mitigation measures are implemented are related to ”Change in water quality” (water quality protection), ”Change in local economy” (economic and social management), ”Change in ecosystem community populations” (fish protection), and ”Change in water quantity” (control of water flow, water level and velocity).

Generally, mitigation measures related to fish protection do not seem to work very well. However, the effect of mitigations to changes in economic management, landscape/vegetation and social impacts could be quite positive.

The examples in the boxes below are showing the most important impact groups within which mitigation measures have been reported, as well as the effect of the most common mitigation measures:

Changes in biota habitat:

Mitigation measure group	Number of answers	Documented effect not marked	Documented effect marked	Positive effect	Negative effect	In-different
Fish protection	35	15	20		20	
Landscape	41	15	26		18	8
Protection of valued ecosystem components	19	18	1		1	
Vegetation	55	15	40	4	18	18

Change in water quality:

Mitigation measure group	Number of answers	Documented effect not marked	Documented effect marked	Positive effect	Negative effect	In-different
Water quality protection	85	13	72	14	5	53

Change in local economy:

Mitigation measure group	Number of answers	Documented effect not marked	Documented effect marked	Positive effect	Negative effect	In-different
Economic management	45	20	25	5	12	8
Social management	11		11	10	1	8

Change in ecosystem community population:

Mitigation measure group	Number of answers	Documented effect not marked	Documented effect marked	Positive effect	Negative effect	In-different
Fish protection	17	4	13	6	6	1

Change in water quantity:

Mitigation measure group	Number of answers	Documented effect not marked	Documented effect marked	Positive effect	Negative effect	In-different
Control of water flow, level and velocity	65	14	51	14	31	6

5. SUMMARY

5.1 The database

To collect information about hydropower and the environment, and specifically the positive and negative environmental and social impacts of mitigation measures in hydropower development, the questionnaire approach was chosen.

The outline of the questionnaire is mainly based on the results of two workshops where national representatives and experts from the participating countries attended. These workshops made decisions regarding parameters and issues that should be included in the questionnaire. During this process a preliminary questionnaire was distributed several times for comments. To make the questionnaire available also in an electronic form, an electronic version was developed in parallel to the paper version.

The objective of the questionnaire is to develop a tool whereby the actual effects of hydropower development in terms of environmental and social impacts, and the efficiency of applied mitigation measures can be compared and assessed in a global perspective.

The questionnaire consists of six main parts: Introduction, Project data, Identification of key issues, Verification of impacts, Mitigation measures and the Regulatory approval process.

Some criteria were worked out to try to assure that relevant data were entered into the database: Each participating country should present a number of ”case studies” reflecting different climatic and topographic regions as well as a variety of project types. The projects selected should be fairly recent to make sure that a real planning phase with environmental and social assessments had been included, and that mitigation measures had been implemented in a defined legal regulatory context.

At present 28 questionnaires are received and included in the database. These questionnaires combined describe 46 projects, 39 of these are new projects and seven are upgrading projects.

The database programme selected has been Microsoft's ”Access 97”.

5.2 Main results

The following information is based on information taken from the project cases included in the database.

<u>Sources of environmental and social impacts</u>
The main physical impacts are related to:

Air temperature	Heavy metals
Drainage from construction work	Oxygen content
Eutrophication	Sedimentation
Flood frequency	Temperature (water)
Flow regime	Transport of elements and matter
Groundwater level	Turbidity or suspended solids

The main biological impacts are related to:
Fauna (aquatic and terrestrial - birds, insects, mammals)
Fish community
Fish migration
Fisheries (fish stocking)
Flora (aquatic and terrestrial)
Mercury (in fish)
Red-listed species (both aquatic and terrestrial)

The main socio-economic impacts are related to:
Access roads
Agriculture
Air humidity
Air temperature
Fisheries (fish stocking)
Fisheries (others)
Forestry
Hospitals
Indigenous people
Landscape appreciation
Recreational areas
Resettlement
Rock tips
Schools
Social intrusion
Tourism employment
Transportation
Water supply
Wind

<u>Mitigation measures</u>
Main mitigation measures on physical impacts:
Mitigation group- *Sedimentation prevention and control*
Sedimentation
- *Water quality protection and adjustments*
Changed transport of elements and matter
Changed turbidity or suspended solids
Drainage from construction work
Eutrophication
Water quantity control
Flood frequency
Flow regime
Groundwater level

Main mitigation measures on biological impacts:
Mitigation group- *Fish protection*
Fish community
Fish migration
- *Protection, replacement and control of vegetation*
Flora (terrestrial)
- *Protection of valued ecosystem components*
Fauna (mammals)
Red-listed species

Main mitigation measures on socio-economic impacts:
Mitigation group- *Economic impact management*
Agriculture
Fisheries
Forestry
Recreational areas
Reindeer husbandry

Tourism employment
Transportation

- *Protecting or mitigating changes to landscape*
  Landscape appreciation
  Rock tips
- *Protection, replacement and control of vegetation*
  Access roads
  Landscape appreciation
- *Social impact management*
  Noise and vibration
  Recreational areas
  Resettlement

Activities commonly connected to mitigation measures (with at least five counts in the questionnaire; see also Table 5 and Appendix 7):

Activity	Count of mitigation measures	Mitigation measures
Altering long-term river flow	80	Water quality protection and adjustments
Altering long-term river flow	65	Water quantity control (flow, velocity, level; including ice formation and movements)
Altering long-term river flow	64	Economic impact management
Altering long-term river flow	61	Protection, replacement and control of vegetation
Altering long-term river flow	58	Fish protection
Altering long-term river flow	41	Protecting or mitigating changes to landscape
Altering long-term river flow	41	Social impact management
Altering long-term river flow	39	Other
Altering long-term river flow	21	Protection of valued ecosystem components (aquatic and terrestrial habitats, communities, rare, threatened species and spaces, and particular species other than fish)
Altering long-term river flow	10	Erosion prevention and control
Dewatering and draining	10	Water quality protection and adjustments
Impounding (reservoir filling)	10	Water quality protection and adjustments
Altering long-term river flow	7	Sedimentation prevention and control
Operating at peak efficiency	6	Water quantity control (flow, velocity, level; including ice formation and movements)
Operating at maximum power	5	Other
Operating at peak efficiency	5	Mitigating effects on resource use

Frequency of reported impacts and mitigation measures

Physical impacts - mitigation and compensation measures:
As may be expected most of the reported physical impacts are concentrated to the groups ”Change in water quality”, “Change in water quantity” and “Sedimentation”.

Biological impacts - mitigation and compensation measures:
Most of the reported biological impacts are concentrated to the groups ”Change in biota habitat”, “Change in ecosystem community populations”, “Changes in resource use” and “Removal of vegetation”.

Socio-economic impacts - mitigation and compensation measures:
Reported impacts on socio-economic matters are concentrated to the groups ”Change in biota habitat”, “Change in channel morphology”, “Change in community and social

services", "Change in local economy", "Changes in resource use", "Change in social and community structure" and "Change in transportation and servicing".

Mitigation measures within each mitigation group with characterisation of success (see also Table 6):

Mitigation group	Sum of projects	High	Indif-ferent	Low
Water quality protection and adjustments	44	40	1	3
Water quantity control (flow, velocity, level; including ice formation and movements)	43	36	4	3
Fish protection	42	33	4	5
Protection, replacement and control of vegetation	42	35	2	5
Economic impact management	35	26	1	8
Other	33	29		4
Social impact management	31	24	1	6
Protecting or mitigating changes to landscape	17	13		4
Erosion prevention and control	11	8	1	2
Mitigating effects on resource use	11	8		3
Human health and safety risk management	9	7	2	
Sedimentation prevention and control	5	4		1
Climatic and local air quality controls	4		4	
Protecting or mitigating changes to aboriginal land use, cultural heritage, archaeological resources	4	2		2
Protection of valued ecosystem components (aquatic and terrestrial habitats, communities, rare, threatened species and spaces, and particular species other than fish)	3	1		2
Minimising soil contamination and loss of soil due to inundation	2	2		
Mitigating cumulative effects of multiple hydroelectric facilities	2	1		1
Protecting or minimising changes in channel morphology	1	1		

<u>Groups of impacts, based on the case studies</u>

The most common impacts reported in the questionnaires are concentrated in the following impact groups (see also Table 4):

	Number of reports
Change in biota habitat	492
Change in water quality	307
Change in local economy	182
Change in ecosystem community populations	164
Change in water quantity	151
Climatic and local air quality changes	58
Change in social and community structure	53
Change in community and social services	31
Change in resource use (recreational areas etc.)	25
Change in resource use (aquatic biota)	20

<u>Efficiency of mitigation measures</u>

Most of the mitigation measures are implemented in relation to the impact group "Change in biota habitat" and are mainly connected to fish protection, landscape, protection of valued ecosystem components and protection of vegetation. The other most important impact groups where mitigation measures are implemented are related to "Change in water quality" (water quality protection), "Change in local economy" (economic and social management),

”Change in ecosystem community populations” (fish protection), and ”Change in water quantity” (control of water flow, water level and velocity).

Generally, mitigation measures related to fish protection do not seem to work very well. However, the effect of mitigations to changes in economic management, landscape/vegetation and social impacts could be quite positive.

5.3 Recommendations on mitigation measures

The following comments are not to be regarded as formal recommendations for mitigation measures to be generally implemented in hydropower development. The information is strictly taken from the questionnaires and includes only those mitigation measures that are reported to have a very high, documented success (see also Appendix 16). However, particular mitigation measures and methods mentioned as very successful in one project do not necessarily have to be so in another project.

Economic impact management:

- Award work and supply contracts to local companies
- Optimum compensation flow
- Local recreational and community facilities
- Sufficient financial compensation (agriculture land, forestry land etc.)
- Traffic regulation for construction vehicles
- Train and hire local workers for project work
- Water supply for irrigation

Erosion prevention and control:

- Stabilising stripped areas, embankments, boom shelter, successful material choice etc.

Fish protection:

- Biotop adjustments
- Creation of spawning areas
- Fish stocking
- General fish population management
- Long term data sets for fish population and detailed knowledge of fish biology
- Minimum flows, optimum compensation flows
- Population biology

Human health and safety risk management:

- Good communication/co-operation with the local authorities
- What is important for the local population? Help to extend local advantages: Ex. main activities, roads for skidoos, information on fish population (heavy metals etc.), navigation safety, dam safety etc.

Minimising soil contamination and loss of soil due to inundation:

- Controls (often)
- Removing of floating peat and debris

Mitigating cumulative effects of multiple hydroelectric facilities:

- Minimising the total impact of the project

Mitigating effects on resource use:

- Access roads
- Economic compensation in connection to local activities like fishing etc.
- Funds to society to "repair"/minimise impacts on natural resources

Other mitigating measures:

- Building of equipment for floating
- Building/rebuilding of access roads
- Control of noise, e.g. specific working hours, not to disturb people at night time
- Create spawning and a rearing zone at the maximal level of the reservoir
- Filling reservoir after ice formation on the river, slower salt intrusion under the ice
- Fishing places where debris and stumps are removed
- Fry releasing
- Give information on the possibility of fishing species and capture methods
- Information on safe routes for boats in summer and skidoos in the winter, new roads etc.
- Information on salinity and ice formation, security and fishing
- Jobsites placed away from the camps
- Landscape adjustment by clearing of shorelines
- Agreements between the corporation and the indigenous people to protect their way of life
- Minimum flow to prevent salt intrusion into the river
- New and up-to-date designed spillway
- Predicted speed of salt intrusion
- Regular patrols to look for water weeds
- The same area used for more than one project, minimising the total impact of the project
- Thresholds for keeping groundwater level

Protecting or minimising changes in channel morphology:

- Ease flow of water

Protecting or mitigating changes to aboriginal land use, cultural heritage, archaeological resources:

- Financial compensation
- Floating equipment for reindeer

Protecting or mitigating changes to landscape:

- Cooperation with local and national authorities regarding historical monuments etc.
- Outline of transmission lines
- Spill-way construction/outline
- Thresholds
- Vegetation on rock tips

Protection of valued ecosystem components:

- Compensation flow regime

Protection, replacement and control of vegetation:
- Cleaning of construction areas
- Landscape adjustment
- Revegetation, use of selected seeds

Sedimentation prevention and control:
- Sedimentation control

Social impact management:
- Boat channel(s)
- Financial compensation, resettlement close by, better social services
- Health education and medical care
- Recreational areas
- Relocation
- Traffic regulations for construction vehicles
- Using local people in the construction work as much as possible
- Water supply

Water quality protection and adjustment:
- Optimum compensation flow
- Embankments
- Installation of bypass waterway
- Oxygen supply to the water/river by air injection into the turbine(s), management of production
- Purification of construction releases
- Selective intake to regulate water temperature (and oxygen?)

Water quantity control:
- Optimum compensation flow
- Min/max flows, limitation of flow variation rates
- Reservoir level management
- Specification of a minimum flow in summer/winter to prevent salt intrusion into the river
- Water supply

6. REFERENCES

6.1 References on mitigation measures

The reference list is organised alphabetically based on name of project in the database and with listing of all the references cited in the questionnaires under "Mitigation measures" and under "Impacts" (see chapter 6.2).

Project name	Author	Document name
Agavanzal	GHESA	Construction plan (1990)
Agavanzal	GHESA	Environmental impact study (1986)
Agavanzal	IBERDROLA	Construction survey report (1993)
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Agavanzal	Vega, J.C.	Water quality survey programme
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Kurkiaska	Sodankylänkunta & Suunnittelukeskus OY. 1987	Sodankylä. The environmental plan for the centre of Sodankylä (in Finnish)
Kurkiaska	Voimalohi OY (published once a year)	The fish stocking and monitoring measures of Kurkiaska (in Finnish)
Kurotani	Electric Power Development Co. Ltd.	Environmental impact assessment report on Kurotani project
Kurotani	Ishimura, Y.	Design and installation of inflatable rubber weir
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La Grande 2A	Chartrand, N. & Thérien, N.	Les enseignements de la phase 1
La Grande 2A	Éditeur officiel Québec	1986 Mercury Agreement
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La Grande 2A	Hydro-Québec & SEBJ	Suréquipement de l'aménagement de La Grande 2
La Grande 2A	Salisbury, R.F.	A homeland for the Cree
La Grande 2A	SEBJ	Internal report
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La Remolina - Riano	Palau, A. 1995	Bases limnologicas para la gestion medioambiental del Embalse de Riano. ENDESA
Lokka	Illikainen, J. 1997	Report on clearing of Lokka and Porttipahta (manuscript in Finnish)
Maan	China Engineering Consultants, Inc.	Environmental impact assessment report of Maan hydro power project

Project name	Author	Document name
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Porttipahta	Illikainen, J. 1997	Report on clearing of Lokka and Porttipahta (manuscript in Finnish)
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Robert-Bourassa	Éditeur officiel Québec	La Convention de la Baie-James et du Nord québécoise
Robert-Bourassa	Salisbury, R.F.	A homeland for the Cree
Robert-Bourassa	SEBJ	The La Grande Rivière Hydroelectric Complex phase
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Takami	Hokkaido Electric Power Co. Inc.	Environmental assessment report on Takami project
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Valparaiso	IBERDROLA	Oxygen control in discharge (1989-1990)

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Kokkosniva	Kemijoen kalatoimikunta. 1972	Management of fish communities in the River Kemijoki in 1963-1971 and the plans for near future (in Finnish)

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Project name	Author	Document name
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Kokkosniva	Seppänen, 1967	General study on the river Kemijoki in 1964-1966 (in Finnish)
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Kokkosniva	Väisänen, T. & Heiskanen, M. (eds.) 1995	Greenhouse gas from Lokka reservoir and Vuotos region (in Finnish)
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Project name	Author	Document name
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Lokka	Mutenia, A. & Oksman, H. 1985	Utilisation of fish stock in Lokka and Porttipahta reservoirs (in Finnish)

Project name	Author	Document name
Lokka	Niini, H. 1964	Bedrock and its influence on the topography in the Lokka-Porttipahta reservoir district. Finnish Lapland. Fennia 90(1) (in Finnish)
Lokka	Niskanen, A. 1995	The greenhouse gas emissions in Lokka reservoir in 1994. Univ. Kuopio, Dept. of Physics (in Finnish)
Lokka	Puro, A. 1995	The composition and production of shellfish plankton in Lokka reservoir in 1988. Univ. of Jyväskylä, Dept. of Biology (in Finnish)
Lokka	Ruuhijärvi, P., Alapassi, M. & Heikkinen, P. 1976	Research on floating peat in Lokka reservoir (in Finnish)
Lokka	Salo, O. 1995	Results of water quality studies in the Lokka and Porttipahta reservoirs and the rivers downstream in 1994 (in Finnish)
Lokka	Salonen, E. & Mutenia, A. 1993	The effects of natural breeding to white fish stock and fishing in Lokka and Porttipahta reservoirs (in Finnish)
Lokka	Sundbäck, K. 1977	The results of fishery studies in Lokka reservoir and the plan for fishing and fish stock management (in Finnish)
Lokka	Sundbäck, K. 1977	The results of fishery studies in Porttipahta reservoir and the plan for fishing and fish stock management (in Finnish)
Lokka	Tekojärvien kalataloussuunnittelutyöryhmä, 1991	The plan for utilisation and management of fishery in Lokka and Porttipahta reservoirs (in Finnish)
Lokka	Verta, M. & Porvari, P. 1995	Mercury studies on fish and water in reservoirs and in the River Kemijoki (in Finnish)
Lokka	Virtanen, M., Hellsten, S., Koponen, J., Riihimäki, J. & Nenonen, O. 1993	Water quality model of northern reservoirs and its validation with field measurements (in Finnish)
Lokka	Väisänen, T. & Heiskanen, M. (eds.) 1995	Greenhouse gas from Lokka reservoir and Vuotos region (in Finnish)
Lokka	Väisänen, T. & Hellsten, S. 1996	Climatic effect of Finnish hydropower. Preliminary research (in Finnish)
Maan	Chan, C.P.	Tachia River fishery investigation study
Maan	Water Resources Planning Commission.	Tachia River water quality long term monitoring project
Maan	Water Resources Planning Commission.	The study of Tachia River. Water resources, water quality and plankton
Mingtan pum-ped storage	Chen, P.H. & Yeh, C.W.	Bird ecological investigation in forest of Taiwan

Project name	Author	Document name
Mingtan pumped storage	Sinotech Engineering Consultants, Ltd.	Environmental impact assessment report of Mingtan pumped storage hydro power project
Mingtan pumped storage	Taiwan Power Company Environmental Protection Department.	Environmental monitoring project of Mingtan hydro power plant
Mingtan pumped storage	Water Resources Planning Commission.	Hydrological year book of Taiwan Republic of China 1983
Mis Dam-Sospirolo	ENEL/DCO	Busche plant. Verification of environmental compatibility
Mis Dam-Sospirolo	ENEL/DCO	Saviner plant II. Verification of environmental compatibility
Mis Dam-Sospirolo	ENEL/DPT	Initial environmental analysis
Okumino	Chubu Electric Power Company	Environmental impact assessment report on Okumino hydro power station (for enlargement)
Porttipahta	Alfthan, G., Järvinen, O., Pikkarainen, J. & Verta, M. 1983	Mercury and artificial lakes in Northern Finland. Possible ecological and health consequences
Porttipahta	Arnborg, L. & al.; AB Hydroconsult, 1965	Study on geomorphological, physical and chemical consequences of water raising on peatland (in Swedish)
Porttipahta	Arnborg, L. & al.; AB Hydroconsult, 1971	Studies on physical and chemical consequences of water raising on peat- and mineral soil (in Swedish)
Porttipahta	Asp, E. & Järvikoski, T. 1974	Man-made lakes and their social consequences in Finnish Lapland. Acta Lapponica Fennicae 3
Porttipahta	Eurola, S. 1967	The vegetation of meadow land in planned Lokka and Porttipahta reservoirs in Finnish lapland. Aquilo Ser. Bot. 5. (in German)
Porttipahta	Franssila, M. & Järvi, P. 1976	On changes in the local climate due to the creation of the Lokka reservoir
Porttipahta	Havukkala, J. 1964	Settlement and economic life in the district of the Lokka reservoir in Finnish Lapland. Acta Lapponica Fennicae 3
Porttipahta	Heinonen, P. & Airaksinen, E. 1974	Development of Lokka and Porttipahta reservoirs in 1971-1974. Vesihallituksen tiedotuksia 77: 1-51 (in Finnish)

Project name	Author	Document name
Porttipahta	Hellsten, S.K. & al. 1993	Relative importance of internal sources of phosphorus and organic matter in Northern Finnish reservoirs. Wat. Sci. Tech. Vol 26, no. 6
Porttipahta	Jantunen, H. & Raitala, J. 1984	Locating shoreline changes in Porttipahta (Finland) water reservoir by using multitemporal landsat data
Porttipahta	Järvelä, J. 1995	Reservoirs and peat production. Vesirakennuslaboratiorion jukaisuja (in Finnish)
Porttipahta	Kemijoki OY: Kivinen, P.	On the environmental effects of the man-made lakes Lokka and Porttipahta
Porttipahta	Kinnunen, K. 1985	State of Lokka and Porttipahta reservoirs and the rivers downstream of them until the year 1984 (in Finnish)
Porttipahta	Kuuskoski, M. & Kovanen, T.	Environmental effects of the Lokka and Porttipahta reservoir
Porttipahta	Kännö, S. 1985	Changes of fishery in the project area of Lokka reservoir. The final evaluation of Lokka reservoir (in Finnish)
Porttipahta	Lenstra, M. 1971	Study on reindeer husbandry in the area of Lokka and Porttipahta reservoirs (in Dutch)
Porttipahta	Lodenius, M., Seppänen, A. & Herranen, M. 1983	Accumulation of mercury in fish and man from reservoirs in Northern Finland
Porttipahta	Luostarinen, M. & Mäkinen, H. 1980	The effect of construction of Lokka and Porttipahta reservoirs on the movers and community. Vesihallituksen monistesarja 1980:14 (in Finnish)
Porttipahta	Martikainen, P., Väisänen, T. & al. 1996	Significance of Northern reservoirs as sources of greenhouse gases (in Finnish)
Porttipahta	Mutenia, A. 1978	The biology of ide (*Leuciscus idus*) in Lokka reservoir (in Finnish)
Porttipahta	Mutenia, A. 1982	White fish in the management of fish stocks in Lokka and Porttipahta reservoirs (in Finnish)
Porttipahta	Mutenia, A. & Oksman, H. 1983	The fish stock of Lokka and Porttipahta reservoirs and the plan for their management (in Finnish)
Porttipahta	Mutenia, A. & Oksman, H. 1985	Utilisation of fish stock in Lokka and Porttipahta reservoirs (in Finnish)
Porttipahta	Niini, H. 1964	Bedrock and its influence on the topography in the Lokka-Porttipahta reservoir district, Finnish Lapland. Fennia 90(1) (in Finnish)
Porttipahta	Niskanen, A. 1995	The greenhouse gas emissions in Lokka reservoir in 1994. Univ. of Kuopio, Dept. of Physics (in Finnish)
Porttipahta	Ruuhijärvi, P., Alapassi, M. & Heikkinen, P. 1976	Research on floating peat in Lokka reservoir (in Finnish)

Project name	Author	Document name
Porttipahta	Salo, O. 1995	Results of water quality studies in the Lokka and Porttipahta reservoirs and the rivers downstream in 1994 (in Finnish)
Porttipahta	Salonen, E. & Mutenia, A. 1993	The effects of natural breeding to white fish stock and fishing in Lokka and Porttipahta reservoirs (in Finnish)
Porttipahta	Sundbäck, K. 1977	The results of fishery studies in Lokka reservoir and the plan for fishing and fish stock management (in Finnish)
Porttipahta	Sundbäck, K. 1977	The results of fishery studies in Porttipahta reservoir and the plan for fishing and fish stock management (in Finnish)
Porttipahta	Tekojärvien kalataloussuunnittelutyöryhmä, 1991	The plan for utilisation and management of fishery in Lokka and Porttipahta reservoirs (in Finnish)
Porttipahta	Verta, M. 1981	Mercury levels in fish in reservoirs in 1980 and estimate of the development (in Finnish)
Porttipahta	Verta, M. & Porvari, P. 1995	Mercury studies on fish and water in reservoirs and in the River Kemijoki (in Finnish)
Porttipahta	Verta, M., Rekolainen, S. & Kinnunen, K. 1986	Causes of increased fish mercury levels in Finnish reservoirs
Porttipahta	Virtanen, M., Hellsten, S., Koponen, J., Riihimäki, J. & Nenonen, O. 1993	Water quality model of northern reservoirs and its validation with field measurements (in Finnish)
Porttipahta	Väisänen, T. & Heiskanen, M. (eds.) 1995	Greenhouse gas from Lokka reservoir and Vuotos region (in Finnish)
Porttipahta	Väisänen, T. & Hellsten, S. 1996	Climatic effect of Finnish hydropower. Preliminary research (in Finnish)
Robert-Bourassa	Berkes, F.	Some environmental and social impacts
Shin-Takanosu	The Agency of Natural Resources and Energy, 1991	Location and environmental investigation report on Shin-Takanosu
Shin-Takanosu	Tohoku Electric Power Co., Inc.,1995	Outline plan report on Shin-Takanosu
Stjørdalselva	Andersen, K.M.	Vegetasjon og flora i øvre Stjørdalsvassdraget, Meråker. DKNVS rapport 1984(6) (in Norwegian)
Stjørdalselva	Gjessing, I.	Vurdering av mulige endringer for lokalklimaet (in Norwegian)
Stjørdalselva	Holmquist, E., 1987	Regulering av Fjergen, m.v. Hydrologisk grunnlag 1987 (in Norwegian)

Project name	Author	Document name
Stjørdalselva	Reinertsen, H. & Skotvold, T.	Resipientforhold i Fjergen, Fossvatn og øvre deler av Stjørdalselva (in Norwegian)
Stjørdalselva	Reitan, O. & Jordhøy, P. 1985	Vilt i området for planlagt kraftutbygging. DVF-rapport 2-85 (in Norwegian)
Stjørdalselva	Stubsjøen, I. & Hansen, J. H.; Nord Trøndelag E-verk (NTE)	Konsekvensvurdering av kraftutbyggingens virkning på områdets landskapsbilde (in Norwegian)
Stjørdalselva	Stubsjøen, I. & Hansen, J.H.; Nord Trøndelag E-verk (NTE)	Konsekvensvurdering av planlagt kraftutbygging på friluftsliv i området (in Norwegian)
Takami	Hokkaido Electric Power Services Co.	Investigation report on water temperature of Shizunai river (1976-1995)
Takami	Miyanaga, Y., Shirasuna, T. & Akimoto, T.	Reductive analysis of water temperature and turbidity on Takami reservoir, Lake Shizunai and Lake Futakawa
Takami	Noro, T. & Okumura, S.	Environmental studies on Takami project
Valparaiso	GHESA	Environmental impact assessment (1985)
Valparaiso	IBERDROLA	Hydrological study of the project
Valparaiso	LIMNOS	Study of the water quality in the Cernadilla and Valparaiso reservoirs. 1989

7. SUBTASK III/1 GLOSSARY

Anadromous	Fish that migrate from salt water to freshwater to spawn
Anthropogenic	Involving the impact of man on nature. Anything induced or altered by the presence or activities of man
Benthic organisms	Organisms of flora or fauna that live on the bottom of water bodies
Berm	An earthwork constructed for stabilisation purposes
Biome	One of the major categories of the world´s distinctive ecosystem assemblages
Capacity	The maximum sustainable amount of power that can be produced by a generator or carried by a transmission facility at any instant. Usually measured in megawatts (MW)
Cascade	A series of waterfalls forming a large waterfall
Catchment	The area of land which drains into a river, a reservoir or an estuary
Cofferdam	A temporary structure affecting all or part of the construction area so that construction can proceed in the dry. A diversion cofferdam diverts a river into a pipe, channel or tunnel
Compensation flow	The fraction of streamflow released through a hydroelectric dam specifically to meet the needs of downstream users and/or habitats
Construction disturbance area	Areas associated with the construction phase of a hydroelectric project where in general the most significant construction activities take place, including the power station(s), main dam, diversion and auxiliary dams and dikes, intake, tailrace, spillway, laydown zones, camp areas, new roads, and railways
Cumulative impact assessment	The assessment of the impact on the environment which results from the incremental impact of an action when added to other past, present or reasonably foreseeable actions regardless of what agency or person undertakes such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time
Denning area	Area where animals have their shelters (particularly caves)
Discharge	The volume of water flowing at a given time, usually expressed in cubic meters per second
Diversion	Leading water from one river to another river or reservoir
Documented degree of impact	What the impact actually was when the encroachment was done. The result must be formally described/proven (documented) in a report
Downstream area	Areas within the confines of the watercourse downstream of the construction area(s) which are, or are perceived to be, affected by the hydroelectric project during or after construction

Drawdown	Regulation height, total regulation amplitude
Energy	1. Force or action of doing work. Measured in terms of the work it is capable of doing. Usually, electric energy is measured in kilowatt-hours (kWh) 2. The capacity of a system to produce external activity
Energy dissipator	A structure installed in a watercourse whereby the energy in flowing water is scattered or diffused (=dissipated)
Environmental impact assessment	Synonymous to Environmental Assessment (EA). The systematic, reproducible and interdisciplinary identification, prediction and evaluation, mitigation and management of impacts from proposed development and its reasonable alternatives. The EIA is an on-going process of review, negotiation and incremental decision-making, culminating in the essentially political action of making a final decision about whether or not the proposal is to proceed and under what conditions. Following the definition made in the EU Directive 85/337/EEC of June 27, 1985, applies to the identification, description, and assessment of the direct and indirect effects of a project on human beings, fauna and flora, soil, water, air, climate and the landscape; the interaction of these factors; and on material assets, and on the cultural heritage
Environmental management system	A structured approach for determining, implementing and reviewing environmental policy through the use of a system which includes organisational structure, responsibilities, practices, procedures and processes (see also "ISO")
Estuary	Semi-enclosed coastal body of water with free connections to the sea in which the salinity is diluted by fresh water from a river
Eutrophication	1. A process where more organic matter is produced than existing biological oxidation processes can consume 2. The process of fertilisation that causes high productivity and biomass in an aquatic ecosystem. Eutrophication can be a natural process or it can be a man-made process accelerated by an increase of nutrient loading to an aquatic ecosystem by human activity 3. Process of nutrient enrichment of a body of water. In advanced state, causes severe de-oxygenation of the water body
Evapotranspiration	Joint effect of the loss of water to the atmosphere from the soil surface (evaporation) and from the plant surface (transpiration)
Expected degree of impact	What is thought to be the impact of an encroachment
Fledging	The process whereby birds develop new feathers (particularly wing feathers)

Flood control	Reducing the risk by building dams and/or embankments and/or altering the river channels
Flood management	Reducing flood risks by actions such as discouraging floodplain development, establishing flood warning systems, protecting urban areas and isolated buildings, and allowing the most flood-prone areas to remain as wetlands
Floodplain	Level land that may be submerged by floodwater
Flume	A channel of steel, concrete or wood that carries water (often used for diverting water in a stream)
Ford	Shallow place in a river where one can wade or drive across
Gabion	A wire basket filled with brick or stone. The baskets are used to line the stream banks and thus protect against erosion
Generator	A machine that converts mechanical energy into electrical energy
Greenhouse gases (GHGs)	Gases that trap the heat of the sun in the Earth's atmosphere, producing the greenhouse effect. The two major greenhouse gases are water vapour (H_2O) and carbon dioxide (CO_2). Other greenhouse gases include methane (CH_4), ozone (O_3), chlorofluorocarbones (CFCs), and nitrous oxides (NO_x). Anthropogenic greenhouse gases constitute the emissions generated by human activities
Groundwater	Subsurface water contained in saturated soils and rocks
Gross head	The height difference between the intake of water to the hydropower station and the turbine
Head	1. The vertical height of water in a reservoir above the turbine (see "gross head"). The more head, the more power is exerted on the turbine by the force of gravity 2. The difference between two water surface elevations
Hearing	A process by which the public, organisations, etc. can express their opinion on the project seeking approval and on the associated environmental studies
Hydroelectric	The production of electrical power through the use of the gravitational force of falling water
Hydrological cycle	The continuous interchange of water between land, sea or other water surface, and the atmosphere
Impact	Negative or positive effect caused by an encroachment, in this case the hydropower development
Impact management plan	A structured management plan that outlines the mitigation, monitoring and management requirements arising from an environmental assessment

Impounding	Creating a body of water by the construction of a dam
ISO	Acronym for the International Organisation for Standardisation
Kilowatt (kW)	A unit of electrical power equal to 1 000 watts (equivalent to about 1.3 horsepower)
Kilowatt-hour (kWh)	A basic unit of electrical energy equivalent to one kilowatt of power used for one hour
Large dam	Dam measuring at least 15 meters in height measured from the lowest point of foundation to the top (crest) of the dam. Dams between 10 and 15 meters in height may be defined as large dams if they meet at least one of the following conditions: 1. The crest length is not less than 500 meters 2. The total capacity of the reservoir formed by the dam is not less than 1 000 000 m^3 3. The maximum flood discharge dealt with by the dam is not less than 2 000 m^3/s 4. The dam had especially difficult foundation problems 5. The dam is of unusual design
Load	The amount of electrical power or energy delivered or required at any specified point or points in a system. Load originates primarily at the energy-consuming equipment of customers
Macrophyte	A member of the macroscopic plant life (here especially of a body of water)
Maximum operating flow	The maximum discharge that can pass through the turbines of a power plant
Megawatt	A megawatt is 1 000 000 watts, a measure of electrical power
Megawatt-hour	A unit of electrical energy equivalent to one megawatt of power used for one hour
Minimum flow	The fraction of streamflow released through a hydroelectric dam agreed upon in the hydraulic management of a hydropower plant (see also "compensation flow")
Mitigation measure	Action taken to prevent, minimise or avoid the real or potential adverse effects derived from the implementation of a project, plan., program, etc.
Mulch	Protective covering spread over the roots of trees and shrubs to retain moisture, kill weeds, etc.
Off-peak period	Period of relatively low demand for electrical energy

Other broad areas	Areas outside the construction area, the downstream area or the reservoir where impacts may occur during or after construction. Such areas may either be within the catchment, in neighbouring catchments, or in geopolitical or other areas wherein activities may take place and impacts may occur as a result of the project
Other specific areas in the catchment	Localised areas within the catchment, but outside the directly affected parts of the catchment where impacts may occur during or after construction
Peak load	The maximum electricity demand in a stated period of time. It may be the maximum instantaneous load or the maximum average load within a designated period of time
Pollarding	The process whereby the top of trees are cut so that many new thin branches will grow, forming a dense head of leaves
Portage	A place where boats or goods may be carried overland between two rivers, reservoirs or lakes
Power	Electrical energy generated, transferred, or used, usually expressed in kilowatts or megawatts
Project	Development of a hydropower facility or a set of related facilities
Project area	Area comprising the studied area(s) and river(s) and area(s) which are directly impacted by the project
Pumped storage plant	A hydroelectric plant that generates electrical energy to meet peak load by using water pumped into a storage reservoir during off-peak periods
Quarry	An open surface excavation for the extraction of building stone, marble, slate etc.
Regulated river	River where the natural flow pattern is altered by a dam or dams
Regulation factor	Percentage of average annual discharge that is possible to store in the reservoirs.
Rehabilitation	Activity aiming at an addition of power output in replacing or restoring existing turbine generator units near the end of their service life
Renewable power resource	A power source that is continuously or cyclically renewed by natural processes
Reservoir area	Areas which during or after construction of the project are converted from land, wetland or watercourse, to an impoundment for storage of water for use by the project hydropower station(s). Includes the riparian zone
Riffle	A construction in a watercourse (usually made of sand or rocks) to make a shallow stretch of water (see also "weir"(1))

Riparian zone	The bank of a river, pond, reservoir, or lake
Riprap	A layer of large stones, broken rock or precast blocks placed in random fashion on the upstream slope of an embankment dam or on a reservoir shore or on the sides of a channel as a protection against wave and ice action
Safety boom/ice boom	A barrier (e.g. a mass of logs) placed across a river to prevent the free movement of floating items (e.g. logs or ice)
Salinisation	The accumulation of salt in soil or water
Sediment	Mineral and organic matter transported or deposited by water or air
Sediment flushing	Method of reservoir operation in which the reservoir is temporarily lowered so that fast flowing water can erode accumulated sediments on the reservoir bed
Social intrusion	Interference with social networks, amenities or habits.
Sodding	The process whereby pieces of turf with grass growth are placed in an area
Spillway	A structure over or through which flood flows are discharged
Sump configuration	Shape of the cavity or hollow area into which waste liquid drains
Tailrace	Pipe or channel through which turbinated water is discharged into a river
Thermal stratification	The tendency in deeper lakes or reservoirs for distinct layers of water to form as a result of vertical change in temperature and therefore density
Topsoil	Superficial soil layer in which vegetation can grow
Transmission grid	An interconnected system of transmission lines and associated equipment for the transfer of electrical energy in bulk between points of supply and points of demand
Turbine	Machinery that converts kinetic energy of a moving fluid, such as falling water, to mechanical power, which is the converted to electrical power by an attached generator
Upgrading	Renovation activity which aims at improving a plant's productivity
Utilisation factor	The ratio between average annual capacity in operation and installed capacity, respectively, expressed as per cent. Plant utilisation factor can also be calculated as the percentage of time, on an annual basis, the plant has been operated at full capacity. The ratio between average discharge through the plant and the maximum operating flow expressed as per cent will generate about the same figure, so these characteristics can be regarded as exchangeable
Utility	A business organisation (e.g. an electric company) performing a public service and being subject to special governmental regulations

Waterlogging	Saturation of soil with water
Watershed	Area drained by a river (see also “Catchment”)
Watt	The basic unit of electrical power (W)
Watt-hour	Unit of energy (Wh) equivalent to the power of one watt over a period of one hour One kilowatt-hour (kWh) is equal to 1 000 Wh, one megawatt-hour (MWh) is equal to 1 000 000 Wh, one gigawatt-hour (GWh) is equal to 1 000 000 000 Wh, and one terawatt-hour (TWh) is equal to 1 000 000 000 000 Wh
Weir	1. A low dam across a stream to raise the upstream water level (termed fixed-crest weir when uncontrolled) 2. A structure built across a stream for the purpose of measuring water flow (=“measuring weir” or “gauging weir”)
Wetland	Area of land which is seasonally, intermittently or permanently waterlogged
Wharf	A structure made of wood or concrete at the edge of a water body where boats may land

8. LIST OF APPENDICES

<u>Volume I</u>: Definitions and categories used in the questionnaire (appendices 1-5):

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Appendix 4: Mitigation measures

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Appendix 6: Activities commonly connected to different impact groups specified on project and locality

Appendix 7: Activities commonly connected to mitigation measures

Appendix 8: Activities, impacts, count of impacts, main environmental issues and mitigation measures

Appendix 9: Main environmental issues and the success of mitigation measures

Appendix 10: Main environmental issues and count of degree of success of the various mitigation measures

Appendix 11: Environmental component type and count of environmental components in each impact group; physical, biological and socio-economic impacts

Appendix 12: Impacts and counts of expected and documented effects

Appendix 13: Documented permanent effect of impacts and connected mitigation measures

Appendix 14: Mitigation measures; success indifferent

Appendix 15: Mitigation measures; success low

Appendix 16: Mitigation measures; success high

Appendix 17: User Guide for the questionnaire on environmental impacts and hydropower

Appendix 18: The IEA questionnaire developed for Annex III; "Environmental Impacts and Hydropower"; paper version

Appendix 1: Locations in watershed

Name	Definition of location
Construction disturbance area	- Areas associated with the construction phase of a hydroelectric project where in general the most significant construction activities take place, including the power station(s), main dam, diversion and auxiliary dams and dikes, intake, tailrace, spillway, laydown zones, camp areas, new roads, and railways
Downstream area	- Areas within the confines of the watercourse downstream of the Construction Area(s) which are, or are perceived to be affected by the hydroelectric project during or after construction.
Other broad areas	- Other, often undefined or widespread areas either within the catchment, in neighbouring catchments, or in geopolitical or other areas wherein activities may take place and impacts may occur during or after construction.
Other specific areas in the catchment	- Localised areas in the same watershed as the hydroelectric project, either upstream, downstream or in parallel with the power station(s), but not necessarily within the confines of the watercourse, wherein activities may take place and impacts may occur during or after construction.
Reservoir area	- Areas which during or after construction of the project, are converted from land, wetland or watercourse, to an impoundment for storage of water for use by the project hydropower station(s)

Appendix 2: List of activities

Name
Aggregate extraction
Altering long-term river flow
Altering river flow route (diversion)
Altering short-term river flow
Blasting and drilling
Chemical spilling
Clearing ice jams
Clearing trash racks
Constructing offshore installations
Constructing onshore installations
Demolition of buildings
Dewatering and draining
Dredging
Effluent treatment and discharge
Emitting dust
Environmental inventory and sampling
Equipment maintenance
Excavating and fill placement in water
Excavating and filling on land
Generating noise
Grouting, concreting and asphalting
Impounding (reservoir filling)
Information delivery (reporting, meetings, hearings, consultation)
Installing and maintaining work camps, laydown areas, parking lots
Making and using stream/wetland crossings
Off-site waste disposal
On-site waste disposal
Operating at maximum power
Operating at peak efficiency
Operating at reduced output
Operating cooling and heating equipment
Operating motorised equipment
Operating on condensing mode
Pest control
Project and maintenance spending
Refuelling and using chemicals
Road maintenance
Sealing gates (cinders etc.)
Site rehabilitation
Soil stripping, grubbing and grading
Storing chemicals and waste
Trenching, ditching and culverting
Using bubblers
Using local services and amenities
Vegetation clearing and control
Vegetation disposal
Vehicle movement
Waste re-use and recycling
Worker leisure activities

Appendix 3: List of impact groups

Name
Biotoxicity
Change in biota habitat
Change in biota mobility
Change in channel morphology
Change in community and social services
Change in ecosystem community populations
Change in housing and property values
Change in human safety risk
Change in land use and policy plans
Change in local economy
Change in material translocation
Change in resource use – aquatic biota
Change in resource use – forestry, mining, agriculture
Change in resource use – recreational areas etc.
Change in resource use – shipping and transportation
Change in resource use – terrestrial biota
Change in social and community structure
Change in transportation and servicing
Change in water quality
Change in water quantity
Change in resource use – water
Climatic and local air quality changes
Cumulative effects of hydro and other facilities
Dust effects on biota
Human health effects of toxins
Increased erosion
Loss of heritage resources
Noise and human presence effects on biota
Physical impacts
Removal of vegetation
Sedimentation
Soil inundation

Appendix 4: Mitigation measures

Name	Comments and examples
Climatic and local air quality controls	- Design construction schedule to limit noise - Design blasting schedule and provide warnings, etc., to limit dust, smoke and noise disturbance - Design powerhouse to reduce operating noise - Design submerged outlet to limit frost mist, changes in winter air temperature, etc. - Provide or retain vegetation or engineered windbreaks for wind and dust control - Controlled burning to limit air quality impact of smoke - Limit construction and operational use of air pollutants - Use of environmentally acceptable dust suppressants - Maintain vehicles and equipment to limit noise and fumes
Economic impact management	- Train and hire local workers for project work - Award work and supply contracts to local firms - Enhance local recreational and community facilities - Enhance municipal infrastructures or create new ones in resettlement areas - Provide regional development planning - Provide monetary or other compensation - Support or enhance medical, social and communications services and facilities
Erosion prevention and control	- Timing of soil disturbance periods to avoid periods of high rainfall - Physical bank stabilisation (riprap, gabions, fibre mats, etc.) - Maximise use of previously disturbed areas during construction and operation (roads, cleared areas) - Stabilise stripped areas (mulch, berms, check dams, matting, hydroseeding, etc.) - Retain buffer strips of vegetation - Minimise water level fluctuation
Fish protection	- Design and construct fish ladders and fishways - Design diversion and by-pass facilities to aid downstream migration - Design intake, turbine and discharge facilities to reduce fish mortality or prevent entrainment - Use fish attractant or repulsion techniques or barriers (physical, acoustic, chemical) to mitigate blasting mortality and entrainment - Avoid in-water work during fish spawning and migration - Minimum flow during spawning and rearing of sensitive species - Water level management to mitigate effects of drawdown - Create or enhance spawning grounds or other habitat - Protect or re-establish areas of sensitive habitat for endangered species. - Promote fish farming - Fish stocking - Fertilisation - Management of harvests (fishing restriction) - Conduct fish rescue and relocation operations

(Appendix 4: Continued)

Name	Comments and examples
Human health and safety risk management	- Provide programs to warn downstream and upstream users of sudden flow variations - Spill prevention and response plan - Emergency preparedness and response plan - Chemical and hazardous materials storage and handling procedures - Provide fencing and safety booms upstream/downstream of stations, dams and spillways - Disease prevention, detection and risk management - Enhance medical services and facilities - Provide mercury-in-fish risk management program (including warnings on fish consumption limits) - Provide medical follow-up and mercury monitoring services - Design and operate facilities to decrease habitat for disease vectors - Vector control
Minimising soil contamination and loss of soil due to inundation	- Engineered landfills to consolidate and segregate potential soil contaminants - Excavate and properly dispose of known areas of soil contamination - Site selection to minimise reservoir flooding - Reservoir shoreline erosion control - Removal of reservoir substrate prior to inundation - Reclamation/stockpiling and re-use of topsoil
Mitigating cumulative effects of multiple hydroelectric facilities	- Site selection - Optimise cascade operation (e.g. improved manual or computerised water dispatching) - Negotiate operational constraints - Develop long-term watershed management plans - Carry out long-term monitoring programs
Mitigating effects on resource use	- Site planning to avoid time periods of important resource use (e.g. high use recreation or harvesting periods) - Design water allocation plans to accommodate large and small resource users in an equitable manner - Design roads (route selection, road standard, etc.) to optimise planning goals for resource use - Design and site facilities to avoid and minimise farm, mine, forest and other resource loss - Establish road access restrictions at levels to limit overexploitation of fish and wildlife and non-renewable resources or to optimise permissible access levels - Maximise recovery, marketing and use (by public, project or established users) of salvageable timber, crops, topsoil, peat, aggregate buildings, etc. prior to impoundment - Recover floating debris from reservoir to benefit recreational and other resource use - Provide wharf and ramp facilities - Provide temporary or permanent bypasses (roads, trails, portages, marine railways) - Provide maps and navigation aids - Increase land/water productivity to enhance resource use on adjacent or damaged lands - Retrain affected resource users and provide resource management programs - Negotiate and plan for integrated land use to reduce land use conflicts - Develop hunting, fishing, boating, commercial ventures - Assist in relocation and/or compensation of fixed commercial establishments (tourists camps, etc.)
Other	- Specify in 'Other mitigation measures'

(**Appendix 4: Continued)**

Name	Comments and examples
Protecting or minimising changes in channel morphology	- Design (site selection, etc.) for minimisation of changes in stream morphology - Design (site selection), block dams, excavation, etc.) for minimisation of size and shore zone characteristics of reservoirs - Dredging to re-establish channel characteristics - Stream restoration techniques - Creation of pools and rapids - Design and use of fords, bridges, and cofferdams - Use temporary flumes and site channels to protect sensitive stretches of river - Use tunnelling technologies under watercourses - Complete in-water work as quickly as possible during low-flow periods
Protecting or mitigating changes to aboriginal land use, cultural heritage, archaeological resources	- Ensure preservation of traditional land uses for aboriginal peoples (e.g. hunting, fishing, trapping, gathering, burial sites) - Re-establish reserved lands or provide alternative reserved lands or other compensation for use by aboriginal peoples - Conduct inventories of cultural resources - Protect cultural heritage features - Relocate cultural resources - Create archaeological or cultural museums, or establish points of interest including lookouts
Protecting or mitigating changes to landscape	- Protect areas with important landscape features - Landscape enhancement by clearing trees from reservoirs or upland areas to improve waterscape and landscape aesthetics
Protection of valued ecosystem components (aquatic and terrestrial habitats, communities, rare, threatened species and spaces, and particular species other than fish)	- Habitat protection (specific to habitat type, e.g. wetland, riparian, upland) - Habitat enhancement (specific to habitat type) - Habitat creation (specific to habitat type) - Retention of key habitat features (stumps, licks, colonial nesting areas, caves, denning areas, etc.) - Protection of rare, threatened and endangered species (fencing; road gating; nest relocation, new nesting structures, etc.) - Programs for rescue and relocation of animals - Schedule work which disturbs animals (due to noise human presence, traffic) during non-sensitive time periods (breeding, nesting, wintering, rearing, fledging, etc.) - Anchor floating peat bogs - Forest management - Wildlife management (hunting restrictions) - Provide environmental awareness training to construction staff
Protection, replacement and control of vegetation	- Design (site selection) to minimise vegetation removal, to selectively clear certain areas for specific benefit (e.g. trimming, pruning, pollarding, etc.), or to retain particular types or zones of vegetation (endangered, riparian, wetland) - Revegetation programs (including monitoring and maintenance): conduct fertilising, seeding, hydroseeding, sodding, and plant tree seedlings and other propagules, either on site or in compensation elsewhere - Habitat replacement or enhancement - Protection of endangered vegetation and spaces (e.g. wetlands) - Retain vegetated buffer strips around work areas and shore zones - Fire prevention and control program and provision of firefighting equipment - Promote aquatic macrophyte growth - Weed control measures (e.g. harvesting for compost, fodder, biogas; regulation of water levels and discharges to control weed growth) in areas stimulated by increased nutrient levels

(**Appendix 4: Continued)**

Name	Comments and examples
Sedimentation prevention and control	- Design intakes to enable sediment bypass and prevent local setting - Reduce sediment mobility by providing settling ponds, silt fences, in-stream silt curtains, cellular cofferdams - Controlled dredging and segregation of dredgeate - Reduce in-water and shoreline work and work on erosive slopes - Use established, specially prepared fords or bridges - Control watershed land use to prevent sedimentation of reservoirs (e.g. reforestation, conservation).
Social impact management	- Site planning and scheduling to accommodate resettlement needs - Avoid dislocation of communities and unacculturated peoples to the extent possible - Create a communications plan, enable local consultation and stage information presentations with local communities - Provide for a community impact agreement - Create liaison committees to solve social problems - Provide compensation - Conduct monitoring programs - Develop dispute resolution processes to handle unforeseen issues
Water quality protection and adjustments	- Design measures (site selection) for keeping contaminants away form watercourses (e.g. refuelling sites, landfills, berms, sewage tile drains, etc.) - Design measures to limit discharges of contaminants (drip-trays; refuelling practices; transformer and sump configurations, etc.) - Spill prevention and response plan and deployment of clean-up equipment - Aeration and provision of weirs or rapids for DO improvement - Provide minimum flow for downstream DO improvement - Water intake design for establishing downstream temperature control and reservoir stratification pattern (selective intake) - Provide minimum flow for downstream temperature control - Provide alternative sources of high quality water - Tailrace tunnel design to control gas supersaturation - Sewage treatment for nutrient and bacteria control
Water quantity control (flow, velocity, level; including ice formation and movements)	- Design and construction of intakes, weirs, dikes, riffles, energy dissipators and diffusers for water level and velocity control - Site selection to avoid activities in areas sensitive to flow and level changes (e.g. groundwater recharge areas) - Manage facility flows to regulate water velocities, flows and levels - Provide minimum flow to prevent dewatering of downstream areas - Provide flushing program - Design of excavations and provision of block dams along reservoir and stream perimeters to manage the size of the drawdown shore zone - Regulation of flow to minimise salinisation of floodplain lands - Maintain minimum flow to prevent salt water intrusion in estuary and upstream - Provide weirs or ice booms to control ice movements - Provide bubble systems to prevent local ice build-up - Flow management to manage ice hinge formation

Appendix 5: Environmental component types

Name	Components
Aquatic biology	Fauna Fish community Fish migration Flora Mercury Red-listed species
Economy	Agriculture Commerce Employment Fisheries (fish stocking) Fisheries (others) Forestry Hospitals Industry Recreational areas Reindeer husbandry Schools Tourism employment Transportation Water supply
Estuarine and coastal habitat	Circulation Coastal habitats Salt intrusion/plume Sediment dynamics Tide
Geophysics	Earthquakes Landslide
Global effects	Greenhouse gas emissions
Hydrology	Erosion Evapotranspiration Flood frequency Flow regime Fluvial geomorphology Groundwater level Recipient Sedimentation
Landscape	Access roads Landscape appreciation Quarries Rock tips Transmission lines
Local climate	Air humidity Air temperature Fog frequency Frost mist Water temperature Wind
Other	Others

(Appendix 5: Continued)

Name	Components
Social	Indigenous people Noise and vibration Nutrition Places of religious/historical value Resettlement Sexually transmitted diseases Social intrusion Waterborne diseases
Terrestrial biology	Fauna (birds) Fauna (insects) Fauna (mammals) Flora Red-listed species
Unspecified	Unspecified
Water quality	Drainage from construction work Eutrophication Extended biotic index Floating peat Heavy metals Oxygen content Temperature Transport of elements and matter Turbidity or suspended solids

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