Structuring of Education and Training Programmes in Hydropower Planning, and Recommendations on Teaching Material and Reference Literature

IEA Technical Report

IEA Hydropowe
Agreement

IADA 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

STRUCTURING OF EDUCATION AND TRAINING PROGRAMMES IN HYDROPOWER PLANNING, AND RECOMMENDATIONS ON TEACHING MATERIAL AND REFERENCE LITERATURE

May 2000

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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 on Positive and Negative Environmental and Social Impacts and the Effects of Mitigation Measures in Hydropower Development – 2000 (available to non-participants on request)

A Comparison of the Environmental Impacts of Hydropower with those of Other Generation Technologies – 2000 (available to non-participants on request)

Legal Frameworks, Licensing Procedures, and Guidelines for Environmental Impact Assessments of Hydropower developments – 2000 (available to non-participants on request)

Hydropower and the Environment: Present Context and Guidelines for Future Action
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Guidelines for the Impact Management of Hydropower and Water Resources Projects – 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).

PREFACE

This report is the result of the work of subtask 4: "Structuring of Education and Training Programmes in Hydropower Planning, and Recommendations on Teaching Material and Reference Literature" of the Task Force on *Annex V: Education and Training*, which is one of four task forces of the *IEA Implementing Agreement for Hydropower Technologies and Programmes*. The subtask started its work in February 1998, and has drawn on the resources and expertise of the three participating countries in the task force.

The objective of the work of this subtask is to improve education and training (E&T) programmes in hydropower planning. An international survey of current E&T practices in this sector was the basis for the development of recommendations and suggestions of potential methods. This survey has been carried out as subtask 3 in Annex V, and the results have been compiled in a separate report. A similar survey of current E&T practices in hydropower operation and maintenance, and a set of recommendations and methods for E&T in this sector, were carried out as subtasks 1 and 2 respectively. Subtask 5 of Annex V will look into the implementation of information technology in hydropower E&T, and create a web-site for Annex V results.

Professor Dagfinn K. Lysne, the Norwegian University of Science and Technology (NTNU) was instrumental in initiating Annex V. Until he sadly passed away in January 2000, he was the Operating Agent for Annex V as well as the subtask leader for subtask 4. He managed to complete a draft report of this subtask, containing all essential information, discussions and recommendations. The undersigned has edited the report and added some minor elements, and Dr Haakon Støle, NTNU, has been very helpful in preparing Appendix C, and has given valuable advise to the report.

Tore S. Jørgensen
Operating Agent
Annex V

SUMMARY

This report describes alternative philosophies of design of university degree programmes for hydropower engineers, on the basis of a growing need for a more multi-disciplinary approach to hydropower development. The reasons fot this are the rising worldwide demand for electricity as well as growing concern about environmental issues. Appropriate subjects in various E&T models are therefore proposed.

The first section discusses which elements are covered by the term “hydropower planning”, and concludes that it comprises the reconnaissance study, prefeasibility study and feasibility study. The academic elements of hydropower planning as aspects of the wide sector of “water resources engineering” are also discussed, and the important role of the project manager in a planning team is underlined.

The results of the survey of current E&T practices in hydropower planning are summarized, and it is concluded that the survey provides a representative picture of available E&T opportunities, although it was not the intention of the work to produce a complete mapping. Relevant activities at certain schools and universities are briefly described, and more detailed information on some selected programmes is found in the appendices.

The next section emphasises the uniqueness of each and every hydropower project, and describes the characteristics of the three different phases in the planning process, or pre-construction period. The importance of a structured screening of projects is described, as is the sequenced split-up of the planning phase. The different roles of the members of the planning team are outlined (project manager, hydropower planner, specialists), and a check-list of procedures involved in a feasibility study is presented. The report clearly demonstrates the need for multi-disciplinary expertise in the planning process, and underlines the importance of well-planned E&T programmes for professionals in this sector.

Section 4 focuses on the characteristics of a degree-oriented education versus hydropower specialisation based on practice and continuing education, or training, which is the term used in this report. Several options are available in order to become a professional specialist, such as taking on-the-job training combined with reading up on new literature, short courses and seminars, and continuing university studies to M.Sc. or Ph.D. level. The most effective combinations of options are discussed, dependent on the topics.

The final section proposes structures for B.Sc. and M. Sc. degree programmes in hydropower engineering and planning respectively. The academic versus the professional approach to a M.Sc. programme is discussed.

1. INTRODUCTION

The hydropower sector is becoming increasingly globalised. One reason for this development is worldwide concern about environmental issues. Others are the rising demand for electricity due to the growth of the world economy, and the growing international trade in electricity. These trends call for international cooperation in developing new knowledge. Even more important is the dissemination of knowledge to those who need it.

The challenges are not limited to technical issues, but also include legislation, economic and environmental issues and better decision-making processes and assessment methodologies. This goes for all kinds of hydropower projects, whether they are small or large, new projects or old power plants in need of upgrading.

This was the reason that the International Energy Agency (IEA) initiated the Implementing Agreement for Hydropower Technologies and Programmes, with one sub-programme covering Education and Training (E&T)

The objective of the work of this subtask is to improve education and training programmes in hydropower planning. As a basis for developing recommendations and potential methods, a survey was carried out. The results of the survey are summarized in chapter 2 of this report. It has been beyond the scope of this sub-programme to produce a complete mapping of all existing E&T offered in hydropower planning. The objective has therefore been to produce a representative picture of the current situation.

In conventional terms hydropower planning comprises the following steps:

<u>STUDIES</u>	<u>PLANS</u>
- Reconnaissance (basin study)	- Master plan
- Prefeasibility study	- Least cost dev. plan
- Feasibility study	- Project implementation plan

Final design, Tendering and Contracts are steps which some people include under "planning". It is more correct, however, to include these steps under "implementation".

Expertise and experience in hydropower planning are, of course, aspects of the wide sector "Water Resources Engineering". The author of this report has assisted in drawing up detailed plans for both formal education and training organized in various ways, covering water resources engineering as well as hydropower more specifically. His experience has been that the main structure of the plan is about the same for the two issues. It is only the priority and scope of some of the topics to be taught which is different.

Hydropower development is a typical interdisciplinary task. In most cases, the person(s) responsible for organizing the activities and coordinating the work of the specialists involved is a civil engineer. A team organized to handle one of the steps in the planning process, say a feasibility study, is illustrated in Figure 1.1

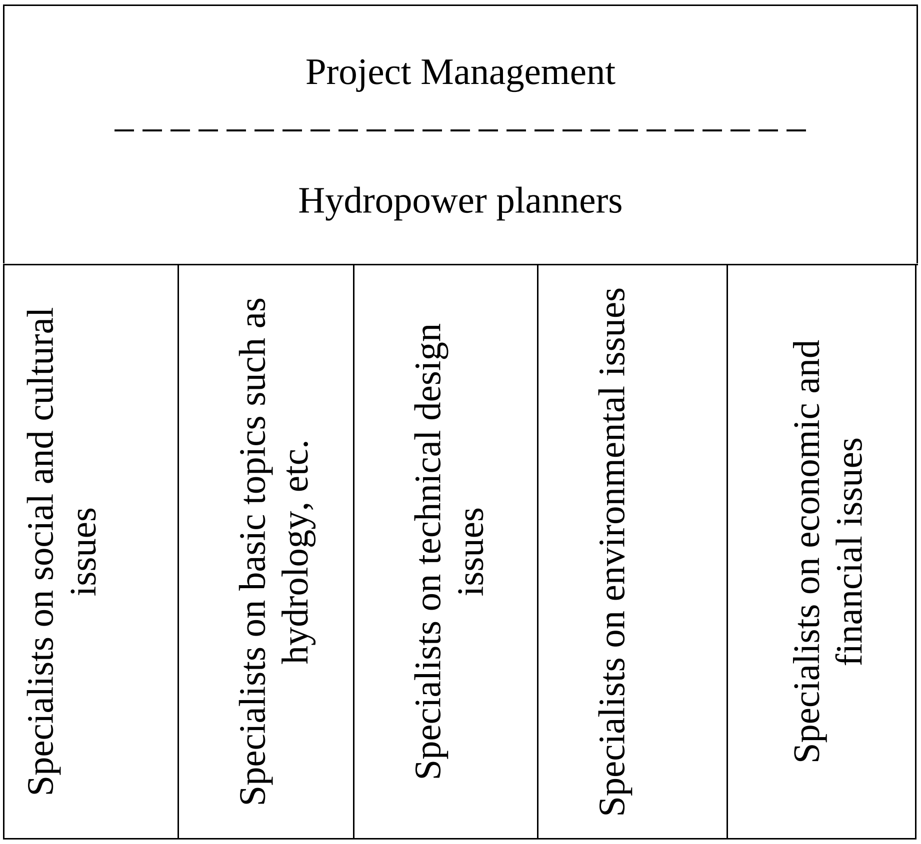

Figure 1.1 Organization principles for a hydropower planning team

Recruitment of specialists is normally the least challenge when a project is being planned. Most specialists may have their education from any good university even if it does not focus on hydropower development. Specialists can relatively easily work in different sectors of engineering. When working in the hydropower sector, a few years will provide the necessary overview with respect to the objectives and scope of a hydropower planning study.

This is different from becoming a project manager and/or hydropower planner. The common practice in most hydropower companies, consulting firms or similar is for young engineers to start their career as design engineers. It is also considered advisable to be involved in construction, i.e. to work on construction sites for some years. To advance to project manager/hydropower planner through on-the-job training takes many years. In addition, courses covering subjects such as economics, characteristics of environmental impact studies (EIA), management etc., are part of the training. Nevertheless it takes many years to be assigned a job as manager or planner. About 20 years is common. Approval for the position as assistant manager and planner requires 12 to 15 years of experience in hydropower. One reason why project managers/planners in hydropower need such comprehensive training on top of a university degree is that good general knowledge of a number of subjects is necessary - easily more than 20 subjects. This report therefore puts some extra focus on E&T for managers and planners in hydropower studies. Some graduate programmes have been designed to meet the specific needs of this target group.

2. SUMMARY OF SURVEY OF CURRENT E&T PRACTICE IN HYDROPOWER PLANNING

The objective of the survey was to identify universities or other institutions that offer E&T in Hydropower Planning in order to provide a representative picture of current opportunities. It was beyond the scope of Annex V to attempt to produce a complete mapping of all existing offers in hydropower planning E&T world wide.

In order to achieve this objective a combination of questionnaire surveys, task force member networking and interviews was employed. Workshops were also arranged, at which contact was established with key persons from several countries. There is reason to assume that some relevant E&T activities have not been identified. Nevertheless it is believed that the survey offers representative information.

In this report the results are summarized in three sections. Section 2.1 covers the questionnaire survey, section 2.2 refers to the outcome of the networking and interviews and section 2.3 offers the results from the workshops.

2.1 Questionnaire survey

It was decided to make use of questionnaires as one of the tools to gather information. A two-step strategy was selected, with a simple, two-stage questionnaire forming the first stage.

This questionnaire was sent to 120 addresses with the intention of establishing a network of contacts throughout the hydropower industry. The results have been compiled and evaluated by regions; Africa, America, Asia, Australia and Europe.

A total of 31 Stage 1 questionnaires from 18 countries were completed and returned. Through additional background knowledge and contacts, the survey actually counts 29 countries.

The coverage of the initial questionnaire was as follows:

Africa:	25 countires
Asia:	15 countries
America:	11 countries
Europe:	6 countries
Australia/NZ:	2 countries
Total	59 countires

<u>Responses from Africa</u>

Question	No	Yes
Is education in hydropower planning available in your country?	11	1
Is there any kind of organised training in hydropower planning in your country?	12	0

The only country responding with a "Yes" was Zambia; The University of Zambia, School of Engineering, Lusaka. The University of Dar es Salaam in Tanzania has established a regionally oriented M.Sc. programme in Hydropower Planning which may be implemented soon.

Responses from America

Question	No	Yes
Is education in hydropower planning available in your country?	3	1
Is there any kind of organised training in hydropower planning in your country?	3	1

Two universities in Brazil report E&T activity in hydropower.

Responses from Asia

Question	No	Yes
Is education in hydropower planning available in your country?	7	5
Is there any kind of organised training in hydropower planning in your country?	10	2

Thailand, China and Taiwan are offering E&T in hydropower. Both universities and national power companies are actively involved.

Responses from Europe

Question	No	Yes
Is education in hydropower planning available in your country?	1	2
Is there any kind of organised training in hydropower planning in your country?	1	2

The questionnaire did not give a true picture of the situation in Europe. As being reported below, E&T in hydropower is found in Sweden, the Netherlands, Russia, Greece and in Norway.

2.2 Personal network and direct contacts

To all responders with an E&T offer in hydropower planning a phase 2 questionnaire was mailed as a follow up. The purpose of this questionnaire was to compile detailed information about how various topics of importance for hydropower planning were being dealt with.

The response to this questionnaire was not satisfactory for the purpose of the study, so our network of personal contacts was brought into action. The information gathered through these contacts is summarized below.

Zambia

A contact meeting was held at Kafue Gorge Regional Training Centre in 1997. Contact was established with 12 participants from four African countries in addition to Sweden and Norway. The meeting also included a workshop which gave valuable input for the work of the subtask.

Tanzania

The University of Dar es Salaam has established the curriculum for a regionally oriented M. Sc. programme in Hydropower Planning. The programme was conceived as a result of a regional survey which showed that there is a great need for E&T in the planning, implementing and operation of hydropower projects in the SADC region. An outline of the programme is found in Appendix A.

Ecuador

At the Latin American Energy Organisation (OLADE) in Ecuador a M.Sc. programme has been developed in Energy and the Environment in cooperation with the University of Calgary. The programme is particularly for students from Latin America and the Caribbean, and is aimed at high-level technical and managerial professionals from the government and energy companies. The programme is thus not a specialized hydropower programme, but touches on a number of areas and topics, both energy and environmental, and tries to establish connections between the two spheres.

Thailand

In Thailand, Kasetsart University and the Asian Institute of Technology (AIT) were cited as institutions that offer E&T, and the Electricity Generating Authority of Thailand (EGAT) also offers internal training programmes. AIT is known to concentrate on water resources engineering. M.Sc. programmes in “Water Resources Development” and “Irrigation Engineering and Management” are outlined in Appendix A..

India

The University of Roorkee offers E&T in Hydropower Planning. Two centres at the university, the Water Resources Development Training Centre (WRDTC) and the Alternate Hydro Energy Centre (AHEC) are actively offering E&T to the region. For many years WRDTC has been running a programme in which the participants may either complete their studies in 10 months or stay on for a further six months to obtain a Masters degree. The M.Sc. course "Alternate Hydro Energy Systems" is being implemented at the Alternate Hydro Energy Centre. Examples of the Roorkee offers are found in Appendices A and B.

China

Several universities are offering E&T in the design of hydropower projects. Special reference is made to the "Graduate School of North China Institute of Water Resources and Hydropower", which offers Graduate Student Education (M.Sc.), distance education (B.Sc.) and continuing education (training). The strategy for the E&T is to engage in "the cultivating of qualified personnel with skills in both hydraulics and hydropower technology and management”.

Nepal

A M.Sc. programme in Water Resources Engineering was started at Tribhuvan University in Kathmandu in 1999. An outline of the programme is found in Appendix A. There are plans to start a M.Sc. programme in Hydropower Development. Discussions are ongoing between Tribhuvan University and the Norwegian University of Science and Technology (NTNU), where there is a similar programme.

The Netherlands

At the International Institute for Infrastructural, Hydraulic and Environmental Engineering (IHE) in Delft, The Netherlands, a core activity is the provision of postgraduate educational programmes leading to M.Sc. and Ph.D. degrees. A large majority of the student body consists of engineers and other professionals from developing countries, while a few come from Eastern/Central/West European countries, Australasia and North America. A total of some 320 students a year take the 12-month M.Eng. or M.Sc. programme. Specialisation is provided in a number of topics. Hydropower is included as part of the specialisation in River Engineering. M.Sc. and M.Eng. research topics cover Hydraulic Structures - Hydraulic and Morphological Phenomena in Rivers - Dams and Dikes - Environmental Impact Assessment/Mitigation Measures, etc.

Russia

Hydrotechnical construction is one of the basic courses taught by the Faculty of Technology Economics and Management, Department of Hydrotechnical Construction at the St. Petersburg State Technical University, for the degree of Professional Specialist Hydrotechnique, code No. 290400. The academic plan of this course is oriented towards the training of Civil Engineers (Hydropower) who will be capable of working in a wide range of fields, such as Energy, Industrial, Urban Planning, Highways, Operation and Maintenance of Hydropower.

Sweden

The Royal Institute of Technology (KTH) in Stockholm, Sweden, Division of Hydraulic Engineering, teaches hydropower-related topics such as Ecology, Geology, River Engineering, Applied Hydrology, Development of Water Resources and Environmental Impact Assessment.

The Luleå University of Technology (LuTu) started up a 3-year B.Sc. programme in hydropower in cooperation with the Jokkmokk Training Centre in 1997. An outline of the programme is found in Appendix A. Due to low response from Swedish students this programme will be terminated when the 1999-class of students has completed its education in 2002. LuTu is now planning an international M.Sc. programme in hydropower engineering as a possible alternative. Asian Institute of Technology in Bangkok, Thailand has been selected as the international university partner. The programme curriculum will be shared between the two universities.

Norway

The Norwegian University of Science and Technology (NTNU) offers a full range of courses and research leading to a M.Sc. or Ph.D. in hydropower planning and design for Norwegian students. Since 1993, the university has offered an international M.Sc. programme in Hydropower Development. This M.Sc. study is replacing the 10-month diploma course which was taught since 1976. An outline of the programme is found in Appendix A.

Since 1997 the International Centre for Hydropower (ICH) in Norway has offered three-week intensive courses on hydropower topics; "Hydropower Resources Development and Management " and "Hydropower and the Environment". The target group for these courses is hydropower professionals who hold at least a B.Sc. degree in hydropower engineering or have an equivalent background in the fundamental engineering aspects of hydropower systems, and a minimum of 10 years of working experience. Outlines of the courses are found in Appendix B.

3. OBJECTIVES AND SCOPE FOR E&T IN HYDROPOWER PLANNING

No two hydropower projects are identical. Each project is designed to meet an existing demand for electric power and energy and must be tailored to this requirement and to the physical conditions at hand.

Precise and reliable knowledge about the market situation, socio-economic trends and development plans are needed in order to make predictions about the future need for electricity and to establish a demand (or load) forecast. In this connection not only the size of the demand needs to be known but also the type of peaking load, peaking requirements, etc.

This statement alone demonstrates that E&T for hydropower planners and project managers needs to impart a certain level of knowledge in a wide range of topics. This includes also authorities and finance institutions which play an important role in the planning process.

To avoid confusion, or even chaos, the development of hydropower follows well-defined stages. Each stage takes the project a step forward in the development cycle, based on the findings from the current and previous stages.

The hydropower development cycle consists of three main stages:

- Pre-construction
- Implementation (Construction)
- Operation

Most of the study, planning and design activities take place in the first stage. Normally, the investigation and planning of hydropower projects pass several milestones before projects are accepted for implementation. E&T covering the pre-construction phase is the scope of this report, and is dealt with in the rest of this section.

Project investigation, planning and design are normally organized in a series of consecutive studies which are listed here in increasing order of detail, importance and reliability:

- Reconnaissance studies
- Prefeasibility studies
- Feasibility studies

The studies are documented in reports. All relevant information shall be reported so that data and findings are available for all other parties which may be involved in the project.

The planning and design of hydropower projects involve so many different technologies and types of technical, environmental, social and economic expertise that investigations must be organized in a rational and structured manner. However, the

results of project investigations may prove negative and investigations are therefore arranged in self-contained steps or phases.
In each phase of development, projects are investigated to the depth needed to reach a conclusion regarding their capability and suitability for the stated purpose. In each subsequent investigation phase, the depth and detail of investigation are increased. The projects pass new suitability criteria and are either included in the catalogue of possible projects or passed on to the next phase of investigation

Only a small fraction of hydropower options will meet development criteria. Time and money are therefore saved if the least attractive options are screened out at an early stage. The sequenced split-up of the planning phase of projects is both practical and, in the long run, economic. The logic of approaching the final result in organized and orderly steps is evident. Each step is based on the findings and results of the preceding steps, after careful examination and modification when necessary.

Such a gradual development of the plans ensures that all probabilities have been investigated and examined. When conducted in a rational manner, it also ensures that unsuitable projects are not pursued further than necessary. Unsuitable projects or project alternatives should be discarded before reaching the conclusion of the planning phase, thus avoiding unnecessary expenditure.

The sequential screening and selection process described above is illustrated in Figure 3.1.

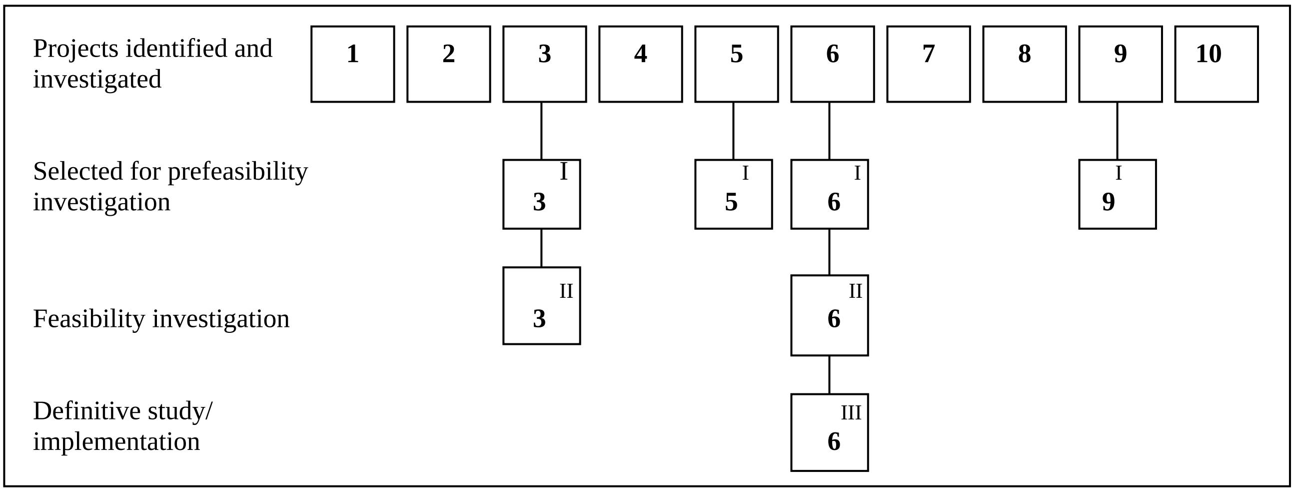

Figure 3.1 Hydropower resources investigation, and selection of projects (from Jarle Ravn; "Planning and Implementation of Hydropower Projects", Tapir 1992)

3.1. Reconnaissance study

Reconnaissance studies are normally the first step in project-oriented planning. Such studies are of a preliminary nature as their purpose is not to investigate projects in detail but, like basic hydropower investigations, to identify and investigate the hydropower resources available.

Unlike basic investigations carried out in connection with hydropower inventories, reconnaissance studies are carried out for specific purposes and have defined terms of reference.

The specific purpose leading to reconnaissance investigations is usually a defined need for electric power and energy, i.e. existing power markets or demand forecasts.

Reconnaissance studies are organized along the same lines as the planning studies that follow them; prefeasibility studies, etc., but with much less detail and accuracy requirements. Having all planning studies organized in a similar way will facilitate investigations as well as reporting, and comparison with other project opportunities.

A project team would normally include the following personnel as a minimum:

- Hydropower Planner/Team leader
- Hydrologist/Engineering Hydrologist
- Geotechnical Expert/Engineering Geologist
- Experts covering various fields and specialities
- Support personnel.

On the basis of planning data and input from other team members, the hydropower planner would formulate a project suitable for the stated purpose. He/she would also be responsible for providing a project description and the necessary drawings to illustrate project lay-out and components. On the basis of this material, preliminary cost estimates and implementation schedules are prepared, and estimates of power and energy production would be drawn up.

The hydropower planner/teamleader is normally also responsible for reporting. He/she would be given inputs by other team members and outside experts consulted but would structure the study report, coordinate and control the text and do the final editing himself.

3.2 Prefeasibility study

The second organized step in hydropower investigation and planning is called the prefeasibility study. In this phase one or more identified projects are brought one step further in the planning process.

The purpose of prefeasibility studies is to:

- Establish the need and justification for the project
- Formulate a plan for developing the project.
- Determine the technical, economic and environmental practicability of the project
- Define the limits of the project.
- Ascertain local interest in and need and priority for the project.
- Make recommendations for further actions.

Selecting identified projects for further study means that they are found interesting in hydropower terms and may become development material. It also means that further investigations and processing are needed. When several projects are involved it also means they are part of a selection process in order to find the best project for the purpose.

During the prefeasibility study, identified projects may change considerably with regard to siting, layout and structures. This is a natural development, a result of the planners becoming familiar with the project area and doing their job of continuously trying to improve the product.

Reconnaissance methods are short-cut methods, involving estimates based on incomplete data and on average or general experience tempered by judgement.

It is obvious that comprehensive and reliable data provide the ideal bases for planning water-resource developments. However, there is often an urgent need for resource development in areas where data are limited or non-existent and time does not permit the accumulation of long-term records. Lack of hydrology data is often the most difficult aspect in this respect. In such cases, it may be necessary to utilise careful estimates and interpretations. Throughout the planning process, however, there is no substitute for wide and relevant experience and sound judgement on the part of the planners.

In principle the project team involves the same type of personnel as the reconnaissance study, but with more responsibility being placed on the hydropower planner/team leader and more input from experts. The overall responsibility is very often shared by two persons:

- the team leader/project manager
- the hydropower planner.

3.3 Feasibility study

The next stage, the feasibility study, is a comprehensive analysis and detailed study of the contemplated project, directed towards its ulitimate authorization, financing, design and construction. The feasibility study is carried out in order to determine the engineering (technical), economic and environmental feasibility of the project. Its report also serves as application documentation for the development licence.

The report also provides a basis for the appropriation of funds and the negotiation of loans from financing institutions for design and construction of the project.

The purpose of the investigation is to establish and define the specific engineering and operation plan and to determine whether the potential development has technical, economic and environmental feasibility and justification under anticipated economic conditions.

The feasibility study plans must be sufficiently firm to ensure that no major alteration or modification which would significantly increase costs or otherwise impair the feasibility of the project will be found to be necessary in the course of final planning and construction; hence, as far as is practicable, plan formulation studies should reduce alternative plans, facilities or materials to a minimum.

The feasibility investigation should provide firm, detailed and reliable information upon which the government and/or owners can base authorization of the project for development and from which lending agencies can determine the desirability of financing it.

International finance institutions and similar organisations have rules and quality requirements for feasibility studies. A study conducted according to these rules for a project and which is found to comply with normal feasibility requirements is termed "bankable". Such studies are generally accepted as basis for loan applications.

The following check-list demonstrates the procedures involved in a feasibility study, as seen from the executing planners point of view:

1. *Mobilisation*
- mobilise study team
- establish liaison and cooperation with owner or developer
- establish study organisation and liaison with authorities

2. *Data and Information*
- collect relevant studies, data and information
- review prefeasibility study data
- screen and control new data and establish project data-bank on:
  - power market
  - existing infrastructure
  - hydrology, meteorology and sedimentology
  - topography and maps
  - geology, soil and materials
  - multipurpose aspects
  - environmental disturbance and constraints
  - socio-economic conditions

3. *Project Formulation*
- review prefeasibility study plans
- revise and update prefeasibility study plans and prepare preliminary project formulation based on all relevant data and information, employing upgraded planning paramenters and criteria
- verify the project formulation in the field and adjust it to physical field conditions, new information, restrictions and requirements.

4. *Field Investigations*
- review and adapt existing investigation programme
- approve contract documents for investigations
- assist owner in engaging contractors for field-work
- start, monitor and supervise field-work
- arrange for laboratory testing of samples
- interpret results and adapt the field investigation programme

5. *Project Layout*

- update and revise planning parameters
- prepare desk project layouts
- reconnoitre in the field for alternative layouts
- establish layout and main project components, verify in field
- obtain owner's approval for project formulation, layout and main components and facilities
- adapt field investigation to accepted layout

6. *Engineering Design*

- prepare preliminary design of the project and optimize layout and main project components, such as:
  - river transfer and diversion
  - regulation works
  - intake and waterways
  - power house and appurtenant facilities
  - transmission lines and substations
  - permanent site installations
  - roads, camps and spoil deposits
- establish dimensions and describe main and auxiliary project equipment and prepare performance specifications for the complete outfitting of the power plant; hydro-mechanical, electro-mechanical and auxiliary equipment:
  - turbines and valves
  - generators and switchgear
  - transformers, power cables, switchyard and substations
  - auxiliary equipment for monitoring, protection, control, etc.

7. *Environmental Impact Assessment (EIA)*

8. *Scheduling and Estimates*

- prepare construction plans and implementation schedules
- prepare cost and price study:
  - establish main item volumes
  - establish unit prices for main items
  - establish percentual (%) additions needed for supplementing main items/elements to complete the estimate
  - establish the "general cost" components
  - establish estimate confidence level, volumes, prices, etc. and establish contingency factor levels
- submit cost enquiries to suppliers of electro-mechanical and other equipment
- prepare cost estimates for project implementation, including:
  - civil works
  - hydro-mechanical works
  - electro-mechanical works
  - transmission works
  - environmental and resettlement costs
  - land acquisition/rights of way
  - investigations
  - engineering and management

- contingencies

· compile above estimates into an implementation cost estimate or budget:
    - arrange disbursement schedules, based on the cost estimates and implementation schedules
    - establish cost figures for annual operation, maintenance, rehabilitation and administration costs
    - establish market value of electricity at places where changes in ownership occur
    - establish annual income flows from sales after correcting for losses and pick-up rate, etc.

9. Economic and Financial Analysis

· prepare cash flow tables showing project costs and income streams over the lifetime of the project:
    - cash flow for economic analysis
    - analysis of financial terms and equity and debt service
    - cash flow for financial analysis
    - carry out economic and financial tests and establish EIRR and FIRR for the project base case
    - carry out sensitivity analysis to register the effects of changes in primary parameters
    - least cost project considerations
    - formulate statement on economic and financial feasibility.

10. Additional and Optional Work

· to complete the feasibility investigations some or all of the following items should be covered:
    - preparation of investigation programme for definite plan study, including cost estimate
    - financing study (optional)
    - tariff study (optional)
    - report on geo-investigations and other investigations carried out during project investigation.

11. Reports

The owner/executing agency is periodically informed through progress reports. Changes and similar items and their approval are documented via interim reports.

The feasibility study report should comprehensively document the feasibility study investigations, the findings and the information they are based on and should firmly attest to the quality of the study. The report must include firm statements about the project's technical, economic/financial and environmental feasibility and recommendations on its suitability and prospects.

Feasibility study reports are rather comprehensive documents and an executive summary is often prepared to make them more accessible to the public.

The executive summary and main report are normally the responsibility of the project manager, assisted substantially by the hydropower planner. The supporting volumes are prepared by the experts.

To illustrate the need for multidisciplinary expertise a list of the main disciplines is shown below. A few of these relate mostly to the implementation phase.

Hydropower Planning and Implementation; Range of expertise required	
Organizational Arrangements Project Management Contract Management Construction Management Technical Supervision Power Market Surveys Power Demand Forecasts Power System Studies Power Studies Operation Studies Hydrology, Meteorology Sedimentology Water Studies Regulation of Flow Reservoir Simulations Floods, Flood Protection Geodesy Geography Topographical Surveys Map Construction Electro-Mechanical Engineering Hydro-Mechanical Engineering Control and Protection Systems Transmission Engineering Tariffs Cost Engineering Power Economy Financial Engineering Scheduling Document Engineering Quality Engineering Quality Assurance and Control Legal Issues, Water Rights Public Relations	Geology Geomorphology Engineering Geology Soils and Materials Foundation Engineering Erosion and Sedimentology Seismology Glaciology Hydrogeology Slope Stability Hydropower Planning and Design River Transfer and Diversion Reservoir and Dam Engineering Hydraulic Engineering Hydraulic Models Sediment Handling Hydraulic Structures Underground Engineering Geophysics Field Investigations Infrastructures Operation and Maintenance Training Quantity Surveying Inspection Services Communications Ecology Environmental Engineering Landscaping Social Anthropology Socioeconomics

It is obvious that the range of expertise required is extensive. Shortcuts intended to reduce the scope and number of experts involved will normally not be tolerated by financing institutions or panels employed to handle quality assurance. The expertise needed covers management (Project Managers), overall planning (Hydropower Planners) and specialists in the different subjects which are to be studied in detail.

The important question is how to structure E&T to meet these needs. It is interesting to note in this respect how a proposed team, say to carry out a feasibility study is evaluated by developer and or financing institution. One technique is to start with a total of 100 points and allocate the 100 points to the individual Team members. The Project Manager and the Hydropower Planner are obviously the two most important members as 45 to 50 points are allocated to these two positions. The remaining 50-55 points are then spread out over the remaining long list of experts.

Consultants are very much aware of this situation and will go to great lengths to satisfy the client when discussing the two positions; Project Manager and Hydropower Planner. After signing of a study contract specialists may be replaced, but it is regarded as a serious problem if the Consultant wants to replace the Project Manager or the Hydropower Planner.

4. APPROACHES TO E&T IN HYDROPOWER PLANNING

This section will discuss degree-oriented education versus hydropower specialisation based on practice and continuing education.

In the academic world a professor is evaluated based on the number of university degrees he or she holds, number of publications, number of post-graduate students and sometimes even his ability to teach.

In the world of industry basic university degrees (B.Sc. and M.Sc.) are a requirement, but professionals are evaluated on the basis of number of years of relevant practice, positions held in projects or international organisations and documented professional achievements. The academic aspect becomes less and less important when a candidate is being assessed for a new task. How the vast amount of knowledge has been acquired after leaving the university is not important. Exceptions may be when applying for government positions. This does not imply that the approach to E&T in Hydropower Development is not important. The listing of subjects given in Section 3 illustrates the wide range of topics that the team must be trained to cover professionally.

The specialists need first of all to offer high level knowledge of their subject. They must also have a superficial knowledge of most of the other subjects in order to function as a team member in hydropower planning. This type of knowledge can be acquired through on-the-job training. For example a junior hydrologist working in different teams for say five years will learn something about the other subjects and how these relate to each other in the planning process. Short continuing education courses and seminars will provide ample input to broadening such an overview. This way of specialising as a hydropower professional based on practice and continuing education is illustrated in Figure 4.1.

In order to become a professional specialist there are several options such as:

- On-the-job training combined with reading up on new literature (applied literature)
- Short courses or seminars on specialised subjects
- Continue university studies to M.Sc. or Ph.D. level.

The choice of hydrology as an example was deliberate. Major hydropower projects needs input from the highest level of knowledge both academically and professionally. If the hydrologist produces the wrong conclusions then the entire project will be off-target.

When structuring E&T the objective must be to produce professional engineers most efficiently. Another opinion is found in some parts of the academic world and in society in general. The main objective of universities is to offer students the opportunity to study. The university then sets examinations (or similar) to ensure that the level of knowledge of its students meets the standards set by the university. Which subjects students choose, how they carry out their studies and when they complete their studies and obtain a degree is entirely up to themselves.

This "free" model is common in the humanities, languages, social sciences, etc. Students studying medicine, engineering etc. are often referred to as profession-oriented students, i.e. graduates typically work in a given sector. Both the "sector", the university and the students are interested in an education which is target-oriented and efficient.

Another aspect that faces everyone dealing with the planning and implementing of education is the fact that we all need to update ourselves, starting soon after we start our professional life. The need for updating is growing considerably and will continue to do so in the future. This is referred to as "continuing education" or could also be referred to as "training", as we use that word in the title of this report.

The most effective way of gaining new knowledge will differ with the characteristics of the subjects and the existing level of knowledge. Some recommendations are made in the following paragraphs. The listing also indicates which subjects are hydropower- and/or water resources-specific. It is assumed that the basic courses in civil, mechanical and electrical engineering as well as economics are included in the first stage of the engineering curriculum, i.e. first and second year of B.Sc. In the listing marks are given in line with the following legend:

Col.1: "Classroom setting". Ordinary class-room education and some years of practice necessary to become a professional.

Col.2: Short courses and on-the-job training is the normal and possibly the most efficient way to become a professional

Col.1+2: A combination of 1 and 2 will be the most efficient way to become a professional

Col.3: Marks subjects that are important in Water Resources Engineering, and in general

Col. 4: Subjects that are specifically related to Hydropower.

SUBJECT	1 Classroom setting	2 Short courses "On-the-job"	3 Water Resources Engineering	4 Hydropower specific
Hydrology	x	x	x	
Meteorology	x	x	x	
Geodesy	x	x	x	
Geography	x	x	x	
Aerial Photography	x	x	x	
Topographical studies	x	x	x	
Map Construction	x	x	x	
Geology	x	x	x	
Geomorphology	x	x	x	
Engineering Geology	x	x	x	
Soils and Materials	x	x	x	
Foundations Engineering	x	x	x	x

Structural Engineering	x	x	x	x
Erosion and Sedimentology	x	x	x	
Seismology	x	x	x	
Glaciology	x	x	x	
Hydrogeology	x	x	x	
Slope Stability	x	x	x	x
Reservoir and Dam Engineering	x	x	x	x
Hydraulic Engineering	x	x	x	x
Hydraulic Models	x	x	x	x
Hydraulic Structures	x	x	x	x
Underground Engineering	x	x	x	x
Geophysics	x	x	x	x
Electro-Mechanical Engineering	x	x		x
Hydro-Mechanical Engineering	x	x		x
Transmission Engineering	x	x		x
Ecology	x	x	x	x
Landscaping	x	x	x	x
Social-Anthropology	x	x	x	x
Socio-Economy	x	x	x	x
Water Rights, Legal Issues	x	x	x	x
Hydropower Planning and Design	x	x		x
Power Market Surveys	x	x		x
Power Demand Forecasts	x	x		x
Power System Studies	x	x		x
Power Studies	x	x		x
Control and Protection Systems	x	x		x
Quantity Surveying	x	x	x	x
Cost Engineering	x	x	x	
Power Economy	x	x		x
Financial Engineering	x	x	x	x
Environmental Engineering	x	x	x	x
Organizational Arrangements		x	x	
Project Management		x	x	
Contract Management		x	x	x
Construction Management		x	x	x
Technical Supervision		x		x
Water Studies		x	x	
Regulation of Flow		x	x	
Reservoir Simulations		x	x	
Floods, Flood protection		x	x	
Field Investigations		x	x	x
Infrastructures		x	x	x
Operation and Maintenance		x		x
Training		x		x
Inspection Services		x		x
Communications		x		x
Tariffs		x		x
Operation Studies		x		x

River Transfer and Diversion		x	x	x
Scheduling		x	x	
Document Engineering		x	x	x
Quality Engineering		x	x	x
Quality Assurance and Control		x	x	x
Public Relations		x	x	x

Column 1 of the table above indicates the subjects that are best taught in a classroom setting in order to acquire the essential basic knowledge. These subjects may be referred to as "theoretical". Most universities that offer engineering courses (B.Sc. and/or M.Sc.) cover these subjects, even though the same university might not cover hydropower development courses in its curriculum. No single person will include all the subjects in his/hers degree programme. It is the team that needs to cover the entire list of subjects.

It is, of course, necessary to continue the learning process through on-the-job training, short courses and seminars and these are indicated by the checks in Column 2. In the same column subjects are listed for which training on the job and seminars can provide the knowledge necessary to serve on a hydropower planning team.

A number of universities offer courses in water resources engineering while only a few offer target-oriented education in hydropower development. When making up the curriculum for water resources engineering it is found that about 75% of the subjects is an educational programme for hydropower development and found in the study programme for water resources engineering. Only about 5% of the hydropower courses are hydropower-specific.

Some of the universities that state that they cover hydropower planning may offer only a single course in this field. This of course does not provide the necessary theoretical background for working on a hydropower planning team.

5. STRUCTURING OF DEGREE PROGRAMMES

Most universities offer degree study programmes at three levels:

Bachelor of Science (B.Sc.)
Master of Science (M.Sc.)
Doctor of Philosophy (Ph.D.)

Some universities eliminate the B.Sc. and take their students directly to the M.Sc. level. Some universities in developing countries and newly established universities may not offer a Ph.D. However, that is normally a temporary situation.

A complete hydropower planning team consists of engineers with basic backgrounds in Civil, Mechanical or Electrical Engineering. By tradition a hydropower engineer will be educated in one of these fields. As the operation of hydropower schemes comes more and more into focus, with increased emphasis on operation strategy, maintenance strategy and safety, a few universities (in countries like Sweden, India, China) are offering a combined degree covering both civil, mechanical and electrical engineering subjects. The intention is that these engineers will be well trained to take responsibility as head of operations.

A team of hydropower planners naturally also includes economists, EIA study specialists etc. Nevertheless, with very few exceptions, hydropower planners/project managers for hydropower planning and implementation are civil engineers. This section therefore concentrates on civil engineering.

5.1 Structuring of B.Sc. programme in Hydropower Engineering

The normal length of a B.Sc. programme is 3 1/2 to 4 years. Assuming 4 years, the general structure of the curriculum is as indicated in the following table:

Year 1	Year 2	Year 3	Year 4
Basic courses in science	Basic courses in Engineering / Civil Engineering	Basic courses in Civil Eng./ Water Resources Engineering *****	Engineering courses in Civil Eng. / Water Resources Eng. / Hydropower Eng.

* Assuming a university offering a degree programme in Water Resources Engineering or Water Resources Engineering/Hydropower Engineering. Even with a programme focusing on Hydropower Engineering about 70% of the engineering courses will be basic to Water Resources Engineering in general.

Most universities with a complete programme will offer a variety of options in Civil Engineering, including structural engineering (most common), transport engineering, surveying and mapping, urban planning, soil mechanics and rock engineering, etc.

A university that focuses on water resources engineering may treat water supply and sanitation as its first priority, covering water quality, water treatment, clean-water distribution and waste-water collection and treatment systems. Irrigation may very well be the second priority, also including food control. Thus hydropower engineering becomes the third priority. This is, however, not the situation in all countries. Most of the Northern Hemisphere experiences ample rainfall and rainfall is reasonably evenly distributed over the year. Thus irrigation is not a major issue in these countries.

It is the experience of this writer that too many universities rank hydropower engineering at the end of all civil engineering topics, and in fact many leave it out. There is more hydropower to be tapped world-wide than has been developed up to now.

A B.Sc. degree programme focusing on hydropower engineering might include the following courses. The course-plan indicated would represent a higher degree of specialization than normally offered by most universities. An important question that needs to be addressed is whether narrow specialization is to be recommended for the B.Sc. level.

Year 1	**Year 2**	**Year 3**	**Year 4**
Mathematics I Mathematics II Physics I Chemistry Mechanics I Geology Surveying I Computer application (basic course) ----- Non-technical topics (Basic economics etc.)	Mathematics III (statistics) Fluid mechanics Physics II (Termodyn.) Mechanics II (Dynamics) Surveying II Computer appl (cont.) Intro to Environmental eng. ----- Non-technical topics (Management issues etc.)	Soil mechanics Structural analysis Concrete and steel structures Hydrology Open channel flow Hydraulic design I Roads Sanitary engineering ------ Non-technical topics	Hydropower plants (main components) Hydraulic design II Rock engineering Dam engineering Water supply & sanitary eng. Intro. to hydropower planning Intro. to Water resources management Project assignments ------ Non technical topics

Common to all students in civil engineering (Years 1–2)

Open for students choosing different direction of specialization (Year 3)

Specialized option with focus on hydropower (Year 4)

5.2 Structuring of M.Sc. programme in Hydropower Planning

Master of Science (Engineering) programmes differ considerably in their objectives and scope. The most common objective in the past has been specialization within a rather narrow field. Those who successfully obtain a M.Sc. degree will either work as specialists in a larger group of engineers (say a consulting firm) or will treat M.Sc as a stepping-stone for studying for a Ph.D. degree; applied research or teaching.

Examples of courses might be:

- Hydraulics, covering:
  - Hydraulic structures
  - River hydraulics
  - Erosion and sediment enginering
- Hydrology, covering:
  - Data collection and quality assurance
  - Run-off analysis
  - Water-balance analysis
  - Flood analysis
- Soil and rock engineering
- Irrigation, etc.

If the university requires a thesis then the subject for the thesis will be within one of the sub-topics.

This type of specialization is offered by almost any university that offers an engineering degree. To obtain a M.Sc. normally takes 1 1/2 years, spending 70% of the time on courses and 30% on the thesis is most common. Some universities make the thesis optional or put less emphasis on research/thesis work. The ratio therefore varies from university to university. This type of academically oriented education is illustrated in Figure 5.1.

Some universities, mostly those which have developed their own M.Sc. programmes, have chosen a more professional than academic orientation. This may be illustrated as in Figure 5.2. This approach is demonstrated in the first two examples in Appendix A.

APPENDIX A:
EXAMPLES B.SC./M.SC. PROGRAMMES

<u>Asian Institute of Technology (AIT), Bangkok; School of Civil Engineering</u>

To qualify for the degrees of Master of Engineering or Master of Science, a student must satisfactorily complete a minimum of 30 credits plus a thesis *or* the minimum of 55 credits including a research study.

<u>Water Resources Development</u>

This field offers instruction in a broad range of engineering concepts needed to link surface and groundwater hydrology with hydropower generation, irrigation and water supply, integrating the quality and quantity of water resources developed. Courses offered in this field focus on the techniques employed to assess the occurrence and availability of surface water and ground water in time and space, their adequacy and the contamination and deterioration of water resources.

Courses offered:

- Water Resources Systems Analysis I
- Hydrological Processes
- Groundwater Pollution and Transport Modeling
- Water Resources Management
- Water Resources Systems Analysys II
- Groundwater Development
- Hydrological Modeling
- Economic Analysis and Environmental Impact Assessment
- Modeling of Groundwater Systems

<u>Irrigation Engineering and Management</u>

This field of study aims to provide knowledge and skills necessary for susitainable development and management of land and water resources for agriculture in general and irrigated agriculture in particular. It addresses various multidisciplinary issues involved in planning, design, implementation, operation and maintenance of irrigation and drainage systems.

Courses offered:

- Pipe and Channel Networks
- Applied Hydrology
- Hydrometeorology and Crop Water Requirements
- Irrigated Soils
- Irrigated Crops
- Drainage Enigineering
- Irrigation Delivery System Engineering
- Paddy Field Engineering
- Farm Irrigation Systems

Computer Applications in Agricultural Water Management
Soil and water Conservation Engineering
Irrigation System Management

The normal length of a M.Sc. programme at AIT is 1 2/3 years.

Tribhuvan University, Kathmandu; Institute of engineering (IOE), Department of Civil Engineering

The objective for the program *Master of Science in Water Resources Engineering* is: The demand for water is continuously increasing and the resources are limited. The new generation of professionals who will be responsible for the development and management of water resources will face problems that go far beyond those that today's water resources technologists and managers are facing, both in terms of scale and complexity. The objectives of this program are to prepare a new generation of professionals to cope with these complex problems and to equip them with the necessary tools to present options for development and management of water resource utilization.

Courses offered:

A. Core Courses (compulsory)

Advanced Hydraulics	4 Credits
Hydrological Analysis	4 Credits
Simulation Laboratory	4 Credits
System Mathematics	3 Credits
River Engineering	4 Credits
Hydraulic Structures I	3 Credits
Hydropower Engineering / Irrigation & Drainage	4 Credits
Hydraulic Structure II	3 Credits
Water Resources Planning and Management	4 Credits
Thesis	16 Credits

B. Elective Courses

Geotechnical Engineering	3 Credits
Ground Water Hydrology	2 Credits
GIS	3 Credits
Advanced Mathematics	3 Credits
Directed Studies	2 Credits
Electrical Equipment	2 Credits
Stochastic Hydrology	3 Credits
Finite Element Methods in Water Resources	3 Credits
Physical Modeling of Hydraulic Structures	3 Credits
EIA of Water Resources Projects	3 Credits
Micro/Small Hydropower	2 Credits
Project Management	3 Credits
Power System Planning	2 Credits
Irrigation System Management	2 Credits

The minimum period of full-time attendance required for the M.Sc. degree is two years. The elective courses allow the students to train in a particular direction, for example in the direction of higher studies and research, practical design or in the direction of field activities. In other words, this M.Sc programme makes it clear to the students (and others) that they should choose between acdemic orientation or professional orientation when making up their individual plan for their studies.

Plans have been worked out, but not implemented yet, to include Hydropower Development as another specialization option. The list of electives is as follows:

Applied Hydrology	3 Credits
Applied Rock Engineering	3 Credits
Sediment Engineering	3 Credits
Dam Engineering	3 Credits
Hydropower Plant Design I	3 Credits
Hydraulic Machinery & Steel Works	2 Credits
Electrical Equipment	2 Credits
Hydropower Plant Design II	3 Credits
Applied Economics	3 Credits
Socio-Economics/Investment Analysis	2 Credits
The Planning, Implementation & Construction Process	2 Credits

Norwegian University of Science and Technology (NTNU); Dept. of Hydraulic and Environmental Engineering

Since 1993, the university has offered an international M. Sc. Programme in Hydropower Development. The programme is a follow-up of the 10-month diploma course which has been taught since 1976.

Place	Norwegian University of Science and Technology, Department of Hydraulic and Environmental Engineering
Programme and duration	The studies comprises lectures, exercises, group and individual project assignments, excursions and M Sc thesis. Two academic years.
Admission and requirements:	Candidates should have a B Sc degree or equivalent in civil engineering and 2-5 years experience from planning, design, and/or construction of hydraulic works. All lectures are given in English. A good working knowledge of English is therefore essential. The candidate has to undergo a TOEFL or ELTS test with good results.
Course management:	Ånund Killingtveit, Professor in charge (preliminary) Hilbjørg Sandvik, Course Coordinator
Steering committee:	Einar Broch, Professor Ånund Killingtveit, Professor Erik Lund, Faculty Director

Course Outline

Hydropower development is a typical interdisciplinary task. Most often, the person responsible for organizing the activities and coordinating the work of the specialists involved is a civil engineer. Consequently he/she needs to have a working knowledge of a wide range of fields but is not a specialist in all of them him-/herself. The Hydropower Development Programme has been organized to meet the training needs of persons who are, or in the future will be, in such key positions.

With this objective in mind a wide range of engineering, economic and environmental subjects are covered in the programme. Both fundamental and applied subjects are included, with main emphasis on the latter. The programme is suitable for young professional engineers engaged in planning and implementation of hydropower and/or other water resources projects.

The different subjects are presented by university staff and/or professional engineers, all with international experience.

<table>
<tr><th colspan="2">FIRST YEAR</th></tr>
<tr><td>Geo subjects
- Engineering geology
- Rock blasting and tunnelling
- Soil mechanics
- Embankment dams
- Concrete dams/structures
- Properties of concrete</td><td>Hydro subjects
- Basic and applied hydrology
- Hydraulics/Hydraulic design
- Scour and sediment transport
- Turbines and hydraulic equipment
- Mechanical equipment
- Power house design</td></tr>
<tr><td>Planning and management subjects
- Project management
- Feasibility studies
- Implementation of hydropower/ water resources projects
- Operation and maintenance</td><td>Environmental and economic subjects
- Basic economics
- Economic design criteria
- Investment analysis
- Socio-economic analysis
- Environmental impact studies
- Choice of energy source for electricity production</td></tr>
<tr><td colspan="2">EXCURSIONS
In September in first year of the studies the students visit some Norwegian hydropower plants. If it is possible there is also arranged one excursion to construction sites.</td></tr>
<tr><td colspan="2">EXAMINATIONS
Examinations are arranged in accordance with the regulations of NTNU. There are two written examinations - in December and February, and one oral in the beginning of May. The students have to pass these examinations to continue to second year of studies.</td></tr>
</table>

SECOND YEAR									
A	S	O	N	D	J	F	M	A	M
* Rock Engineering, A.C.				EXAMINATIONS	Master of Science THESIS				
* River System Analysis, A.C.									
* Withdrawel of water from sediment carrying rivers, A.C.									

In spring term in second year of the studies the students visit institutions and companies engaged in planning and constructions of hydropower schemes and in manufacturing equipment.

University of Dar es Salaam; Dept. of Civil Engineering

The university proposes a M.Sc programme in Hydropower Planning. The undergraduate teaching in Civil Engineering includes courses on hydraulic structures that cover limited topics on hydropower plants and sources of renewable energy.

Objectives of the proposed programme

- To equip the graduates with up-to-date knowledge in the planning and design of hydropower plants for which Africa and Tanzania has a good potential
- To provide a curriculum which covers the environmental aspect and impact of this multidisciplinary undertaking
- To equip engineers with modern aspects of design and selection of equipment

Main features of the curriculum

The full programme offers altogether 540 hrs (lectures) out of which a student is required to select at least 480 hrs composed of 360 compulsory and 120 hrs from electives. Five units of 40 hrs each are from the already existing Water Resources Engineering programme. The first 12 months will be devoted to coursework. The courses will be offered on unit basis. One unit is equivalent to 40 hrs of lectures, tutorials and demonstrations. The minimum number of units required for a M.Sc. is 12.

Six months of the second year are devoted to an individual research project involving about 800 hrs and to be concluded with a dissertation. Normal programme length will therefore be 18 months full time. One month may be extended to allow candidates make corrections and finally submit the dissertation after examination.

Entrance requirements

The minimum qualification for admission to the programme is a Lower second B.Sc. (Eng) in Civil Engineering or its equivalent from the University of Dar es Salaam or any other recognized university.

Candidates are required to have basic knowledge of computers, and minimum number of any one intake is five as per Faculty of Engineering recommendations.

Course content

Compulsory courses:

Mathematical analysis	1 unit
Statistics for Engineers	1 unit
Applied Engineering Hydrology	1 unit
Hydraulics of Open Channels	1 unit
Environmental Management	1 unit
Hydrosystems Simulation Models	1 unit
Applied Rock Engineering	1 unit
Design of Hydraulic Structures	1 unit
Hydropower Plant Layout	1 unit
Project	

Electives for HP Planning students:

Embankment Dams	0.5 units
Concrete Dams	0.5 units
Hydropower Planning and Management	1 unit
Hydropower Electro-mechanical Equipment	1 unit
Hydrometry	0.5 units
Computation in Water Resources Engineering	1 unit

University of Roorkee; Alternate Hydro Energy Centre (AHEC)

AHEC was established at the University of Roorkee in 1982 to promote power generation through development of small hydro and other renewable energy sources, and to impart short term and long term training to field engineers. This includes a three semester (18 months) Master of Engineering programme in Alternate Hydro Energy Systems. Additional research work may lead to a Ph.D. in the same field.

Entrance requirements

The medium of instructions is English.

For sponsored Indian and Foreign candidates the minimum qualifications for admission are a recognized Bachelor Degree in Civil/Electrical/Mechanical/ Industrial/Chemical/Electronics or Computer Engineering or any other equivalent qualification (with at least 60 % marks) acceptable to the university and 2 years of practical experience (Marginal deficiency in the experience may be condoned), or AMIE/MIE in Civil/Eletrical/Mechanical/Electronics/Computer/Chemical or Industrial after passing examination to section “A” and “B” of the Institution of Engineers (India) and possessing a B.Sc. degree or a 3-years Diploma in Engineering and having at least three years of research or professional experience in responsible position in renewable sources of energy or allied fields. However, such candidates with AMIE/MIE qualification seeking admission to the M.E. course will be required to pass a written as well as an oral test and will also have to produce a proof of their having been elected as AMIE/MIE before they fill in forms for 1st semester university examination.

<u>Programme content</u>
Compulsory courses:

Small Hydro Power System Planning & Management	1 unit
Design of SHP structure	1 unit
Numerical Methods	0.5 units
Renewable Energy Resources Development Technology	1 unit
Environmental Planning & Management	1 unit
Fluid Mechanics	0.5 units
Computer Programming (Non-Credit Course)	0.5 units
Small Hydro Generator Protection and Control System Equipment	1 unit
Energy System Economics, Policies and Laws	0.5 units
Hydro Mechanical Equipment	1 unit
Elective I	0.5 units
Elective II	1 unit
Seminar and visits to projects	0.5 units
Project	1.5 unit
Dissertation	4 units

Elective I courses:
- Construction Planning & Management
- Biomass Production & Utilisation
- Operation and Maintenance of Small Hydro Power Plants
- Solar Photo-Voltaic Design and Applications

Elective II courses:
- Wind Energy Application Technology
- Design and Testing of Hydro-Mechanical Equipment
- Instrumentation
- Rural Electrical Energy System Planning and Design
- Remote Sensing and GIS for SHP Planning
- Electrical Design of SHP Station
- Solar Energy Thermal Processes
- Sediment Transport and River Engineering
- Welding Technology

University of Roorkee; Water Resources Development Training Centre (WRDTC)

The centre was established in the year 1955 to meet the training needs of the developing countries to harness and utilise the vast water resources for the benefit of the mankind.

WRDTC offers a broad based programme of education and training inall aspects of water resources engineering to in-service engineers holding recognised degrees in related branches of engineering and having at least three years job experience.

The following programmes are presently available in Water Resources Development:

- Twelve-month Training cum Post-graduate Diploma course in Water Resources Development (Civil and Mechanical), and Hydroelectric System Engineering and Management.
- Master of Engineering Degree in Water Resources Development (Civil and mechanical), and in Hydroelectric System Engineering and Management.
- Ph. D. Degree in Water Resources Engineering

A similar set of programmes is also available in Irrigation Water Management.

The programme content in Post-graduate Diploma/Master of Engineering in Water Resources Development (Civil) is listed below as an example:

Construction Technique-I	0.5 units
Hydrology	1 unit
Computer Programming	0.5 units
Design-I	1 unit
Design-II	0.5 units
Geotechnical Engineering	1 unit
Water Resources Planning and Management	0.5 units
System Design Techniques	0.5 units
Numerical Method	0.5 units
Design-III	0.5 units
Construction Technique-II (C)	0.5 units
Elective (any one of following)	
Hydropower Stations and Appurtenant Works	
Earth and Rockfill Dams	
Concrete and Masonry Dams	1 unit
Irrigation, Water Use Management and Flood Control	
River Engineering	
Ground Water Development and Management	
Seminar	0.5 units
Visits to works	0.5 units
Project	2 units
Dissertation or	3 units
Course work constituting:	
Selectives 4 subjects, and	2 units
Special problem	1 unit

The Luleå University of Technology, Sweden

The Luleå University of Technology started up a 3-year B.Sc. Programme for Hydro-Electric Engineers in cooperation with the Jokkmokk Training Centre in 1997.

Objectives for B.Sc. degrees in Hydro-Electric Power Technology at Luleå University of Technology.

Degree programmes at Luleå University of Technology combine knowledge, built upon the experience of the lecturing staff, with knowledge that has its basis in scientific research.

The degree programme will give:

- Skills in effectively using computers, software and measurement instruments applied to lab-based work and also practice in combining skills and knowledge related to this work.
- Skills in presenting in both written and spoken Swedish, technical problems and their results or solutions for technical personnel as well as non specialists and also the ability to use technical documentation written in English.
- Awareness of the importance of working environment as well as the role of the individual and groups at work
- An ability to both work in a group and also act as a group leader.
- Awareness of the broader sense of technology, developments in society and the environment.
- Competence in tasks such as running, maintenance, development and modification within hydroelectric power technology.

Scope

This B.Sc. degree programme consists of courses totalling 180 ECTS. All these courses must be successfully passed. The degree also includes a post study final year project of at least 15 ECTS. For this the student, alone or with a peer, must successfully complete a project that demonstrates his/her/their ability to apply the knowledge and skills obtained during the taught part of the degree. This project must be presented in both written and oral forms.

Specific requirements

In order to be awarded the B.Sc. degree in Hydro-Electric Power Technology, the student must have completed all the, so-called, core courses that are specified for this programme.

The final year project will be completed at a 41-60 point's level and must be related to the subject Hydro-Electric Power Technology.

Six weeks of approved industrial experience must be completed between years one and two and two and three respectively (12 weeks total.) This work must lie outside any courses whose points count towards the final degree. This work experience must be related to Hydro-Electric Power Technology.

APPENDIX B:
EXAMPLES CONTINUING EDUCATION PROGRAMMES; SENIOR COURSES

SwedPower AB; Dept of Training & Organizational Development, Sweden

The company offers the 5-week training course “Management of Hydropower Development” on a yearly basis. The objectives are to improve the managerial capacity and to broaden and update knowledge in the field of hydropower and orientation of innovations and trends for the future in civil, mechanical and electrical engineering.

The target group is general or functional managers in power companies with several years of experience in executive positions and promising career prospects in the field of hydropower development, holding a degree in civil, mechanical or electrical engineering.

Main topics:

- Project management
- Feasibility studies, engineering and design, construction, operation, maintenance and rehabilitation of hydropower plants
- Contracting and procurement
- Economy and financing
- Study tours

University of Roorkee; Alternate Hydro Energy Centre (AHEC), India

General information about AHEC is also found in Appendix A.

The centre offers a wide range of ad hoc short-term courses (1 to 4 weeks) with the emphasis on small hydro. In the period 1986-1998 more than 30 course were arranged.

AHEC is offering two courses on a regular basis:

- Renewable Energy Technology
- Small Hydro Power Development

International Centre for Hydropower (ICH), Norway

ICH offers two 18-days intensive training courses on a yearly basis:

- Hydropower Resources Development and Management
- Hydropower and the Environment

Both courses consist of lectures, discussions, case studies, group work and visits to companies and institutions. All lecturers and resource persons are recognized specialists within their field, and they have extensive international experience. At the end of the course there is a four-day long field trip to visit hydropower plants and other relevant sites.

A minimum of about 10 years of working experience is required, and the applicants should hold a B.S. degree in hydropower engineering or have an equivalent background in the fundamental engineering aspects of hydropower systems. Proficiency in English is necessary.

Hydropower Resources Development and Management

The objective of the course is to provide the participants with the knowledge of the fundamentals of hydropower resources development and management. By focusing on both theoretical and practical issues, the participants should be able to contribute more effectively in the management of the energy resources in their own countries.

The syllabus is built around the overarching concepts related to the planning, construction and operation of hydropower facilities as part of a mixed energy system that also includes thermal power. Environmental issues and financial questions are central themes. National restrictions and commercial conditions, which can be expected to apply in the future, are also treated.

The course is aimed at middle management personnel from power companies, ministries and public agencies.

Main topics:

- Energy needs; planning requirements
- Design cost estimates
- Legal and institutional frameworks
- Economic and financial assessments of projects
- Environmental impact analysis
- Financing of HP development
- River system simulation model
- Operation and management
- Hydropower in mixed supply systems
- Project management
- Planning methods
- Multipurpose projects

Hydropower and the Environment

The course will look at procedures that should be followed in order to comply with today's requirements for good environmental planning. The international financing of hydropower depends on this, and the well being of millions of people rely on it.

Participants will learn how Environmental Impact Assessments (EIA) are typically organised and carried out, and they will be better prepared to analyze the results and identify proper mitigating measures. The focus is on proactive planning in order to ensure the sustainable utilisation of natural resources.

The course is aimed at senior professionals who deal with environmental issues in hydropower and dam projects. Executives of power companies, ministries, water resource and energy agencies and relevant private sector enterprises with management responsibility or influence on project planning will benefit from this course. The course will also be of value to engineers working in water resources planning and multipurpose projects.

Main topics:

- Environmental effects of hydropower
- Hydropower developments
- Licensing and the legal frameworks
- Water resources utilization
- The EIA study process
- Aquatic and terrestrial effects
- Environmental Management Plan
- Social and cultural issues; resettlement
- Physical effects in a river basin
- Economic and financial aspects

APPENDIX C:
LITERATURE FOR E&T IN HYDROPOWER PLANNING

Planning of hydropower projects is a complex task, which involves professionals from many fields as pointed out in this report. Each river basin is a unique combination of physical characteristics as well as environmental and human habitats. All hydropower projects are therefore tailor-made to the complex context where it shall serve a wide range of purposes. There is no textbook that covers all aspects of E&T in hydropower planning. Most textbooks are dealing with one or a few of the topics. A major element of education in hydropower planning must therefore be case-oriented with experience-based teaching. Selection of teachers must be based on their involvement in planning, construction and operation of hydropower plants as well as their communication skills. The objective is to facilitate a transfer of experience in the entire planning process to the students in a more efficient way than the individual build up of experience through professional involvement in hydropower development projects.

Students in hydropower planning must have access to written material (literature) through various sources. A university library together with access to the Internet are needed. Some written information is more directly linked to the teacher and his/her experience and professional network as outlined below

Information available through a library and the Internet:

- Text books
- Professional journals
- Scientific journals

Information available through teachers and advisors:

- Conference and seminar presentations (papers)
- Cases documented through reports
- Applied research reports

Most of the teaching material given to the M.Sc. students at the HPD Course at NTNU is not available in the bookstore. The various teachers, who are selected on the basis of their professional performance rather than university rank, are making use of documents as:

- Lecture notes
- Parts of project reports
- Parts of research reports
- Selected papers from various seminars and conferences.

The documentation handed out to the students will vary somewhat from year to year in order to include new know-how and new experience. For more detailed references, the booklet from NTNU "Master Programme in Hydropower Development" can be studied. This booklet includes a presentation of each topic lectured and each teacher at the course and a list of literature and reference material applied for each topic. This booklet is, however, not included in this report.

Textbooks that should be considered included in study programmes in hydropower planning are:

- *Water Power Development*, E. Mosonyi, Budapest 1991.
- *The Hydropower Development Book Series* published by the Norwegian University of Science and Technology (NTNU), Trondheim 1992-1999, consisting of the following volumes:
  - *Hydropower Development in Norway*, V. Hveding
  - *Coordinating Hydropower and Thermal Power*, I Haga
  - *Environmental Effects*, E. Helland-Hansen, T. Holtedahl, K. A. Lye
  - *Landscape Design in Hydropower Planning*, K. O. Hillestad
  - *Planning and Implementation of Hydropower Projects*, J. Ravn
  - *Economic and Financial Analysis of Hydropower Projects*, K. Goldsmith
  - *Hydrology*, Å. Killingtveit, N. R. Sælthun
  - *Rock Engineering*, B. Nilsen, A. Thidemann
  - *Rockfill Dams*, B. Kjærnsli, T. Valstad, K. Høeg
  - *Concrete in Hydropower Structures*, E. Kleivan, G. Kummeneje, A. Lyngra
  - *Electrical Equipment*, E. Westgaard, A. K. Enger, H. J. Mellbye, J. Sonstad, Ø. Torkildsen, S. Vikanes

  To be published:
  - *Hydraulic Design*
  - *Mechanical Equipment*
  - *Power House Design*
  - *Construction Management*
  - *Transmission and Distribution*
  - *Maintenance Management of Hydropower Plants*

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