REPORT

NVE
NORWEGIAN
WATER RESOURCES AND
ENERGY ADMINISTRATION

DAM SAFETY AND SEDIMENTATION IN TANZANIA

Fact finding mission

By

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NVE *NORPLAN* *TANESCO*

NVE, Oslo, Aug. 1993

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L Conclusions from the DUSER Soil Erosion Project in Tanzania, by Anders Rapp in Studies of Soil Erosion and Sedimentation in Tanzania, Research Monograph Number 1 1973, University of Dar es Salaam, 1973, 379 p.

1.0 SUMMARY

Introduction

NVE has been selected to assist Tanesco in the fields of dam safety and sedimentation in connection with the Pangani Falls Redevelopment Project . This report, based on the fact finding mission in May '93, is ment to be the first preparation for the workshop to take place in Tanzania in the beginning of 1994.

Dam safety

The team visted the four major dam sites in Tanzania, Pangani, Nuymba ya Mungu, Mtera and Kidatu. The safety of the Mtera and the Nyumba ya Mungu dams are of vital importance to Tanzania considering that they are the main water reservoirs in the country. The resources spent on surveillance and maintenance of these dams are not in proportion with the importance and value of these dam. A dam failure would be fatal, and larger emphasis must be put on the safety aspect.

The dam at Kidatu is a rockfill dam with a gated spillway. Rockfill dams are very sensitive to overtopping, ie. possible malfunctioning of the gates can be catastrophic. At the moment a full inspection of the gates is very difficult as there is no means for lifting equipment for the stop logs.

Efforts must be done to secure a reliable power supply for operation of the gates. Further, the surveillance and maintenance of the dam body and monitoring equipment must get a higher priority.

A provisional team of experts within the TANESCO organization should be appointed to deal with safety matters requiring immediate action at Kidatu,MyM and Mtera.

Relevant papers on the topic are enclosed as appendices.

Sedimentation

Due to the difference in climatic and morphological regions, Tanzania is a country with varying erosion rates. Increased settlement, depletion of the vegetation as well as changes in land use within the catchments have influence on the erosion rates over time.

There is a hydrolological monitoring network in Tanzania. Some of the stations are equipped for sediment measurements. However, the four reservoirs visited are the most important reservoirs in Tanzania and there are no monitoting or quantitative knowledge on the sedimentation rates. As sedimentation within the active storage will affect the long time value of the water resources, TANESCO is interested in establishing a monitoring system connected to the four reservoirs. Except for the Nyumba ya Mungu dam, which is owned by MAJI, the dams are owned by TANESCO. In Tanzania, monitoring of hydrology and sediment transport in the rivers are the responsibility of MAJI.

A sediment monitoring programme ought to be implemented, restricted to reservoir sedimentation in NyM, Mtera, Kidatu and Pangani Falls as a first step. During the work shop, organization and implementation of a sedimentation monitoring programme will be discussed.

Workshop

The workshop is scheduled to be in the beginning of 1994 and it will last for about 2 weeks. The main objectives of the workshop are:

- To bring dam safety on the agenda to a larger extent than now in Tanzania.

- To discuss a programme for monitoring sedimentation in reservoirs and how it can be initiated.

The first week will be arranged at Hale with presentation of relevant topics and cases. The majority of the presentations will be done by people from TANESCO, MAJI and the University of Dar es Salaam. TANESCO will be responsible for the selection of contributors.

During the second week, field trips to the sites discussed during week 1 will be organized.

1 INTRODUCTION

The Norwegian Water Resources and Energy Administration (NVE) has assisted the Norwegian Agency for Development Cooperation (NORAD) in reviewing the Pangani Falls Redevelopment Project also from a dam safety point of view. The matter was dicussed at a meeting in Oslo 29 April 1992 where TANESCO, NORPLAN and NVE were represented. During the meeting, the TANESCO delegates expressed a need for the following:

* An assistance programme in supervision and control during construction and operation of Pangani, and further the possibility of extending the programme to cover all of TANESCO's dams above a certain size or with a certain risk factor related to a possible dam failure.

* Increased know-how in the field of sedimentation in reservoirs and related problems.

NORAD with the other donors agreed to include a programme comprising the above in the assistance to the Pangani hydro power project. IVO/NORPLAN, on behalf of TANESCO, made a request to NVE to handle this matter. NVE accepted to take on the assignment, as described in TOR (see Appendix A), with a budget of NOK 420 000.

According to TOR, an important issue is the involvement of local manpower resources. NVE, therefore, proposed a plan in 3 phases:

Phase 1. Meetings with relevant administrative and professional institutions within Tanzania. Of special importance are the following organisations: 1)TANESCO, 2)Ministry of Water, Energy and Minerals, 3)Maji, 4)Pangani Basin Water Office and the 5)University of Dar es Salaam.

Field trips to the dams of Pangani, Nyumba ya Mungu, Mtera and Kidatu and meetings with the local Tanesco staff. The field trip will cover dams being under construction, and 10, 20 and 30 years of age, respectively.

The purpose of Phase 1 is to gain knowledge about the situation related to monitoring and surveillance on dam safety and sedimentation. Organization, routines and responsibilities within TANESCO and between TANESCO and Maji are key elements in a surveillance programme, due to different ownership and responsibilities connected to the dams and river basins in Tanzania. Furthermore, an overview of the available resources, such as professional competance, technical equipment, maintenance, transport and economy, will play an important role in a future surveillance programme.

Phase 2. Make preparations for the workshop in cooperation with professionals and administrators in Tanzania. The results stated in the report from Phase 1, will determine the approach to the problems to be presented and discussed during the workshop. All planning of technical and practical issues connected to the workshop will be included in phase 2.

Phase 3. Implementation of the workshop, planned to take place in February 1994, most probably at Hale. The workshop will include presentations, working groups, discussions and field trips with practical exercises and demonstrations. The main issues are: field methodology, how to implement the monitoring, organisation, responsibilities, financing, motivation and cost/benefit analyses of a surveillance programme, and also improved communication between institutions within Tanzania.

2 DAMS AND RESERVOIRS IN TANZANIA.

The construction of dams in Tanzania is principally connected to irrigation and power production. The oldest ones, for public use, date back to the late 1940s, even though a few privately owned dams were constructed earlier. The Principal Water Officer in MAJI has made a short review, which gives both the historical background and the organisation on dam safety and sedimentation in Tanzania (See Appendix G). In 1973 the results from the comprehensive "DUSER soil erosion project in Tanzania" were published (Rapp, Berry and Temple, 1973). In their conclusion (see Appendix L) extended studies of water and sediment budgets were recommended in the mountain areas as well as in the semi-arid regions.

In Tanzania, arid and semi arid conditions prevail over half the territory. In these regions the streams are eiter intermittent or ephemeral and artifical water reservoirs have been constructed to meet the water demand during the dry season. During the last 30 years the 3 large dams of Nyumba ya Mungu (NyM), Mtera and Kidatu have been constructed.

The NyM reservoir was constructed for the purpose of irrigation, water supply and fishery, and is the responsibility of MAJI. However, the value of NyM has increased due to the hydro power development at Pangani Falls. NyM is the main reservoir for Pangani.

Mtera and Kidatu are located in the catchment of the Great Ruaha river. Mtera being approximately 10 years old is the largest reservoir in Tanzania. Kidatu was constructed some 30 years back. These reservoirs were originally constructed for hydropower production and are the responsibility of TANESCO.

3 DAM SAFETY

3.1 General

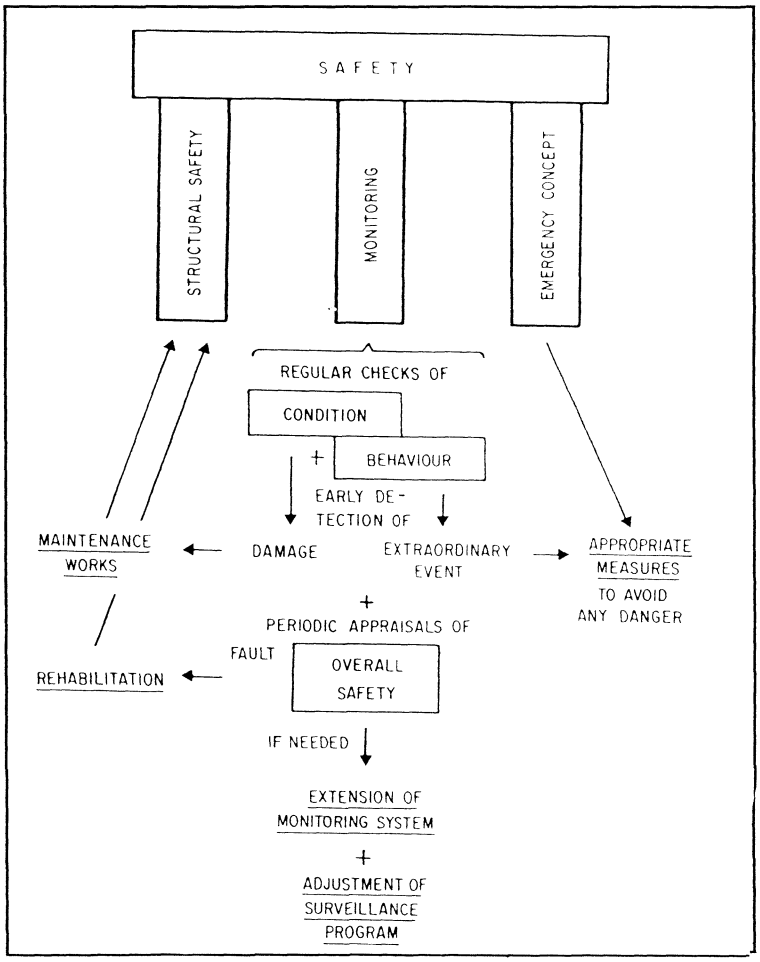
Dam safety is a general term involving many different aspects. The safety linked to a dam can in general be said to comprise the following:

- Structural safety (including the reservoir)

- Monitoring/Surveillance (including monitoring of floods)

- Emergency preparedness

These factors are linked to each other in different ways which are illustrated by the figure below.



A schematic presentation of dam safety.

Large dams are normally completed with several different instruments installed. These enable us to communicate with the dam in order to identify possible weaknesses and changes. The type of instruments and surveillance procedures will vary from dam to dam. The importance of a systematic following up of the dam can not be enough emphasized.

There are more than 36 000 dams registered in the World Register of Dams. These are mainly dams higher than 15 meters. More than 85 % of the dams are built in the last 35 years.
Dam accidents occure and as the dams and reservoirs are getting larger, the risks involved increase as well. Below are some statistics for dam failures in the world.

Dam type	A Total number of failures	B Failures caused by overtopping	B/A (percentage)
Embankment	132	33	(25)
Embankment and concrete or masonry	15	8	(53)
Concrete	17	2	(12)
Masonry	21	8	(38)
Not specified	31	–	–
	216	51	(24 per cent)

Dams (up to 1988) which have failed.

The main actor in the world within the field of large dams is ICOLD - International Commission on Large Dams. During the stay in Tanzania the possibility of Tanzanian membership of ICOLD was discussed. It is assumed to be very valuable for Tanzania to become a member of a larger international organisation which deals with dam safety.
A membership will enforce a national dam commitee to be settled in Tanzania, which could comprise persons from the main actors within the dams and hydro power business. Information about ICOLD is enclosed in Appendix J.

3.2 Surveillance-instrumentation

The primary objectives of surveillance-monitoring programmes can roughly be divided into the following:

1. To provide confirmation of the design assumptions.

2. To identify slow processes in order to identify changes and hence to plan maintanence work.

3. For emergency purposes. To identify any situations requiring emergency action.

4. For research purposes.

The number of instruments and their distribution within the dam and its foundations and complementary systems depend on type of dam and foundations, site topography,regional seismicity, etc. It should also be taken into account the general situation in the country in which the dam is built and the organisation which is going to record and treat the data. In most cases monitoring is vital throughout the life time of the dam.Very often simple instruments are the most appropriate.

The complexity and extent of monitoring systems to be deployed on a dam will also reflect the "hazard rating" of the dam based on the potential economic loss and loss of life which may stem from a dam failure or a mis-operation of the dam and its facilities. Additionally, during the life of the dam, adverse behavior, like abnormal seepage or settlements of the dam, may require expansions of the instrumentation systems to provide additional knowledge on this particular behaviour.

The presence of monitoring within the following fields should be considered:

- Visual inspections and reviews
- Seepage measurements
- Groundwater/seepage pressure measurements
- Surface displacement and strain measurement
- Stress and load measurement systems
- Internal displacements and strain measurement
- Hydrometerological measurements
- Seismicity monitoring

Instrumentation is of little use for the monitoring of a dam unless there is a competent organization to analyze and evaluate the results.

3.3 Dam Safety at the major dams in Tanzania

The three major dams, Nyumba ya Mungu(NYM), Mtera and Kidatu are all different in design and built in different periods. Maji owns NYM and Tanesco the other two.

Due to several reasons the surveillance of these dams are not carried out satisfactory today. This report will not attempt to identify particular reasons. An important task for the workshop, is to identify these reasons and try to find constructive solutions in order to improve the situation. At this stage it should be mentioned that there are resources available for monitoring at all the dams visited as well as at Tanesco's main office.

Tanzania is extremely vulnerable if a dam failure at any of these sites should occure because these are the main reservoirs for power production as well as very important sources for water supply and irrigation.

Globally roughly 1/3 of all dam failures are caused by overtopping, 1/3 by foundation weaknesses and 1/3 be seepage and piping. By constant monitoring and evaluations of the state of the dam, indications of potential problems can normally be identified at an early stage. These topics are dealt with in relevant literature and some very interesting articles on the matter are enclosed as appendices to this report.

The site visit reports in Appendices C-F indicates that there are many deficiencies at the different dams we visited. This is illustrate by the two examples below.

Example 1)
The Kidatu dam is an embankment dam equipped with three radial gates for flood control. It is vital that the gates can be operated. The embankment will fail if exposed to overtopping. At the moment there is no emergency power supply.

The gates at Kidatu are very tall, i.e. they are sensitive to seismic activities and might easily jam.

Is the situation adequate? (ref. Appendix no. H)

Example 2)
The Nyumba ya Mungu dam is an embankment dam completed in 1966. The reservoir is about 1000 mill. m3. At the moment the surveillance and monitoring carried out at the dam is not satisfactory due to organisational and economic reasons.

The hydrological estimates for the dam design was done about 30 years ago.

Is the situation adequate? (ref. Appendix no. I)

The workshop will try to deal with these and similar situations. The workshop is described in more detail in chapter 5.

4 SEDIMENTATION

4.1 General

Reservoir sedimentation is a term involving all accumulation including organic matters and inorganic particles, taking place within both natural and artificial lakes. Usually, the latter have a much larger variation in water level during the year than under natural conditions. In turn, this will affect the sedimentation processes within the reservoir. The water volume between the highest and lowest regulated water level is known as the active storage, while the dead storage is the water volume not affected by the regulation. The economic value of a reservoir is linked to the active storage. Due to the reservoir morphology and location of the sediment loaden inlet rivers, sedimentation will take place within both storages.

Data from Ichari dam in India between 1976 and 1984 showed a reduction in dead storage of 70 % while the reduction in the active storage was 35 %. The monitoring demonstrated that as much as 40 % of the sedimentation took place within the active storage (Bhargava et al. 1987) (see Appendix K).

Due to the fact that sediment transport in rivers is difficult to measure and estimate, the sedimentation rates in many reservoirs have been greatly underestimated in calculating the life time of reservoirs (see table below).

RESERVOIR	EXPECTED	OBSERVED	% UNDER ESTIMATION
Bhakra	23 000	33 475	45.5
Maithon	684	5 980	874
Panchet	1 982	9 533	481
Ranganza	1 089	4 366	401
Tungabhadra	9 796	41 058	419
Mavurakshi	538	2 000	372
Ukai	7 448	21 758	292
Nizimsagar	5 300	8 725	165

Underestimation of sedimentation rates (acrefeet) in India (World Bank, 1988).

Reservoir sedimentation will influence on the project economy as the available volume of water decreases. Furthermore, as the active storage decreases, the through flow increases and more and coarser particles may enter the intake. Dam structures as the gates and spillway may also be affected due to more frequent overflow as well as larger sediment consentrations and coarser particles passing through the reservoir.

Generally, a program on reservoir sedimentation should comprise the following:

* Sediment budget
* Monitoring and surveillance
* Calculations, effect analyses and mitigation measures
* Emergency

Sediment budget

The objective of calculating the sediment budget is to quantify the life time of the reservoir. The sediment budget will change from year to year dependent on several parametres. The precipitation and runoff will change from one year to another, while increased human settlement and pressure within the catchment may drastically increase the erodability over time. Such a development will gradually induce an increase in sediment inflow to the reservoir and thus influence the storage capacity.

Monitoring and surveillance

The objective is to establish a system with frequent monitoring to catch up with the sedimentation rates within the reservoir area in such a way that unexpected situations as regards the water resource and impact on technical installations can be avoided. Key elements are location of sedimentation, calculation of sedimentation rates and the distribution of particle sizes. A monitoring and surveillance programme has to be adjusted to each reservoir due to the size, volume and morphology. Furthermore, factors like logistics, financial opportunities and local conditions constitute important issues when choosing the optimal methodology at each reservoir.

The monitoring can be based on:

* Direct measurements
* Indirect measurements
* Models

Calculations and effect analyses

The objective is to implement the data from the monitoring and surveillance programme to foresee the long time development within the reservoir. Necessary precautions as regards available water resources and negative impacts on the dam structures and intakes may then be taken in time. As reservoir sedimentation, normally, is a long time process, mitigation measures should be possible in many cases. Construction of upstream sediment traps and soil conservation programs in the catchment are measures which will reduce the sediment inflow. Cost benefit analyses may elucidate the importance of such mitigating measures.

For smaller reservoirs or in the vicinity of the dams, dredging or flushing through the gates may be actual measures to avoid or minimize the problems created by sediments.

Emergency

As reservoir sedimentation is a slow process, normally no sudden impacts will occur. However, without knowledge of the development within the reservoir the value of the reservoir as a national or regional energy or water resource, suddenly may be degraded and new sources may have to be developed. Most probably, it will then be too late to implement mitigation measures, which could have resulted in cheaper solutions than alternative constructions.

Unexpected damages on turbines, gates and spillways may also be avoided or reduced if precautions are made at an early stage.

4.2 Primary objectives of monitoring

The primary objectives of a sediment monitoring programme are:

1. *Water resources:* determination of volume of water available for maneovering, gain adequate data regarding sediment budget and accumulation rates and thereby the life time of the reservoirs, calculation of the value of water in economic terms to clearify the optimal alternatives.

2. *River systems:* To quantify the sediment flow in the rivers and streams, erosion rates in the cathment and the sediment inflow in lakes and reservoirs. To provide data of the fluvial processes of erosion, transport and sedimentation and their variation with time. To establish erosion rates for the cathment area.

3. *Environmental issues:* To quantify and identify changes in the natural processes caused by encroachments in the river system or changes in hydrology. To gain information on the effects of succesive changes in the development within the catchment area. To identify the effects of compensation measurements (erosion protection works, flood protection works, reforestation etc.) within the catchment . To obtain information on water quality. Identify and predict the expected consequences of reservoir sedimentation on the natural environment within and adjacent the lake as well as the effects on tecnical structures at the dam.

4. *Research purposes:* To study different hydrological and geomorphological processes. To optimize and develop new methodologies and equipments adapted to the needs and situation within Tanzania.

4.3 Primary elements

The primary elements to make a sediment monitoring programme work:

Objective: Background and necessity for the monitoring (water resources

	planning, economic reasons (utilization of the water resources such as power production, irrigation, water supply etc.), dam safety (including spillway and gates), turbine wear, environmental issues, mitigative measures, legislation connected to utilization of water resources etc.
Organisation:	Responsible institution, financial sources, available human resources.
Implementation:	Methodology, field equipment/field station, field technicians, maintenance, transport.
Analyses:	Laboratory facilities, laboratory engineers, data processing.
Reporting:	Data evaluation, data presentation, publication routines.
Motivation:	The importance and use of the results must be clearified and published frequently. The responsible institution has to follow up at the local level. Arrange optimum conditions as regards the field technicians and their work.

The workshop should discuss these factors as regards both the kind of measurements and monitoring needed, and the appropriate methodology. Both the extent of a programme and the choise of instrumentation have to be geared to the goal and the resources available.

4.4 Sediment monitoring in Tanzania

Comprehensive studies and investigations of the erosion and sedimentation in Tanzania was executed during the DUSER project (see Appendix L) in the early 1970's (Rapp, Berry and Temple, 1973). In their report, erosion rates of 260 m3/km2 in the mountain areas of Morogoro and sedimentation rates corresponding to annual sediment yields of 200 - 730 m3/km2 in the semi-arid savanna lands near Dodoma and Arusha were published. However, the latter figures will decrease with the size of the catchment. The erosion rates are among other factors, dependent on the vegetation cover. Any depletion or destruction may easily result in accelerated erosion and increased sedimentation in the reservoirs. Due to increased cultivation, deforestation and cattle, the erosion rates are expected to have increased during the last years.

An erosion hazard map of Tanzania has been published by SADCC, Soil and Water Conservation and Land Utilization Co-ordination Unit. People from the University of Dar es Salaam, Land Use Planning in Sinynaga, Forestry Department and Ministry of Agricultural have contributed to the production. According to the map, high erosion hazard categories are found in the Usambara Mountains, Pare Mountains, the Moshi area, south of Arusha, some areas along Great Ruaha upstream Mtera and between Mtera and Kidatu reservoirs.

Appendix M gives an overview of todays situation regarding dam safety and sedimentation monitoring in Tanzania.

4.5 Monitoring reservoir sedimentation in Tanzania

There is a hydrological monitoring network in Tanzania consisting of a number of hydrometric stations, and some are equipment for sediment monitoring. However, there are no continously monitoring of sediment transport.

Due to the dry and hot climate in the interior of Tanzania, storage of water from the wet to the dry season is crucial. The value of water for irrigation, water supply and power production is therefore very high. The dams and their active storage volume constitute the key elements in a system saving water from one season to another. In regions with high erosion rates the reservoirs are vulnerable to sedimentation, which may drastically reduce the possibilities of utilizing the water resources in the dry season or from one year to another.

In 1990, the Hydrolgy Section, Water Research Division at MAJI made a study proposal on a reservoir sedimentation study (see Appendix N).

The site visits demonstrated that there were no monitoring of reservoir sedimentation in either one of the large reservoirs visited.

The mission suggests that the work shop should discuss a sediment monitoring program to be implemented and restricted to reservoir sedimentation in Nyumba ya Mungu, Mtera, Kidatu and Pangani as a first step.

A field unit including personell from TANESCO and MAJI and with the responsibility of reporting to the Ministry, should be established. Such a unit must have sufficient funding and equipment to handle their function. TANESCO indicated willingness to be responsible for sedimentation surveys in the large reservoirs. Routines regarding field work and sampling, transport, communication, analyses, data processing and data presentation have to be worked out. Routines to utilize the domestic resources represented at the University of Dar es Salaam should be developed, rather than using foreign companies and resources.
The work shop has to cope with these matters more thoroughly and discuss the best ways to implement and organize a sediment monitoring program.

At a later stage a more comprehensive programme including all reservoirs in Tanzania and river monitoring should be worked out. As such a programme also gives valuable environmental information of the condition in the catchment and it will also be important for the area planning. Therefore, possible financial support from other ministries, such as the Ministry of Agriculture and the Department of Forestry, should be considered.

Litterature:

Bhargava, D.N., Narain, L., Tiagi, S.S. and Gupta, P.P., 1987. *Sedimentation problems at low dams in the Himalayas.* In Water Power & Dam Construction, January 1987, p. 30-33

Rapp, A., Berry, L., & Temple, P., (eds.), 1973. *Studies of Soil Erosion and Sedimentation in Tanzania.* Research Monograph Number 1, 1973. Bureau of Resource Assessment and Land Use Planning, University of Dar es Salaam.

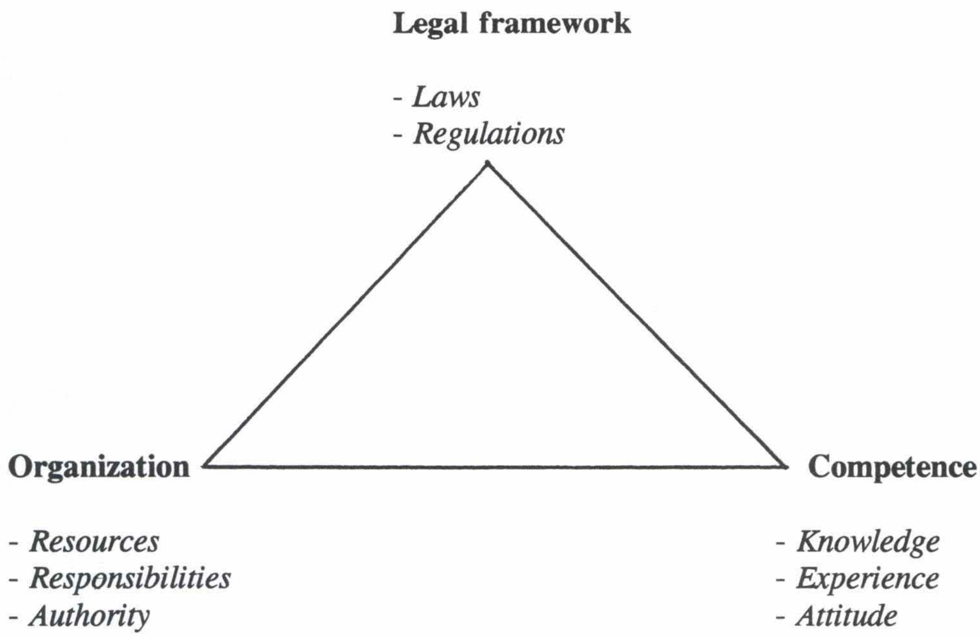
World Bank, 1988. *The Economic and Environmental Evaluation of Large Dams.* A Review (draft), 1988.

5 WORK SHOP

5.1 Introduction

An outline of a programme for the work shop was discussed in a meeting at Tanesco 6 May 1993. The following was agreed upon:

Legal framework, organization and competence are keywords for the work shop. They will be main elements for the presentations and discussions as indicated below.



Objectives for the work shop:

* To bring dam safety on the agenda to a larger extent than now in Tanzania. Keywords: Legislation, organisation, competence.

* To discuss a programme for monitoring sedimentation in reservoirs and how it can be initiated.

5.2 Suggested programme

WEEK 1

DAY 1, **<u>DAM SAFETY</u>**

Welcome/introduction

The value of water in Tanzania.	Supply - demand in Tanzania Concequences of a dam failure at NyM or Mtera
Introduction	What do we want to achieve during these weeks in the field of dam safety.
Legislation	Legal framework for water management and safety in Tanzania. Organisation of responsibilities and authority within water management and safety.
Dam failures	Main factors influencing the safety of a dam, dam failure mechanisms and examples.
Dam types	Description of embankment dams, arch dams, gravity dams, buttress dams. Their advantages and disadvantages.
Instrumentation of dams	Main types of monitoring devices. Why are they installed and how do they function?
Surveillance programmes	The main dams in Tanzania presented by the resident engineers with emphasis on dam safety.

(dam safety videos will be shown).

Presentations within the various fields will be given from people within Maji, Tanesco, The University in Dar es Salaam and NVE. Mr. D.N'Gula and Mr.K.Luteganya will contact persons suited for the tasks and prepare a detailed time-table.

DAY 2 **SEDIMENTATION**

Introduction

Background for reservoir sediment monitoring connected to the managment of dams and dam safety. What to achieve during the seminar, workshop and field exercises.

Sediment monitoring in Tanzania

Presentation of the hydrological monitoring network (including sediment transport) in Tanzania. Basis for erection, methodology, maintenance, analyses and reporting routines.

Competence level on hydrology and sediment transport (theorethical and practical)

Today's situation regarding dams and water resources in Tanzania. (available volume (hydro power, irrigation, water supply etc.), desilting problems, lifetime of reservoirs, future alternatives).

Experiences

Main factors to make a monitoring programme work over several years.

Financing and cooperation between Tanzanian institutions.

Water fees - presentation of the "Pangani River Basin" model.

Reservoir sedimentation monitoring at Pangani/Hale, NyM, Mtera and Kidatu.

Today's situation, presentation of the different reservoirs, their morphology, hydrology, sediment situation.

Aspects of monitoring, what to achieve by a reservoir sedimentation monitoring programme.

How to implement a monitoring/surveillance programme in the different reservoirs.

Reservoir sedimentation programme and dam safety - integrated or separated issue?

DAY 3

Field visit to Hale and Pangani. Focus shall be put on the topics discussed during day 1 and day 2.

DAY 4

Group work, based on the topics highlighted during days 1-3. A list of suggestions are attached in the appendices.

Presentation of the group work, discussion.

DAY 5

Group work, based on topics highlighted during the previous days. (see suggestions attached in the appendices).

Presentation of the group works, discussions.

Sum up of the work shop (including "where do we go from here").

WEEK 2

Days 1 - 3 Site visit to Kidatu and Mtera (the programme and necessary arrangements to be worked out by TANESCO).

The programme shall include field exercises in dam safety and reservoir sedimentation monitoring and measurements.

APPENDICES

A Terms of Reference for assistance project and programme for phase 1.

B Abbreviations

C Site visit, Pangani and Hale

D Site visit, Nyumba ya Mungu

E Site visit, Mtera

F Site visit, Kidatu

G People met

G.1 Some suggested topics for group work and discussions

H Gated vs. ungated spillways. By Mr.I.Torblaa

I BC Hydro's approach to dam safety by Mr.N.M.Nielsen

J Constitution statuts for ICOLD

K Sedimentation Problems at Low Dams in the Himalayas. Article in Water Power and Dam Construction January 1987, by Bhargava et al.

L Conclusions from the DUSER Soil Erosion Project in Tanzania, by Anders Rapp in Studies of Soil Erosion and Sedimentation in Tanzania, Research Monograph Number 1 1973, University of Dar es Salaam, 1973.

M Dam Safety and Sedimentation Monitoring in Tanzania. By Mr. S.G Mkuchu, Principal Water Officer, MAJI, 03.05.1993.

N Reservoir Sedimentation Study (study proposal) by Hydrology Section, Water Research Division, Ministry of Water, Dar es Salaam, 1990.

PRELIMINARY TERMS OF REFERENCE

Dam Safety and Sedimentation Monitoring Assistance Programme for Tanesco, Tanzania. Phase 1 - Fact Finding Mission and Preparation of Detailed Programme.

Introduction

The following is a proposed framework for programme for assistance of control and supervision during construction and operation of the Pangani dam and the operation and monitoring of other existing Tanesco dams. Problems related to sedimentation is included in the programme.

Background

The Norwegian Water Resources and Energy Administration (NVE) has assisted The Norwegian Agency for Development Cooperation (NORAD) in following the planning and construction of Pangani from a dam safety point of view. The matter was discussed at a meeting in Oslo 29. April 92 where Tanesco, NORPLAN and NVE were represented. During the meeting the Tanesco delegates expressed a need for the following:

- An assistance programme in supervision and control during construction and operation of Pangani, and further the possibility of extending the programme to cover all of Tanesco's dams above a certain size or with a certain risk factor related to a possible dam failure.

- Increased know-how in the field of sedimentation, and related problems.

Objectives:

a) To ensure an independent supervision and control during the construction period of the dam. The task will be carried out in accordance with a pattern which is practiced in Norway by the Safety and Emergency Planning Department in NVE on similar projects.

b) To assist Tanesco in developing a competent Unit on Dam Safety, in order to ensure safe and strict operation of the dam in the future. The project can be extended, if required, to cover all Tanesco's dams which will cause damage of significance if a dam failure occurs (in Norway these are defined as dams higher than 4 meters or dams impounding more than 500.000 m^3 of water).

c) To assist Tanesco in gaining and systematizing experiences related to sedimentation.

OR

Scope of work

Phase 1

Two NVE representatives visit Tanzania for 2 weeks in April 1993, in order to do a survey of demands and resources in the fields of sediment monitoring and dam safety.

This survey will comprise:

* An overview of all relevant institutions in Tanzania. Of special interest are the manpower available, their professional level and the institutional responsibilities.

* In order to understand Tanesco's demands and requirements of the dams, the following sites will be visited: Pangani, Nyumba ya Mungu, Mtera and Kidatu.

The survey shall lead to the following:

* Terms of Reference for Phase 2, including:

    - Professional content and training exercises
    - Possible involvement of adequate resources within Tanzania
    - Development of surveillance and maintenance instructions for the Pangani dam and the other sites visited
    - Work programme

* Specified budget and time schedule for Phase 2

Phase 2 (preliminary programme)

NVE supplies representatives from Tanesco with literature relevant to the project. These representatives will study the material either in groups or as individuals. The training is based on theory, case studies and videos on dam safety. (Parts of the training material was introduced to the Tanesco delegates at NORPLAN's head office April 29, 1992.)

Two NVE representatives visit Tanzania at the end of the construction period in order to carry out training on dam safety and sedimentation monitoring as described in Terms of Reference.

Ski, 05 April 1993

Ove Ruster

for Jan Lindemark
Project Director

PROPOSED PROGRAMME FOR PHASE 1

Meetings and site visits:

19 April Arrival in Dar es Salaam. Meetings with Norad and Norplan. Orientation and discussion concerning this project.

20 April Meeting with TANESCO (key persons: Francis Saidi and David Ngola (training officer)) introduction and presentation of the mission.

Items for discussion:

* Organization and responsibilities for hydrology, sediment transport and dam safety in Tanzania
* Laws and regulations
* Tanesco's ideas for this project
* Field trip (practical info., participants etc).

21 April Meetings with Maji, University of Dar es Salaam (Dep. of civil eng. concerning sediment transport, hydrology), Tanesco (drawings of dams, etc)

22 April Travel to Pangani. Presentation and discussion of the Pangani project related to dam safety and sedimentation problems. Site visits to the dam and reservoir area. In addition to meetings with relevant personnel from Tanesco and IVO/Norplan, the stay must include a meeting with the Pangani Basin Water Office and Mr. Audun Bjørknes.

23 April If necessary additional site visits and discussions. Travel to Nyumba ya Mungu reservoir.

24 April Site investigations Nyumba ya Mungu (dam and reservoir, inlet?).

25 April Sightseeing at Ngorongoro crater

26 April Travel to Mtera

27 April Site investigations at Mtera.

28 April Travel and site investigation Kidatu.

29 April Travel Kidatu - Dar es Salaam

30 April Summing up with Tanesco, Norplan and Norad.

OR

Abbreviations

APPENDIX B

NVE:	Norwegian Water Resources and Energy Administration
NORAD:	Norwegian Agency for Development Cooperation
NyM:	Nyumba ya Mungu
TANESCO:	Tanzania Energy Supply Company
PBWO:	Pangani Basin Water Office
MWEM:	Ministry of Water, Energy and Minerals
ICOLD:	International Commission on Large Dams

SITE VISIT, PANGANI FALLS. APPENDIX C

Date: 29 April 1993

CONCRETE WORKS

A considerable portion of the concrete work was completed. The intake and the spillway were partly finished. There were visible signs of deformations in the concrete. The contractor said that this was mainly caused by formwork not satisfying the requirements.

Attempts to install the trash rack has failed due to misalignment of the concrete in the intake. This task is postponed until the damage is repaired.

Indications of unsatisfactory vibration of the concrete could also be seen.

Resident Civil Engineer explained that they took the problems seriously and that the control task will be strengthened. This is obviously of great importance for the success of the construcion. The present system for control is not satisfactory.

EMBANKMENT WORK

The embankment work has not yet started. Preparations of the foundations will start in August 1993.

It is important to appreciate the necessity for strict control during the construction of the embankment. The control should be performed by an engineer with experience from similar work. The preparation of the foundation and the first placement of fill material is critical.

Hale Hydro Electric Development

EMBANKMENTS

The embankments are small earthfill structures with a slope protection built up of stones and concrete. In some places these slopes were heavily deteriorated and should be repaired. The most serious damage was identified at the intake dam, close to the intake. Here, a large quantity of rocks and fill material has been removed for other purposes. The concequensis of this is a reduced cross section in this area of the dam and hence a reduced safety. The fill should be replaced and the fence which is placed at the dam crest should be moved to outside the downstream toe to prevent this to happen in the future.

VEGETATION

There are trees growing at the embankment. These should be removed because their root system can pose a threat by providing seepage paths, which eventually can lead to internal erosion and threaten the integrity of the dam.

GATES

While we visited the dam, repair works was carried out on the gates at one of the dams. This work consisted mainly of replacement of wires for operation of the radial gates. The staff at Hale explained that this was normally done every three years. And that they used ordinary steel wires.
If a galvanized wire had been used the life time would probably be lengthened.

The front of the gates has not been inspected or painted for many years according the staff. The stop logs for maintenance of the gates are available but we were informed that the equipment for placing the stop logs is out of order and must be repaired. Alternatively, other means for placement of the logs can be used.

SEDIMENTATION

The catchment area at Pangani is 42 000 km^2. The dam at Kalimawe has been silted up. Siltation near the intake at Hale dam is a problem reinforced by growth of organic matters such as root systems. There was equipment installed to grab up sediments for investigation. The slushing gate is not working as planned and the sediments near the intake has to be removed manually.

A sediment chamber is under construction at the new dam at Hale.

There were no systematic monitoring of sedimentation rates or accumulation in the dams.

SITE VISIT NYUMBA YA MUNGU DAM. APPENDIX D

Date: 30 April 1993

The main objective of this visit was to inspect the dam from a dam safety point of view.

Water level: 115.45 ft ASD

GENERAL

Nyumba ya Mungu dam (NYM) was completed in 1966 and was at that time the biggest dam impounding the largest reservoir in Tanzania. The dam is an earth-rockfill structure, about 42 m high and 397 m long. The reservoir volume is 1 135 mill. m3. The spillway is constructed as an open, ungated spillway located some hundred meters away from the dam body.

The dam is owned by MAJI while Tanesco is the owner and the operator of the power station just downstream the dam.

The responsibilities connected to surveillance and monitoring are therefore somewhat confusing. But as the situation is at the moment, MAJI is responsible for carrying out these tasks. Due to lack of resources, this task is almost neglected and the recording which is done is random and has no address.

The situation is not satisfactory and a new strategy must be developed as soon as possible.

INSTRUMENTATION

The dam is apparently equipped with instruments to record the following:

- Water levels
- Pore pressures
- Settlements and deflections of the dam

The drawings on site were in a very poor condition due to poor storing facilities. The design features and the dam drawings should be ordered from the consultant if these are the only existing record for the dam in Tanzania.

There is probably a surveillance programme worked out by the same consultant. This should be located as well.

The piezometers are out of order. One of the reasons for this is lack of mercury. The settlements and deformations are not recorded.

EMBANKMENT

It was difficult to do a satisfactory inspection with the lack design material available. The dam is an earth-rockfill structure with an inclined core of clay. In the zone between the core and the downstream shell there is a horizontal strip drainage layer to release excessive pore water pressures. No instruments for monitoring seepage were identified.

The downstream slope has a gradient of 1:1.5 and the upstream gradient varies from 1:3.5 in the bottom to 1:1.5 at the top.

There is some deep rooted vegetation at the embankment which should be removed. This was discussed on site and the resident Tanesco staff promised to cut this.

There are some signs of beaching at the upstream slope. Exept for this the visible slope protection seemed to be in good condition.

SPILLWAY

The spillway is a large open spillway some hundred meters away from the dam. The intended capacity of the spillway is defined by a large conrete paving and abutments. At the moment the capacity is reduced by heavy vegetation upstream and downstream the concrete section. This vegetation must be removed.

The water level gauges in the spillway need to be replaced.

The concrete seems to be in good condition.

HYDROLOGY

There are many years between every time the NYM reservoir is full. For the last two years there has been no water in the spillway.

Anyway, the safety of the dam is closely linked to the relation between floods and spillway capacity. Since the dam is almost 30 years and the knowledge in the field of hydrology has developed it might be a good idea to reevaluate these estimations.

SEDIMENTATION

The volume of the reservoir is 871×10^6 m^3 at the highest regulated water level. The regulation height is 9 meter. The reservoir is mainly fed by rivers from north east. The evaporation is estimated as high as 2 500 mm/year. The water abstraction is approximately 50-55 m^3/s, mainly for irrigation purposes from tributaries and the north side of the reservoir. NyM is the only reservoir for Pangani hydro power project. The mean discharge at Hale is 30-35 m^3/s. The topography around the reservoir is characterized by very low gradients and a small rise in water level will result in a large increase in surface area. There are much loose material around the lake, but due to the low gradients no signs of slides or extreme wave erosion were seen.

There are several hydrometric monitoring stations in the area. However, there are no systematic monitoring of either sediment transport or sedimentation in the reservoir or the catchment. The accumulation since construction is unknown. Due to the semi-arid conditions and the hilly catchment, the erosion rates may be high and perhaps increasing, because of depletion of vegetation cover.

SITE VISIT, MTERA.

APPENDIX E

Date: 3 May 1993

GENERAL

The Mtera dam is a buttress dam, about 50 m heigh and 260 m long. It was completed in 1980. The active storage of the reservoir is 3 200 mill. m3. The spillway which is constructed on the right bank has four radial gates with a total discharge capacity of 4000 m3/s at full reservoir supply level.

INSTRUMENTATION

The directions for inspections and measurements for the dam is included in the manual for " Great Ruaha Power Project - Tanzania, Mtera dam " worked out by Sweco.

The dam is equipped with instruments to record the following:

- Water levels
- Leakage
- Pore pressures
- Stresses in the concrete
- Settlements and deflections of the dam

Instruments for concrete temperature measurements was not identified.

The strain meters are out of order and contact will be established with Geonor in Norway which supplied the instrument.

At the present situation water level recordings are the only measurements carried out regularly by Tanesco. The situation is not satisfactory. A new strategy for monitoring of the dam must be established. A simpler programme than the programme first suggested by Sweco may be adapted.

CONCRETE

The main impression of the concrete is good. There were very few signs of cracks and deterioration. Nevertheless quite extensive vegetation in between and just downstream the buttresses was observed which must be removed for inspection and maintenance purposes. The deep rooted vegetation closer than 5 m from the buttresses should be removed.

There was no light in the inspection galleries under the spillway. This should be fixed so that inspection is possible. No leakage was identified. The gallery is dry and tidy.

GATES

The four radial spillway gates were told to be in good condition and that the operation works well. The gates are equipped with emergency power supply. The stop logs for revision purposes have not been used since construction.

Additionally there is a radial bottom discharge gate. There are permanent stop logs upstream this gate. The gate is therefore normally left in open position for maintenance purposes.

SEDIMENTATION

Mtera, which is the largest reservoir in Tanzania, has a surface area of 600 km2 at the highest regulated water level. The evaporation is estimated to about 25 % of the inflow. The yearly inflow is 125 m3/s. The maximum volume is 3,800 x 10^6 m^3 of which 600 x 10^6 m^3 is dead storage and 3,200 x 10^6 m^3 is live storage. Under natural conditions, the outflow at the dam site varied between 0 m^3/s (absolutely minimum) and 1 500 m^3/s (absolutely maximum). Today the outflow downstream the dam varies between 10 m^3/s and 300 m^3/s. The water level was 695.7 m asl. during the visit, while lowest and highest regulated water lever are 690.0 m asl. and 698.5 m asl. respectively. Mtera is mainly fed by 5 large rivers named: Little Ruaha, Great Ruaha, Kisigo, Bubu and Fufu. Because of the semi-arid conditions Kisigo, Bubu and Fufu are dry between June and November, while there is minimum flow in Great Ruaha from September to November.

The topography around Mtera is open and wide with low gradients. The outlet of an ephemeral stream, which was visited, showed that the accumulation within the live storage can be serious. In this case a smaller bay were nearly filled up with sediments even though the stream is quite small. The mouth bar consisted of alternating layers of accumulated fine sand and coarser material such as gravel and pebbles. The fine layers indicate reservoir accumulation, while the coarser layers most probably are settled bedload. This demonstrates that the sedimentation takes place at various areas in the reservoir caused by the interaction between the inflow parameters and the water level, and indicate that the accumulation can be considerable in the live storage in front of the major inlet rivers.

There are some hydrometric monitoring stations in the catchment, but they were not working due to lack of transport and funding. MAJI have the responsibility of monitoring. There has also been some monitoring of sediment transport, but not during the last years. Therefore no systematic records are available. Furthermore, the sedimentation in the reservoir was unknown. However, a group from SWECO shall do a follow up environmental study this summer and sedimentation is included. During the pre-impoundment study in 1976 the total sediment inflow was estimated at approximately 8 x 10^6 tonnes /year. Due to increased pressure on the environment within the catchment during these years, the erosion rates most probably have increased. Some indirect methods to follow up the sedimentation in the reservoir have been introduced, but the results are unknown to the mission.

Water weeds in the Mtera reservoir represent a problem. Effort should be done in trying to stop or limit this growth.

The results from SWECO's follow up studies and their recommendations will be of special interest as regards the workshop.

SITE VISIT, KIDATU.

APPENDIX F

Date: 4 May 1993

GENERAL

The Kidatu dam is an earth-rockfill dam, about 40 m high and 350 m long. It was completed in 1975. It has an active storage capacity of 125 mill. m3. There is a gated concrete spillway and spillway chute combined with a spillway channel on the southern river bank. The spillway has three radial gates. The discharge capacity is 6 000 m3/s.

INSTRUMENTATION

The directions for inspections and measurements for the dam are included in the manual for " Great Ruaha Power Project, Kidatu Power Plant " worked out by Sweco.

The dam is equipped with instruments to record the following:

- Seepage
- Pore pressures
- Settlements and deflections

Further, there are test procedures for analysis of the seepage water specified in the directions.

The only monitoring carried out today is some seepage records at random intervals. The records are taken by the Kidatu staff and the results are kept at the dam. A new strategy for surveillance must be adapted.

EMBANKMENT

The embankment is an earth and rockfill dam founded on alluvial sand, rock and natural soil which has been tightened by means of grouting. The dam has a central core of impervious earthfill. Between the core and the supporting fill there are transition zones with filters of different gradings.

At the downstream toe of the dam there is a system of collecting drainage conduits. The system was inspected through the entrance man-holes. We found that the total seepage was about 5 l/s. According to the staff, the seepage has been constant for a long time.

The seepage instruments are heavily corroded as well as the entrance ladders. The situation is not satisfactory. It is also very risky to enter the seepage conduits.

GATES

The gates at Kidatu are of vital importance for the safety of the dam. The earth and rockfill structure of the dam will not withstand a possible overtopping which would be the result if the gates do not work as required. The necessity for regular surveillance and maintenance can therefore not be overemphasized.

It was informed about an emergency situation in 1977 when the power supply to Kidatu failed due to flooding. The result of this was that the operation of the gates failed and the gates required manual operation. This is a very resourceful and timeconsuming operation.

The gates are not tested for a year due to the shortage of water. We were informed that they are maintained regularly.

There is a total leakage of about 5 l/s through the bottom of the gates. It would be interesting to do a cost - benefit analysis of a possible pumping back into the reservoir of this water. 5 l/s is about 160 000 m3/year. What is the value of 1 m^3 in Kidatu? Of course, the leakage has a negative effect on the gate structure as well.

In some places within the structure of the gate, earth, grass and water is trapped. The earth and grass should be removed and the water drained away in order to prevent corrosion.

SEDIMENTATION

Kidatu is a relatively small reservoir with a volume of 165 x 10^6 m^3 of which dead storage consitutes 40 x 10^6 m^3 and the active storage 125 x 10^6 m^3. The catchment is 80.000 km^2 including Mtera which is located upstream. The reservoir is long and narrow compared with NyM and Mtera and the sides are steeper and the surface area compared with the volume are small. The yearly precipitation is 1.400 mm/year.

There are no records on sedimentation in the reservoir or sediment transport in the rivers. However, there are some problems with sediments at the intake (most organic, but also some pebbles and fines). Sediments are clogging the intake filters, but there is no sign of turbine wear. Sedimentation was noticed at the confluence between Yovi river and Ruaha.

PEOPLE MET

Abdulla, K. R.	Manager Projects; TANESCO
Adeler, A. V.	Senior Program Officer; NORAD.
Bjørkenes, A.	Senior Advisor, IVO-NORPLAN.
Dahl, B.	Engieer Geology; IVO-NORPLAN.
Eriksson P.	Resident Civil Engineer, Pangani Falls Redevelopment; IVO Engineering International
Kachwamba, N. Y.	Electrical engineer, Mtera; TANESCO
Kibassa, P.	Civil Engineer, Mtera; TANESCO
Kyulule, A. L.	Dr., Senior Lecturer and Head of Soil Mechanics Section; University of Dar es Salaam.
Lema, F. M.	General Superintendant, Hale; TANESCO.
Luhumbika, B. A. S.	Water Officer; Pangani Basin Water Office.
Luteganya, K.	Civil Engineer; TANESCO.
Lyarun, J. A.	Maintenance Engineer; TANESCO.
Malekela, H. S.	Assistant Operation Engineer; TANESCO.
Mbwatila, A.	Director Corporate Planning & Research, TANESCO
Mgeyekwa, J. Z.	Assistant Environmental Engineer; Sewage and Drainage Section, Ministry of Water, Energy and Minerals.
Mihayo, J. M.	Senior Hydrologist in Charge of Field Operations; Ministry of water, Energy and Minerals.
Mkucho, S. G.	Principal Water Officer; Water Law Office/Water Rights, Ministry of Water, Energy and Minerals.
Mmari, G. E.	E. Engineer; TANESCO.
Mrutu, J. S.	Senior Hydrologist in Charge of Sediment Transport; Ministry of Water, Energy and Minerals.

Mtalo, F.	Dr., Senior Lecturer/Head of Hydraulics, Water Resources & Environmental Engineering Section; Civil Engineering Department, University of Dar es Salaam.
Munwo, F. J.	Operation Engineer Kidatu; TANESCO
Ngula, D. P.	Manager Research and Development; TANESCO.
Ngurumi, E.	Director Kidatu Hydro Power Plant; TANESCO.
Nkinda, D. E.	Acting Head of Construction Unit; Ministry of Water, Energy and Minerals.
Nyamboha,	Senior Civil Engineer; Design Department, TANESCO.
Nyaoro, D. L.	Dr., Lecurer in Foundation Engineering; University of Dar es Salaam.
Pettersen, E. T.	Civil Engineer; IVO-NORPLAN.
Rwenyagira, V.	Civil Engineer; TANESCO.
Saidi F. X.	Director of Projects, Design & Construction; TANESCO
Sechu, L. M.	Acting Commissioner for Water Resources (Head of Design Unit); Ministry of Water, Energy and Minerals.
Senkondo, S. M.	Senior Supervisor; TANESCO.
Shekalaghe, A. S.	System Superintendant, Hale; TANESCO.
Swila, L. A.	Communication Engineer, Kidatu; TANESCO
Tesha L. A. M.	B. Sc Mechanical Engineer; TANESCO
Waziri, H. R.	Assistant System Superintendant; TANESCO.

Suggested for topics for group work and discussions:

Is the legal framework in Tanzania satisfactory to ensure safe dams?

Are the responsibilities and legal authority between institutions clearly defined? If no, make a proposal for improvement.

Why is the situation at Kidatu with respect to dam safety, not satisfactory, and what should be done?

Make a surveillance programme for NyM and describe how it should be implemented, resources required, where to get the resources etc.

Make a suggestion for how the surveillance and monitoring of the major dams in Tanzania can be organized in order to ensure the highest possible degree of safety with the resources available within the country.

How do we implement these new ideas within Tanzania and Tanesco?

The need of training and motivation. What can be done by the local staff members and professionals? Is there a need for external training?

The surveillance programme for Mtera is handed out to you. Make a suggestion for how this can be reduced or maybe altered but still give the necessary information to tell whether the situation is satisfactory or if something should be done with respect to dam safety. Bear in mind the resources available.

Is it possible with cooperation between MAJI, TANESCO and UiDeS to utilize Tanzanias resources in a better way? Suggestions of how can this be done in practice. Are there possibilies of establishing a field unit consisting of people from the different institutions? How will this fit in with the existing structure (water offices etc.) and their fields of responsibility?

Discussion on suitable methods for monitoring sedimentation in reservoirs.

Discussion on suitable methods for monitoring sediment transport in rivers or streams.

COMMISSION INTERNATIONALE
DES GRANDS BARRAGES

Seizième Congrès
des Grands Barrages
San Francisco, 1988

Q. 63
R. 9

OPINIONS ON UNGATED VS GATED SPILLWAY FOR EMBANKMENT DAMS (*)

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Chief Engineers, Ingenior A.B. Berdal A/S
Partner of Norconsult A.S.
NORWAY

1. INTRODUCTION

Even if dams are not being designed for eternity, it can be expected that a large number of the dams built in this century will still be here and serving a purpose some 100 years from now.

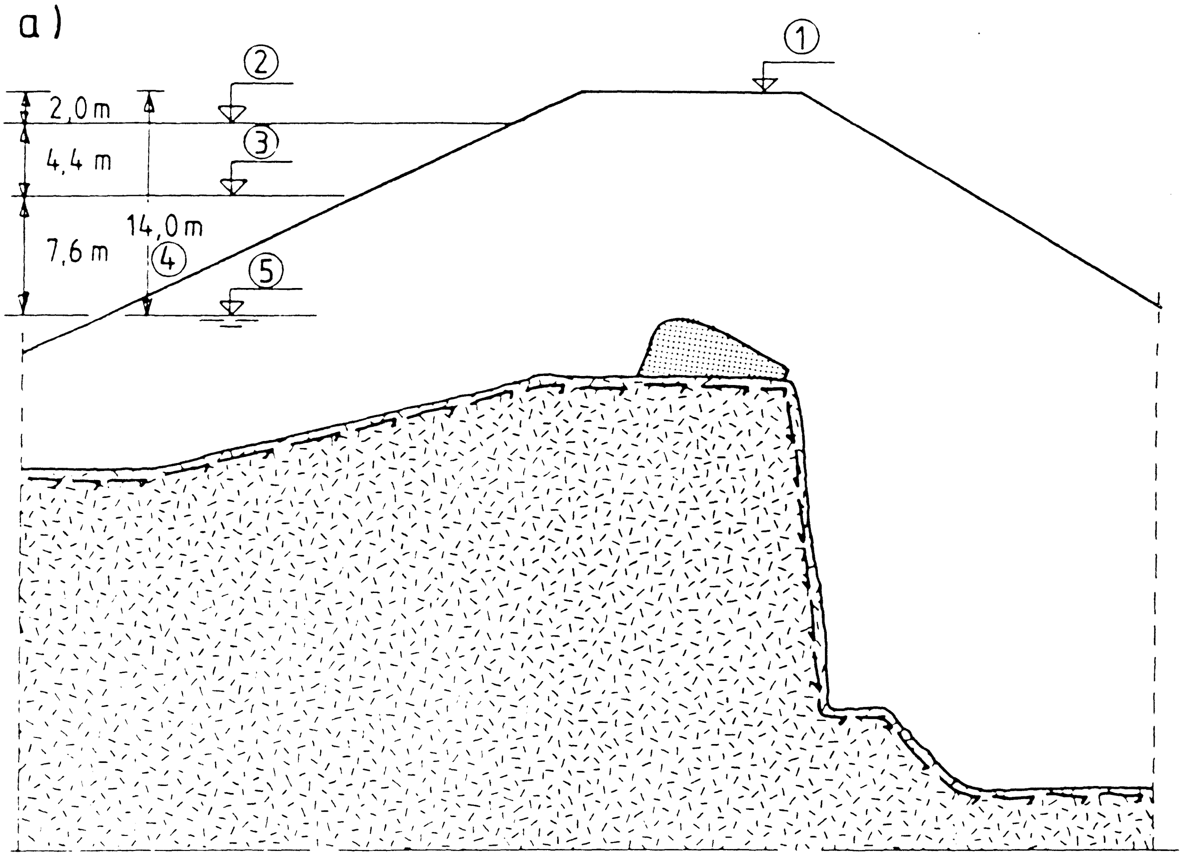
The longevity of embankment dams, more vulnerable to the consequences of overtopping during major flood events than the concrete dams, is likely to be affected to a large extent by the spillway arrangements — on whether gated or ungated.

Since large reductions in the height and volume of an embankment can be the result of designing the spillway with gates, see example in Fig. 1, where a height reduction of 6 m can be achieved, the ensuing cost saving may tempt designers to choose that solution. This apparent cost benefit may, however, be reduced or even reversed when safety considerations are taken into account.

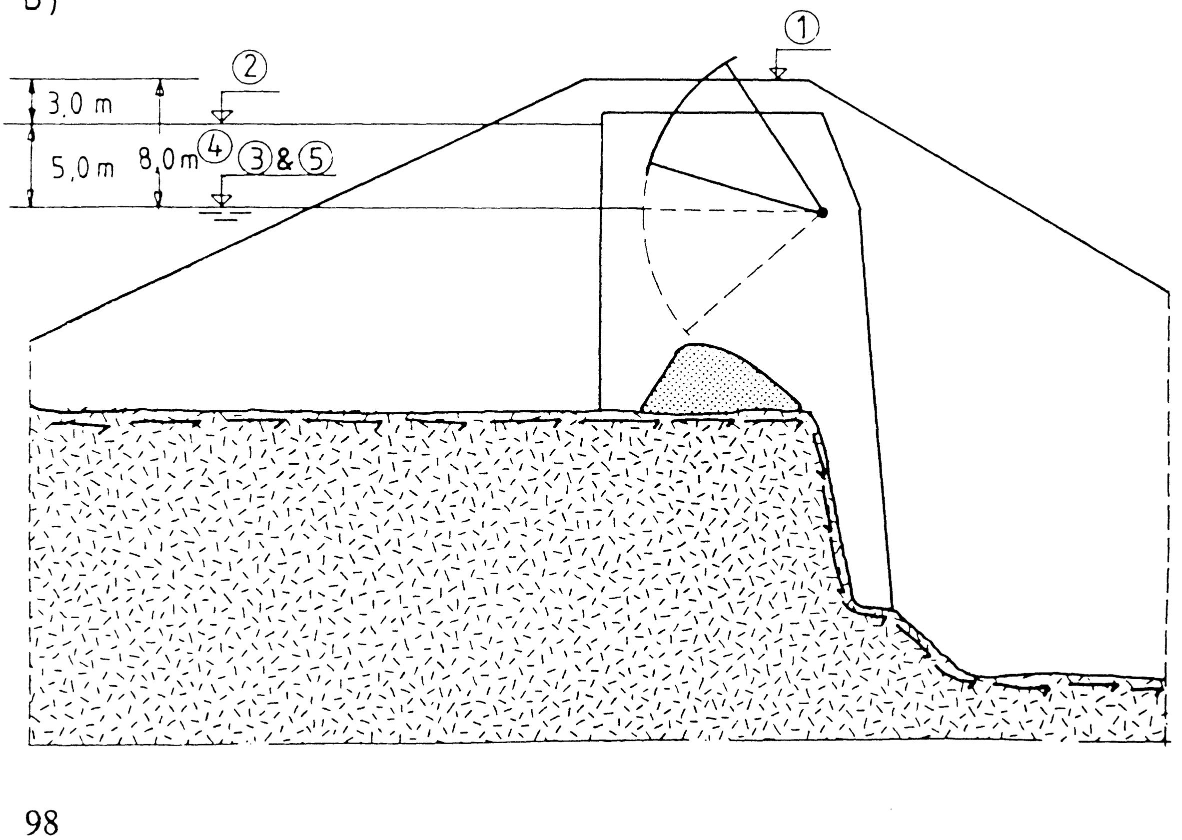
Based on literature published on the subject of controlled and uncontrolled spillways it may be deducted that the present trend is away from gating of the spillways, at least in some parts of the world. Ref. [1], [2] and [3].

(*) *Points de vue sur les évacuateurs de crue sans vannes comparés à des évacuateurs avec vannes pour les barrages en remblai.*

a)



b)



2. SAFETY CONSIDERATIONS

When it comes to dam safety, the gated spillways have several disadvantages, such as :

— Malfunctioning of the gates may result in overtopping of the dam and dam failure.

— Faulty operation of the gates causing artificial floods and inundation of downstream areas.

— Possible failure in communications, power supply and availability of manpower in an extreme flood situation may cause overtopping and damage even if the gates are well maintained and fully operable.

— The vulnerability to destruction through sabotage.

Some recent examples of malfunctioning of gates are the following :

— Euclides da Cunha Dam (1977, Brazil). Dam failure caused by overtopping at least partly due to a bridge being taken by the flood, blocking access to the dam for the crew on their way to open the spillway gates. This dam failure triggered the failure of facilities at another dam further downstream.

— Machhu Dam II (1979, India). Dam failure due to overtopping, which caused heavy losses including human lives. Three out of eighteen gates were out of order due to electrical failure.

Fig. 1

Practical example on how the height of an embankment dam is influenced by the spillway solution

Exemple pratique de l'influence exercée sur la hauteur d'un barrage en remblai par le type d'évacuateur de crue retenu

a) Ungated version, resulting in a dam crest of 14 m above HWL

b) Gated version, resulting in a dam crest 8 m above HWL

1. Dam crest
2. PMF (Probable Maximum Flood)
3. Design Flood
4. Freeboard above RWL
5. RWL (Retention Water Level)

a) Sans vanne, donnant un niveau de crête situé à 14 m au-dessus de la retenue normale

b) Avec vanne, donnant un niveau de crête situé à 8 m au-dessus de la retenue normale

1. Crête du barrage
2. Crue maximale probable
3. Crue de projet
4. Revanche au-dessus de la retenue normale (R.N.)
5. R.N. (Niveau normal de retenue)

— Hirakud Reservoir (1980, India). Heavy unseasonal flood, caused by over-reaction on the part of a gate operator, resulting in material losses.

— Tous Dam (1982, Spain). Dam failure attributable to overtopping because power failure made it impossible to open the spillway gates. Losses included 40 human lives.

— Noppikoski Dam (1985, Sweden). Dam failure due to overtopping caused by jamming of one out of two gates, resulting in material losses.

— Lutufallet Dam (1986, Norway). Part of an embankment dam had to be cleared away by blasting, due to a jamming spillway gate.

In a 10-point plan for dam safety proposed by Mr. Pierre Londe in 1982, the points 4 and 5 deal with spillways :

4. In designing spillways and other reservoir outlets, utilise the best hydrological methods with a clear appreciation of the catastrophic consequences of overspilling the main embankment. Fuse plug spillways provide a good safety measure if correctly designed.

5. With a gated spillway, very detailed and strict operating rules are required for safety. Any possible human or mechanical failure has to be anticipated and emergency arrangements made to overcome it.

If a gated spillway is preferred, for instance in a region with severe earthquake conditions, it is obvious that an extra spillway with emergency fuse plug is required.

A brief review of the literature published on the subject of controlled and uncontrolled spillways reveals that in Australia, the trend since 1955 has clearly been away from gated spillways at large dams. According to Ref. [1], only 25 % of the total number of spillways built between 1955 and 1972 were gated, with the percentage dropping to 19 % for spillways built between 1970 and 1972. A similar count from Austria, Ref. [2] shows that only 10 % of all embankment dams in that country were built with gated spillways.

The ungated spillway will never fail to discharge even when unattended, and under the most extreme conditions such as earthquake damage together with power failure and broken communication lines, or under panic conditions during large floods.

3. RISKS AND CONSEQUENCES

According to statistics from ICOLD, referred in ref. [3], which includes more than 10 000 dams higher than 15 m, 216 of these dams have failed. The diagrammes in Fig. 2 and Fig. 3 inform in more detail about the dam failures.

Fig. 2 shows the relative importance of the causes of failure, on top for concrete dams, in the middle for fill dams and at the bottom for all dam types together. It is interesting to note that the three main causes of failure — overtopping, foundation defects and piping — have all about the same rate of incidence.

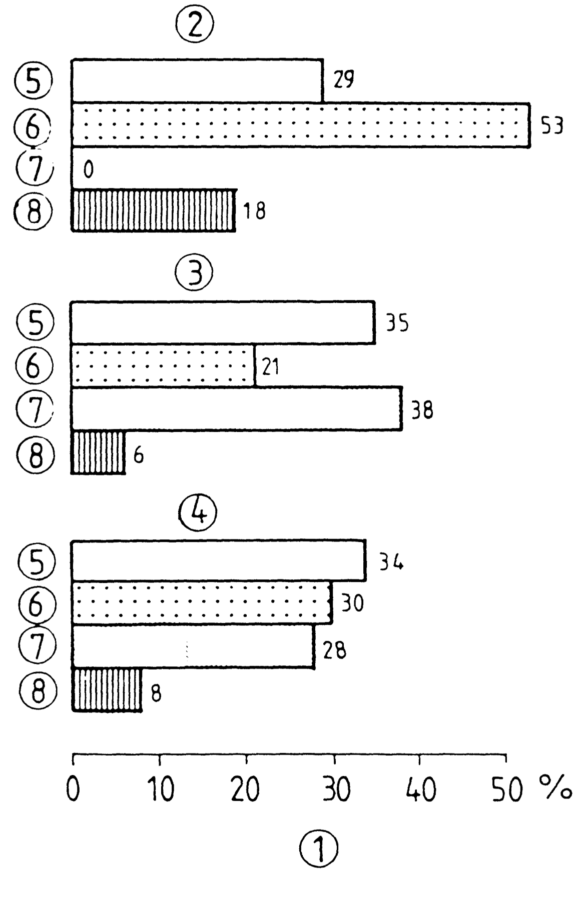


Fig. 2

Causes of dam failures, not including failures during construction and acts of war

Causes de rupture des barrages, ne comprenant pas les ruptures pendant la construction ou à la suite d'actes de guerre

1. Percent of failures
2. Concrete dams
3. Embankment dams
4. All dam types
5. Overtopping
6. Foundation
7. Piping and seepage
8. Others

1. Pourcentage de ruptures de barrages
2. Barrages en béton
3. Barrages en remblai
4. Tous types de barrages
5. Submersion
6. Fondation du barrage
7. Renard et infiltration
8. Autres causes

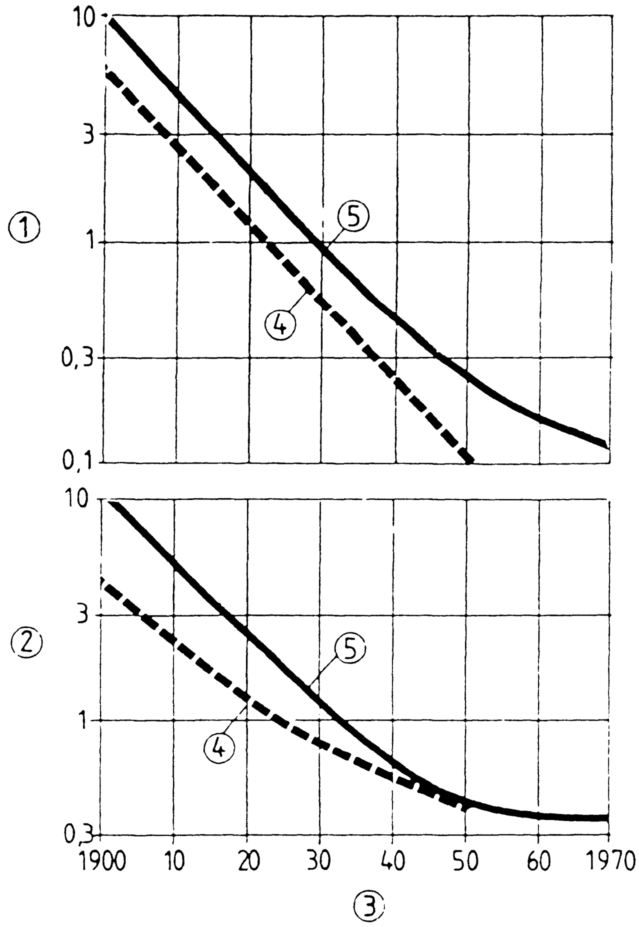


Fig. 3

Risk for dam failure, not including failures during construction and acts of war (ref. [3])

Risque de rupture des barrages, ne comprenant pas les ruptures pendant la construction ou à la suite d'actes de guerre (réf. [3])

1. Percent of all dams in operation
2. Percent of dams built simultaneously
3. Year
4. Concrete dams
5. Embankment dams

1. Pourcentage de tous les barrages en service
2. Pourcentage des barrages construits simultanément
3. Année
4. Barrages en béton
5. Barrages en remblai

Fig. 3 shows the improvement of the rate of failure over the period 1900-1970, separately for concrete and fill dams. The upper graph gives in logarithmic scale the percentage of failed dams in relation to all dams in operation or at risk at a given time. The lower graph gives the proportion of the built dams which later failed and shows :

a) the dramatic (at least tenfold) improvement in safety since the beginning of the century,

b) that modern fill and concrete dams are about equally safe.

It can be concluded that according to statistics the risk for failure of a new embankment dam is approximately 0.4 %, or one out of 250. One third of the failures will be caused by overtopping, but with reference to the previous chapter, it seems probable that the majority of the overtopping cases are explained by malfunctioning of gates. As an estimate the risk for overtopping can probably be set to one out of 1 000.

When evaluating risks, also the consequences should be considered. Fig. 4 presents a relation between stored water height and maximum flood due to dam failure. The diagram is based on observations from 15 dam failures and theoretical estimates.

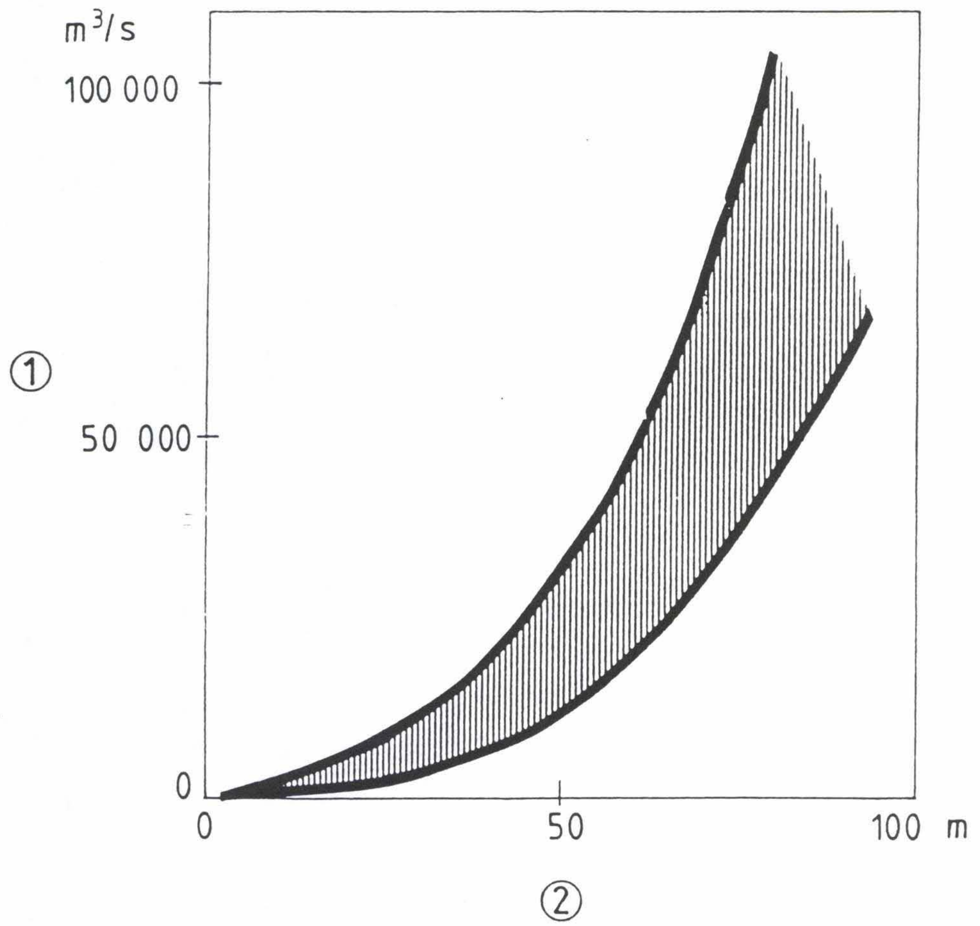


Fig. 4

Relation between stored water height and maximum flood due to dam failure (after G.W. Kirkpatrick)

Relation entre la hauteur de la retenue et la crue maximale due à la rupture du barrage (d'après G.W. Kirkpatrick)

1. Maximum flood, m^3/s
2. Stored water height, m.

1. Crue maximale, m^3/s
2. Hauteur de la retenue en mètres

In their Bulletin of 1986 on Design of Spillways for Dams, ref. [4], the ICOLD Committee on the hydraulics of dams have reviewed experiences from a total of 182 existing spillways around the world, and made some clear statements regarding the question of gating. Some key excerpts are the following :

— « Gates are optional on surface spillways. This is a distinct advantage in that an ungated spillway is preferable when local conditions such as high seismic activity, lack of confidence in maintenance and/or operating skills, short peaking time of the inflow hydrograph, remoteness of the site and difficulty of access mean that there are doubts as to the dependability of the gates and the way they will be operated » (paragr. 3.2.1.).

— « The seismicity of the area and confidence in the operating system are the prime factors in deciding whether it is appropriate to design a gated structure » (paragr. 2.2.2.).

— « Regarding reliability of operation, the designer must weigh the risk of one or more gates failing to open when the flood arrives because of power failure to the hoisting mechanism or a gate or gates jamming through faulty maintenance. He must also consider the possibility of human error in opening the gates at the wrong time, or too late because the operating rules are misconstrued. The operator must have ready access to the gate controls at all times. It must be realised that en exceptionally large flood may cause panic. If there is the slightest doubt on the reliability of gate operation or the competence of the operating staff, the wise choice is for an ungated spillway » (paragr. 2.2.2.).

— « Standby diesel-electric generators should be provided if power failures are likely » (paragr. 3.4.).

— « Regardless of how reliable gate operation is, it is often stipulated, sometimes by national regulations, to design the spillway to prevent overtopping of the dam with one or more gates failing to open. Gates can also be designed for overtopping. This leads to a larger number of gates or the use of an emergency spillway (uncontrolled overspill, breaching dyke or exploding plug) » (paragr. 3.2.2.).

4. COSTS

As stated in the introduction, the saving for the gated alternative come from the reduction in embankment volume due to the lower crest level.

If, however, the safety situation is such that the gating of the spillway calls for an emergency fuseplug-type spillway in addition, the cost of that extra spillway will reduce or even exceed the saving, depending on the local conditions.

With gated spillways in seismic areas it is also prudent to endeavor reducing the risk for jamming, by setting the gates inside stiff, one-piece frames. The net result is a larger number of moderately sized gates rather than a few very large ones, paragr. 3.4. in ref. (4). This will further penalize the costs of that alternative.

For a proposed project in Burma, where the downstream area for the 130 m high dam is a 3-400 km long flood plain with a large population, the consultant recommended an ungated spillway based on safety considerations. The cost for that alternative incidentally came out as 4 MUSD (or 3.5 % of the dam cost) less expensive than the gated one, mainly due to the cost of the emergency fuse-plug required for the gated alternative.

5. CONCLUSIONS

In cases where the consequences of a dam failure or of faulty operation of the gates may become severe, costs alone should never be made the deciding argument in the choise between a gated or an ungated spillway — where the latter alternative clearly provides a safer existence for the population in the downstream area it should be selected in any case.

Gated spillways should be contemplated only when :

— the consequences of a dam failure is less severe and the cost saving is significant,

— the higher flood rise in the reservoir implied by the ungated alternative is of great inconvenience.

In all other cases ungated spillways should be preferred.

The authors have had the fortune of seeing a dam in Central Burma dating from the year 1200, still in serviceable condition. Needless to say, the spillway was ungated. It is the guess of the authors that if this was not the case, the dam would not still be there.

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SUMMARY

The reduced dam height and volume obtained by the gating of the spillway may tempt designers to rule out the ungated alternative.

A closer look at the safety aspects for the two alternatives, together with a list of recent accidents related to gated spillways, should give rise to second thoughts.

Risks and consequences of an overtopping related to a gated spillway is discussed, and an example given of a cost comparison of gated/ungated alternatives.

The trend worldwide, judging from the somewhat meagre statistics available, seems to be away from the gated spillway.

The conclusion is clearly in favour of ungated spillways when there is a freedom of choice.

RÉSUMÉ

L'évacuateur de crue avec vannes entraîne une réduction de la hauteur et du volume du barrage, ce qui pourrait inciter à rejeter la variante évacuateur sans vanne.

Toutefois, on devrait être amené à une conclusion différente lorsqu'on examine de plus près ces deux types d'ouvrage du point de vue de leur sécurité et lorsqu'on tient compte de tous les accidents liés aux évacuateurs avec vannes survenus récemment.

Ce rapport traite en détail des risques et des conséquences de submersions liées aux évacuateurs avec vannes et donne ensuite un exemple de comparaison des coûts des solutions avec/sans vanne.

On constate, à la lumière des statistiques assez maigres dont on dispose actuellement, une tendance, dans le monde, à s'éloigner de l'évacuateur équipé de vannes.

On conclut en se prononçant nettement en faveur des évacuateurs sans vanne lorsqu'il est possible de choisir entre les deux types d'ouvrage.

more than 5 was successfully predicted 25 days in advance, on the basis of changes in the drainage discharge (Fig. 4).

The physical explanation for this phenomenon is that the accumulation of the tectonic energy during the period preceding the earthquake "squeezes" water from pores and cracks into the dam drainage system. Before the time of the beginning of the creep movement, the volume of the cracks increases and the seepage discharge diminishes. After the shock the cracks close, and the seepage flow increases again.

Also, the response of vibrating wire transducers installed at the rock/concrete interface, at the dam abutments and in the foundation, is of great importance because these instruments record the variations of the main shear strength parameters such as friction and cohesion. The readings from these instruments enable one to estimate the real strain stability of the structure subjected to the impacts of various extreme loads combined with the seismic effects. Besides the usefulness of data obtained from these instruments, the technique resulting from this research may be helpful in forecasting seismic events and checking the warning signals registered by other instruments.

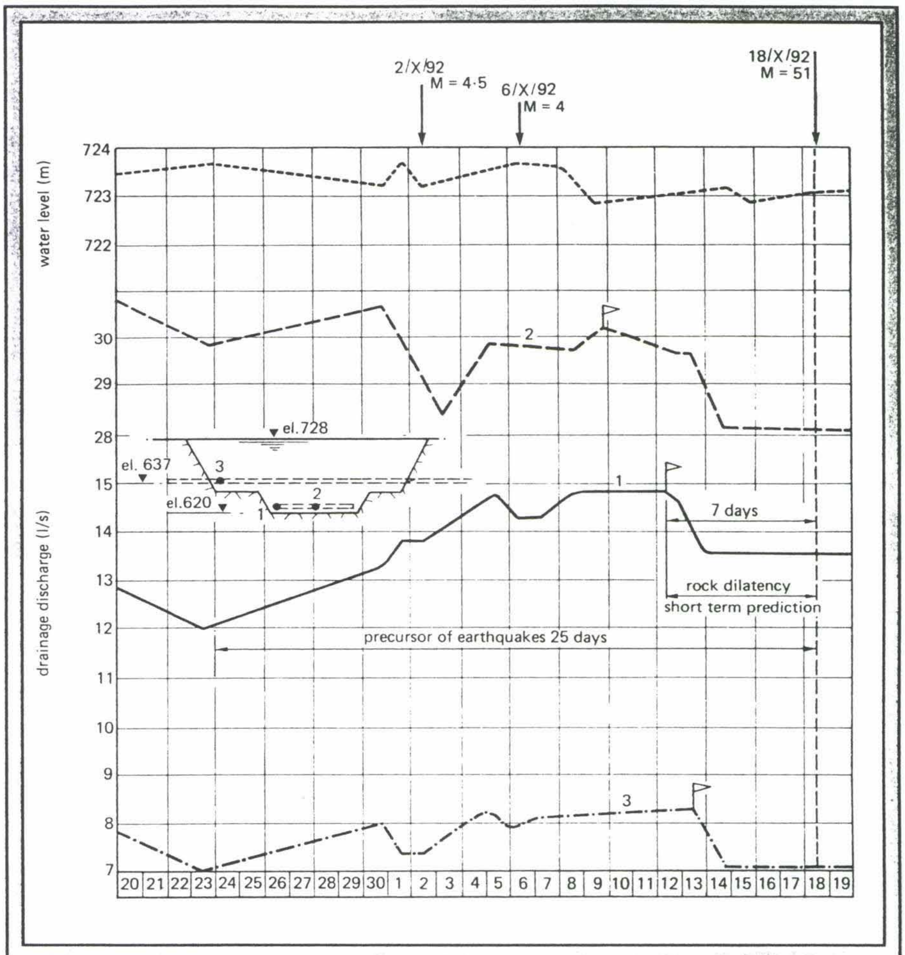

Fig. 4. Earthquake prediction with the help of seepage flow measuring at Kurpsai dam, Kirghizistan (change of trend before shock is marked with flag symbol).

When considering the merits of the proposed methods of earthquake forecasting using the conventional dam monitoring system, not only the high sensitivity of the system to the neotectonic impact should be taken into account, but also the possibility for multiple checking of every signal throughout the whole system of measuring instruments and with account being taken of all the parameters measured. When two or three dams are located in the same region of high seismic activity, the signal checking and the epicentre direction-finding could be done using the measuring systems of all the dams.

This method of earthquake prediction is patented. At present in our country, a programme for the establishment of a state network of services for seismic observations and earthquake prediction at all high dam sites is under consideration. □

BC Hydro's approach to dam safety

By N. M. Nielsen, Manager, Project Engineering*

Innovative methods of analysis and ways to improve dam safety have been developed in British Columbia, Canada, as part of BC Hydro's dam safety programme. As the programme matures, specific initiatives are being pursued in the areas of consequence-based dam safety criteria, flood and seismic analyses, operational reliability, and techniques for investigation and monitoring.

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In 1979 BC Hydro initiated a comprehensive dam safety review to cover dams built before 1961. The present Dam Safety Program (Fig. 1), which started in 1982, covers all BC Hydro dams. The management of the Dam Safety Program is shown in Fig. 2.

Dam safety review

The understanding of dam behaviour under seismic and other extreme load conditions has changed significantly in recent years. Many older dams were designed with limited hydrological and seismic data and to design criteria

British Columbia is Canada's westernmost province and covers nearly 1×10^6 km^2 of rugged terrain. The major electrical utility, BC Hydro, has 61 dams at 43 locations, built between 1908 and 1985. The reservoirs behind the dams vary from small, run-of-river headponds, to immense bodies of water, and the reservoir rims are mostly steep and forest covered. Table I shows the number and heights of the various types of dams. The powerplants associated with these dams provide about 90 per cent of the utility's generating capacity; thus their continued safety and operating performance is vital to the provincial economy.

The Provincial Water Act empowers the Comptroller of Water Rights to ensure that all dams in the province of British Columbia are constructed, operated and maintained to acceptable safety standards.

BC Hydro's corporate policies to ensure dam safety are based on the tenet that in utilizing the natural resources of British Columbia to produce electric energy, unacceptable risks should not be imposed on its residents or the environment.

Table I — BC Hydro dams

	Height	Type	Number
Concrete dams	>60 m	Gravity	4
	>30 m	Gravity	4
		Arch	1
		Buttress	1
	<30 m	Gravity	16
		Arch	1
		Buttress	2
Embankment dams	>60 m	Earthfill	3*
		Concrete faced-rockfill	1
	>30 m	Earthfill	6
	<30 m	Earthfill	13
		Concrete faced-rockfill	1
Freeboard dykes and diversion structures			8

*Mica dam is 240 m high.

which were less stringent than those required by current standards.

Initially an inventory review was carried out and all dams were classified in terms of size and consequences of a dam breach. Design floods and earthquakes were assigned, based on the resulting hazard category. Each dam was then ranked by the likelihood of failure, based on an understanding of the original design parameters, the existing condition of the dam and engineering judgement. The Dam Safety Program started with those dams perceived to have the highest risks.

Comprehensive Inspections and Reviews (CIRs) started in 1984 and are carried out on each dam approximately every six years. The CIR consists of inspections of the dam and reservoir slopes, followed by an assessment of their performance since construction and a review of operational, maintenance and surveillance procedures. An extensive review of the as-constructed design of the dam is undertaken and compared with current evaluation guidelines and criteria. All auxiliary structures are included, such as gates, conduits, debris booms, and so on, the malfunction, damage or failure of which could affect the continued safe operation of the dam, or otherwise jeopardize the safety of the public, property or the environment. From this review, an assessment of the dam's safety is made.

If the CIR team cannot confirm the safety of the dam, either operational or structural improvements are made or, if the assessment is not definitive, more detailed deficiency investigations are carried out.

Assessment of the safety of each dam is based on evaluation criteria and procedures contained in BC Hydro guidelines. The guidelines cover:

- Undertaking a comprehensive inspection and review;
- Selecting and routing inflow design floods;
- Reservoir freeboard;
- Closure requirements for power intake gates;
- Selecting and applying seismic criteria for dams;
- Selecting and applying seismic criteria for dam appurtenances;
- Review of reservoir slope stability;
- Determining reservoir evacuation requirements; and,
- Modelling procedures for dam breach inundation studies.

Further guidelines are being prepared, as follows:

- Consequence-based dam safety criteria;
- Management of reservoir debris;
- Design of debris booms;
- Reliability of dam operation; and,
- Assessment of foundations of existing dams on rock.

Studies are being undertaken to provide basic parameters and information necessary for the assessment of dam safety.

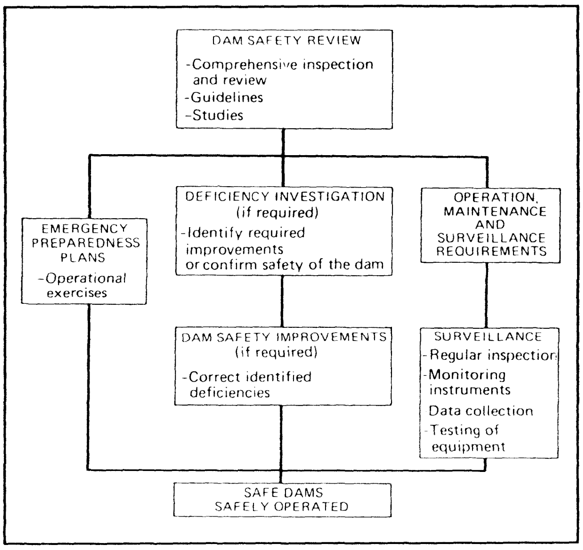


Fig. 1. Structure of BC Hydro's Dam Safety Program.

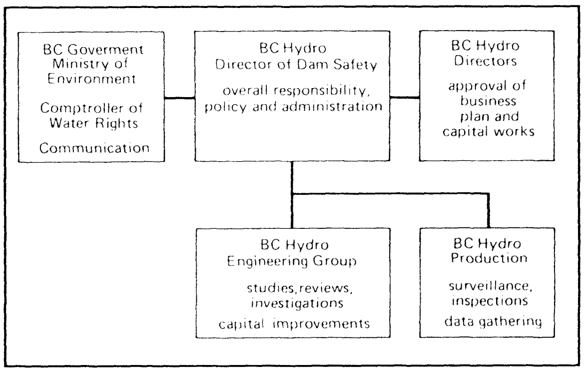
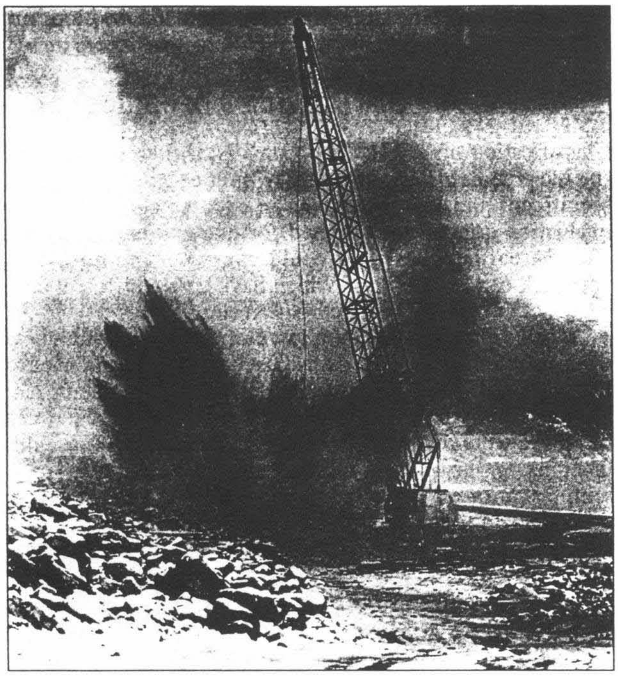
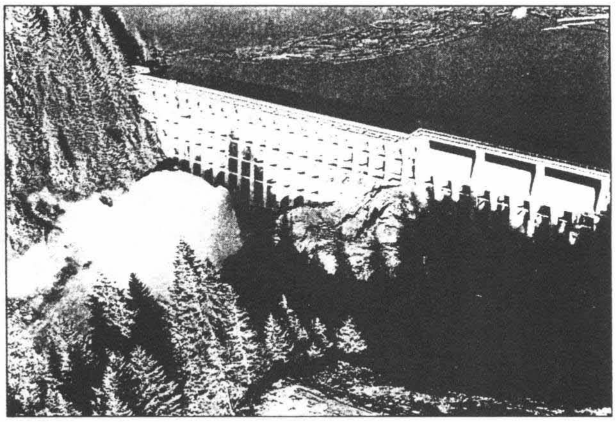


Fig. 2. Dam Safety Program management.

- **Seismic:** Design earthquake parameters for the Maximum Design Earthquake (MDE) and the Design Basis Earthquake (DBE) are derived on a site-specific basis to reflect the prevailing understanding of the seismo-tectonic



Densifying upstream foundations to withstand seismic loading using dynamic compaction at Daisy Lake dam.



Strengthening of buttresses to withstand seismic loading using pilasters and struts at Jordan diversion dam.

environment.

- **Flood:** Probable Maximum Precipitation (PMP) and Probable Maximum Floods (PMF) are derived on a watershed-specific or regional basis.
- **Reservoir slopes:** The behaviour of potentially hazardous slopes is assessed where failure of these slopes could affect the dam by direct contact or a slide-generated wave.
- **Inflow forecasting:** Prediction of reservoir inflows and hence warning of the onset of large floods is improved.
- **Dam breach inundation:** The consequences of dam failure are determined. The results are used as input for the selection of evaluation criteria for safety assessment, and for the preparation of inundation maps which are incorporated into the emergency preparedness plan for each dam.

Emergency plans

Emergency Preparedness Plans (EPPs) have been prepared for each dam. The EPPs, which provide procedures for responding to alerts and actual dam breach conditions, are distributed to agencies involved in emergency preparedness. Testing of the EPPs is carried out on a regular basis. A recent operational exercise involved a simulated, earthquake-triggered dam breach. As part of the exercise, the BC Hydro Corporate Emergency Centre in Vancouver was activated and 23 agencies participated in the community emergency operating centre set up near the dam. These exercises are accepted well by the public and agencies.

Operation, maintenance and surveillance

A set of specific and unique operation, maintenance and surveillance requirements for dam safety is identified for each dam. A concise document detailing these requirements is prepared, primarily for use by production (site) staff.

Regular inspections, monitoring, data collection and testing, carried out on each dam, include:

- Routine visual inspection and collection of data by site personnel;
- Intermediate inspections by a dam safety inspector, usually twice a year, at high and low reservoir levels;
- Continual monitoring of instruments in dams and reservoir slopes for piezometric pressures, displacements, stresses and seismic activity, augmented by Automatic Data Acquisition Systems;
- Special inspections, when unusual conditions are suspected or known;
- Reservoir slope inspections of existing or known potential slides. For slopes where the consequences of failure would be high, movements are carefully monitored by elaborate instrumentation; and,
- Inspection and testing of discharge gates and other auxiliary equipment required for dam safety purposes.

Deficiency investigations

Deficiency Investigations, if required after the dam safety review, either confirm that the dam is safe or that a deficiency exists. In the latter case, a preferred method of improving dam safety is identified. The components are as follows:

- Assessment of the potential deficiency to determine whether the dam is safe or poses an unacceptable risk to life or property. This can include installation of instruments, field investigations, and rigorous analysis and modelling.
- Determination of whether or not short-term risk is acceptable, or implementation of interim measures.
- Identification of various permanent measures to remedy any deficiency.
- Engineering and economic analysis of options and selection of one for implementation.
- Preparation of preliminary design and cost estimate for the selected option.

Many of the investigations have resulted in dam safety improvements being required. However, in one case, the WAC Bennett dam, it was concluded after significant investigation that the observed behaviour of piezometric pressures in the core, initially viewed with alarm, was not unusual for dams having thick impervious cores made of glacial till[1]. In the case of Duncan dam, a major earthfill structure founded on loose compressible foundations, there has been settlement of up to about 5 m since construction. Screening studies indicated potential seismic stability problems under the Maximum Design Earthquake. However, extensive geotechnical investigations and finite element analyses have concluded that the liquefaction and subsequent deformation of the foundations and fill would not jeopardize the integrity of the dam and that the risk to the dam is acceptable. This study demonstrated the value of a staged assessment, where the cost of additional, more complex, investigation and study was weighed against the cost of remedial measures at each stage.

Dam safety improvements

Twenty-five of BC Hydro's dams have been, or are being, upgraded to meet safety requirements, and it is expected that 13 others will require upgrading. Although some measures are significant, the majority are to correct deficiencies that seem relatively small, but which could have led to dam failure. The choice of improvements is normally based on the alternative that has the lowest total cost (including construction, lost energy and the risk costs of future physical and environmental damage). To meet this goal, both structural and non-structural improvements are considered.

Non-structural options include changes to reservoir rule curve operation, warning systems for flood events, and project abandonment. A number of reservoir rule curves have been amended, but no projects have, as yet, been abandoned. Although reliance on warning systems has not yet been accepted as a permanent non-structural mitigative measure, one is being considered for the Wahleach project. At present, an interim warning system is in place at this project which is based on flood forecasting from a hydrometeorological network, inspection of the spillway for evidence of distress and, if necessary, alerting authorities through the procedures outlined in the EPP.

Structural improvements that have been implemented include the following:

- Strengthening and minimizing the liquefaction potential of the earthfill sections and foundations at the John Hart dam, using a combination of techniques including slurry trench, jet grouting, stone columns, vibroflotation and material replacement[2];
- Rock buttressing of the Coquitlam dam and increasing the height of the dam to increase spillway capacity;
- Rebuilding Alouette dam using the existing dam as an upstream cofferdam;
- Reinforcing the Jordan diversion dam buttress and slab structure using pilasters and struts designed on the basis of a three dimensional finite element dynamic analysis[3];
- Strengthening a number of concrete dams and spillway piers for seismic loads using large capacity, post-tensioned, corrosion-protected anchors;
- Providing automatic flow shut-off capability for power intake gates and turbine units using seismically activated triggers[4];
- Densifying foundations to improve seismic stability at the Daisy Lake dam using dynamic compaction and berm loading; and,
- Installing drainage adits to provide stability for Dutchman's Ridge (Mica dam) and Downie Slide (Revelstoke dam). Elaborate instrumentation to measure water pressure and deformation was also included[5].

Future directions

The first cycle of dam safety reviews has been completed and more than C$100 million has been spent on dam safety improvements; these have mainly been to improve seismic stability and the ability to pass design floods. Work will continue on the basic Dam Safety Program and completion of outstanding deficiency investigations and improvements. Based on experience to date and an assessment of future trends, some specific operational research and development initiatives are being pursued, which have particular importance to the system.

Evaluation criteria for dams

Classification of BC Hydro's dams is at present based on the Incremental Hazard system, with three categories: high, significant and low. For dams in each category, specific evaluation criteria are assigned for extreme natural events (floods, earthquakes) that could cause dam failure. This approach can lead to dams which have vastly different consequences of failure being classified similarly.

A new approach is being developed that would select evaluation criteria for all dams based on a uniform level of exposure to the consequences of failure, but maintain reasonable upper and lower bounds[6]. Where the consequences of failure would be truly catastrophic, dams would be evaluated using maximum flood and earthquake criteria. Dams with insignificant failure consequences would be evaluated based on minimum criteria or economics. Dams falling between these two extremes would be evaluated using criteria determined on the basis of an acceptable (or tolerable) level of exposure to life and economic loss. The criteria would include the consequence of dam breach, the probability of occurrence of natural events and the probability of dam failure as a result of these natural events.

Provincial seismic review

A current review of seismic hazards is providing seismic ground motion information for the entire province. Probabilistic methods are mainly being used to develop ground motion parameters. It includes compiling and sorting earthquake catalogues for BC and adjacent areas, developing a seismogenic zone model, reviewing recently developed attenuation relationships, and performing extensive computations. Two commonly used parameters, peak ground acceleration and peak spectral response, have been developed in the form of regional contour maps and site-specific curves. Deterministic methods are also applied where potentially active faults can be identified. Ground motions from a potential Cascadia Subduction earthquake off the west coast of Canada are considered in this manner. Where only probabilistic methods are applied, one of the key issues to be resolved is the selection of an appropriate risk level for the Maximum Design Earthquake. An annual exceedance of 10^{-4} is being considered for those dams with catastrophic consequences of failure.

Probability of occurrence PMPs and PMFs

Design floods obtained by conventional flood frequency analysis using historical data are generally satisfactory for low hazard dams. However, for high hazard dams, the design flood is usually based on the Probable Maximum Flood (PMF) concept which, in turn, is based on the Probable Maximum Precipitation (PMP). A methodology is being developed to estimate the probability of occurrence of PMP and PMF events from which to determine acceptable levels of flood risk.

A recent pilot study investigated the concept of multivariate analysis to obtain an operational estimate of the probability of the one-day PMP for a watershed[7]. The results were used to develop probability estimates and confidence limits through the full range of storm potential up to and beyond the PMP design event. On the basis that the storm mechanisms and climate during the estimated 100-year lifetime of the project will remain similar to the 40-year period of historical records, the annual probability of a one-day PMP may be in the order of 10^{-5} to 10^{-6}. It is planned to test the method of PMPs for different durations and at other locations where long-term climate data are available.

Procedures to estimate PMFs

Procedures for determining project Probable Maximum Floods (PMF) are being reviewed and revised, based on state-of-the-art techniques and concepts. This field is rapidly evolving, because of improvements in data availability and computing power. The main components being considered for determining PMFs are:

- **PMP**: Guidelines for determining project PMPs and distributing them in time and space.
- **Snowpack:** Appropriate return periods and design temperature melt sequences.
- **Pre-storm:** Review of pre-storms and determining the magnitude, duration and dry day separation from the PMP.
- **PMF scenarios:** The selection of PMF components and their combination with prestorms.
- **Models:** Similarities and differences between watershed simulation models and comparison of their extension to PMF conditions.
- **Design flood routing:** Initial reservoir levels for use in PMF studies.

Structural investigation techniques

Current state-of-the-art analytical techniques are not capable of providing a rigorous assessment of the seismic safety of concrete dams. Judgement evaluations are usually made relying on a combination of two-dimensional and three-dimensional dynamic analyses providing bounds to the predicted responses[8]. Research and development initiatives are being made through the Canadian Electrical Association (CEA) and the Electric Power Research Institute (EPRI). These will investigate the effect of horizontal joints and concrete/rock interfaces, with or without the hydrodynamic effects of pore pressures, on the dynamic response of gravity dams to earthquakes. The application of fracture mechanics to concrete dam analysis is also being investigated.

Procedures are being developed for calculating reliability numbers that correspond with probabilities of failure appropriate for the consequence classification of the dams.

Reservoir debris management

Two incidents occurred, in the 1950s, at dams which BC Hydro now owns, which showed the potential consequences of reservoir debris blocking or damaging discharge facilities[9]. Procedures are being developed to manage debris in reservoirs to meet safety, economic and reservoir use considerations[10]; these include an assessment of the amount of debris which might enter reservoirs from the reservoir rim or watershed during floods, and guidelines for the design of debris booms.

Reliability of dam operation

External physical conditions, such as extreme weather, equipment malfunction, operating error and upstream releases, may be more likely to cause damage or failure to projects than conventional design loading conditions (extreme floods or earthquakes). Guidelines to assess the potential vulnerability of dams to such conditions and to help develop a means to evaluate the associated risks are being prepared and will cover:

- A review of main and auxiliary power supply and electrical, mechanical and automatic control systems, particularly those that could affect the overall operation of discharge facilities; and, probabilistic analysis of the reliability of those systems that could affect the safety of the dam.
- Response of the reservoir levels to imbalances in the inflow and discharge conditions, such as large upstream releases.
- Review of operating procedures to identify potential events which could affect dam safety.

Geotechnical techniques

The assessment of the performance and stability of embankment dams and foundations under seismic loading has required the development of special techniques, for example:

- Extremely high quality undisturbed frozen samples of critical foundation sands were successfully recovered at Duncan dam using a large diameter core barrel. Ground freezing to depths of 20 m was completed using liquid nitrogen. Cyclic simple shear and cyclical triaxial tests gave a comprehensive understanding of liquefaction resistance and subsequent residual strength.
- High quality, in situ measurements of density have been obtained using a compensated gamma-gamma logging tool. The technique is coupled with laboratory testing and X-ray diffraction for parametric adjustment.
- Finite element analysis has been used to predict deformation of embankments as a result of liquefaction from earthquake loading, and development of rational and cost-effective remedial measures.
- Methods to investigate and assess coarse gravelly soils have been developed, and research on various techniques is continuing.

Data acquisition

Automatic data acquisition systems have been developed to obtain real time information for monitoring seepage, deformation, water levels and dynamic pore pressures under seismic loading[11]. This allows a continuous evaluation to be made of the performance and stability of dams and reservoir slopes which are a potential hazard, and also provides an early warning function. Instrumentation at nine major sites, six dams and three landslide areas, has been automated to date. Data are collected and transmitted to a central location for processing and analysis; key instruments have alarm thresholds which are monitored on a 24 h basis.

Hydrometeorological networks have been installed in five major drainage basins. These enhance streamflow forecasting for warning of the onset of large floods and for their safe routing. The networks are also used to optimize power generation. Ninety-five data collection platforms collect hydrological and meteorological data which are transmitted by satellite through a downlink receiving station to BC Hydro's control centre.

Technology transfer

BC Hydro's Dam Safety Program is now well established, and the utility's policy is to share knowledge and experience with other utilities, dam owners and the engineering community, through a technology transfer programme, which includes joint research and development ventures. BC Hydro organizes a week-long dam safety seminar, held in Vancouver and presented by its staff. □

Acknowledgements

The author wishes to thank staff of BC Hydro involved in the Dam Safety Program for their valuable assistance in the preparation of this article.

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Dam safety discussed at Hydropower '92

Several papers covering various issues relating to dam safety were presented and discussed at the Hydropower '92 conference in Lillehammer, Norway, in June 1992 (see also *WP&DC* September 1992, p4). This brief report highlights papers under this topic, which were presented in two sessions. The first was chaired by K. Høeg of Norway and J. A. Veltrop of the USA; the second was chaired by D. K. Lysne of Norway and G. N. Rimal of Nepal.

In the first of the two sessions on dam safety, three papers were presented and discussed.

Reservoir debris

The first paper was by N. M. Nielsen of BC Hydro, Canada, entitled, "Reservoir debris: safety, economic and environmental considerations". He described how reservoir debris (namely, tree debris) could affect the safety of dams, the efficiency of power production and the attractiveness of the reservoir for other uses. Increasing awareness of dam safety, the need to maximize power production at existing schemes (before building new ones), and public awareness and attitudes on the use of reservoirs had led to increased debris management programmes at reservoirs operated by BC Hydro, which owned 60 dams. The cost of managing debris could be high, especially where the reservoir was not cleared prior to filling or where large volumes of debris entered from the watershed. Nielsen described the debris management practices of BC Hydro, as well as an approach to co-ordinate the concerns of various interested groups. The paper discussed examples of debris management at Strathcona dam, and the Stave Lake reservoir.

Measures to ensure dam safety at BC Hydro dams included: protecting discharge facilities from blockage; allowing debris to pass such facilities prior to maximum discharges; designing debris booms not to fail, but to allow debris to pass over or under them during extreme conditions; and, sizing discharge facilities to pass safely any debris sizes and volumes which could occur. Debris boom replacement and upgrading was completed or under way at 12 sites.

Internal erosion in rockfill dams

The second paper was by A.Wörman of the Swedish State Power Board and M.Skoglund of SINTEF NHL, Norway, and was entitled, "Overtopping of the core in rockfill dams: internal erosion" (see *WP&DC*, June 1992, p58).

Recent research in Scandinavia had shown that the original design floods for dams might have been underestimated. This had raised the related question of whether temporary overtopping of the central moraine core in earth- and rockfill dams could be allowed for in very extreme floods. It was necessary to understand the risk of, and processes of, resultant erosion on the top surface of the core or of the sand filter above it. Both a theoretical investigation and observations at prototype-scale clearly indicated that erosion started at the downstream side of the lower, finer stratum, and propagated rapidly upstream, if the geometrical filter criterion was not satisfied in the interface between two soil layers subjected to through-flow. The time scale of the process was very sensitive to variation in the ratio of the grain sizes in the layers and to the void ratio of the upper stratum. However, it did not depend significantly on the height of the overtopping. If only a small fraction of the erodible grains were retained at the interface by mechanical interaction (filtration), then erosion ceased quite quickly and the degradation of the interface was limited.

The paper concluded that some support was given to the idea of allowing temporary overtopping during extreme floods. Future studies were to focus on filtration effects and on an extension of the investigated range of the hydraulic gradients used as a basis for the transport relationship.

New concepts in spillway design

D. K. Lysne, of the Norwegian Institute of Technology, Norway outlined new concepts in spillway design. He discussed the question of spreading the energy dissipation over the length of the spillway channel. This could be achieved, he said, either through rough surface energy dissipation or by adapting stepped spillway designs. The design implied moderate erosion/cavitation intensity which, in turn, allowed for unlined, rough surface spillways as a safe and low-cost design option.

Lysne suggested that there was a strong tendency

APPENDIX J

CONSTITUTION
STATUTS

CIGB
ICOLD

Constitution as of November 1988 after the 56th Executive Meeting, San Francisco, 1988.
The first Constitution was adopted at the 37th Executive Meeting in Dubrovnik (1969)

Statuts tels qu'ils sont en novembre 1988 après la 56e Réunion Exécutive, San Francisco, 1988.
Les premiers Statuts furent adoptés à la 37e Réunion Exécutive de Dubrovnik (1969)

TABLE OF CONTENTS(*)

(*) The Constitution is divided into Sections I to XIII, and the Sections are divided into Sub-Sections (1), (2), (3), etc.

TABLE DES MATIÈRES(*)

(*) Les Statuts sont divisés en Chapitres I à XIII, et les Chapitres divisés en paragraphes (1), (2), (3), etc.

NAME

(1) The organization whose constitution forms the subject of this document is officially known as The International Commission on Large Dams (ICOLD) and is hereinafter called "The Commission".

(2) The present Constitution is supplemented and implemented by a set of By-Laws.

Section II.

OBJECTIVES

(1) The objectives of the Commission are to encourage improvement in the planning, design, construction, operation and maintenance of large dams and associated civil engineering works by bringing together relevant information and studying related questions including technical, economic, financial, environmental and social aspects.

(2) The Commission accomplishes its objects :

(a) by interchange of information among its several National Committees;

(b) by holding Executive, Public or other meetings at intervals;

(c) by organizing and co-ordinating studies and experiments;

(d) by publication of proceedings, reports and documents.

(3) The Commission is not a profit seeking body.

APPELLATION

(1) L'organisme, dont les Statuts font l'objet du présent document, est officiellement connu sous le nom de « Commission Internationale des Grands Barrages » (CIGB) et est désigné ci-après par « La Commission ».

(2) Les présents Statuts sont complétés et précisés par un Règlement Intérieur.

Chapitre II.

OBJECTIF

(1) L'objectif de la Commission est de favoriser les progrès dans l'établissement des projets, la construction, l'exploitation et l'entretien des grands barrages et des ouvrages de génie civil associés, en rassemblant les renseignements qui les concernent et en étudiant les questions qui s'y rapportent et notamment les aspects techniques, économiques, écologiques et sociaux.

(2) La Commission remplit sa mission par :

(a) l'échange d'informations entre ses divers Comités Nationaux;

(b) la tenue de temps à autres de Réunions Exécutives, de réunions publiques ou d'autres réunions;

(c) l'organisation et la coordination d'études et d'essais;

(d) la publication de comptes-rendus, de rapports et de documents.

(3) La Commission est un organisme sans but lucratif.

PARTICIPATION IN THE COMMISSION

(1) Any independent country may submit an application for membership so as to participate in the activities of the Commission and become a "Member Country". For this purpose a National Committee as hereinafter defined shall communicate with the Secretary General signifying that it wishes to be considered for membership and is prepared to adhere to this Constitution and collaborate fully with the Commission. The National Committee must also indicate to the Secretary General that it will undertake to compile and submit to the Central Office as soon as possible after election, a register of the large dams in its country, so that this list can be added to the World Register of Dams which has been prepared and is periodically kept up to date by the Commission. The formal application together with such supplementary information as may be required by the Secretary General shall thereafter be submitted to the Central Office. If the Secretary General is satisfied that the application is in order he shall include the application in the Agenda at the next Executive Meeting for consideration by the Commission and formal election as a "Member Country"

Section IV.

NATIONAL COMMITTEES

(1) When the term "National Committee" is used it shall, according to the circumstances obtaining in each country, be either a Committee specially organized with a view to its participation in the Commission or a National Committee, or a sub-committee thereof, of any International Organization such as the World Energy Conference approved by the Commission.

PARTICIPATION A LA COMMISSION

(1) Tout pays indépendant peut solliciter son admission à la Commission afin de participer aux activités de celle-ci et devenir un « Pays Membre ». A cet effet, un Comité National d'un pays, constitué dans les conditions indiquées ci-après, devra se mettre en rapport avec le Secrétaire Général, en stipulant qu'il désire que sa candidature au titre de membre soit examinée et qu'il est prêt à adhérer aux présents Statuts et à collaborer pleinement avec la Commission. Le Comité National doit aussi indiquer au Secrétaire Général qu'il entreprendra de préparer et de transmettre au Bureau Central, aussitôt que possible après son admission, un registre des grands barrages de son pays de façon que cette liste puisse être ajoutée au Registre Mondial des Barrages qui a été préparé et qui est mis à jour périodiquement par la Commission. La demande formelle d'admission sera ensuite soumise au Bureau Central avec toutes informations complémentaires qui pourraient être jugées nécessaires par le Secrétaire Général. Si le Secrétaire Général estime que la demande est recevable, il devra l'inscrire à l'ordre du jour de la réunion exécutive suivante pour examen par la Commission et élection officielle à titre de « Pays Membre ».

Chapitre IV.

COMITÉS NATIONAUX

(1) Lorsque le terme « Comité National » est employé, il s'applique, suivant les conditions particulières à chaque pays, soit à un Comité spécialement constitué en vue de sa participation à la Commission, soit à un Comité National (ou un sous-comité de ce Comité National) de tout organisme international, tel que la Conférence Mondiale de l'Energie, agréé par la Commission.

of persons competent in matters relating to dams. They shall be at liberty to establish their Articles of Association and their Organization freely in accordance with their requirements, having regard to the circumstances of the country itself and the national legislation.

(3) The Commission before electing any National Committee to membership shall require a report from the Secretary General confirming that the detailed application by the National Committee complies with the requirements of this Constitution. Only one National Committee shall be elected for each country.

(4) Any National Committee which is carrying out studies and experimental work shall keep the Central Office informed of the results of these studies and experiments.

Section V.

ORGANIZATION OF THE COMMISSION

(1) The organization of the Commission and the means for carrying out the objects for which it has been created shall be provided as follows :

(a) Officiers;
(b) Central Office;
(c) Executive Meetings;
(d) Technical Committees and Administrative or Special Committees;
(e) Public Meetings (Congresses);
(f) Subscriptions and Contributions.

(2) Throughout the Constitution and Bylaws, the meaning of the following terms will be as undernoted :

"Member Countries" :

Countries that have been elected and registered in the Central Office as members of the International Commission on Large Dams.

composés de techniciens compétents en matière de barrages. Ils auront toute latitude pour établir leurs Statuts et leur organisation selon leurs besoins, eu égard aux conditions particulières à chaque pays et dans le cadre de la législation nationale.

(3) Avant d'élire un Comité National en qualité de membre, la Comission demandera au Secrétaire Général de lui confirmer que l'acte de candidature est en accord avec les présents Statuts. Il ne sera admis qu'un seul Comité National par pays.

(4) Tout Comité National qui exécute des études et des travaux expérimentaux doit tenir le Bureau Central informé des résultats de ces études et de ces expériences.

Chapitre V

ORGANISATION DE LA COMMISSION

(1) L'organisation de la Commission et les moyens dont elle disposera pour remplir la mission pour laquelle elle a été créée seront les suivants :

(a) Bureau de la Commission;
(b) Bureau Central;
(c) Réunions Exécutives;
(d) Comités Techniques et Comités Administratifs ou Spéciaux;
(e) Réunions publiques (Congrès);
(f) Cotisations et Contributions.

(2) Dans l'ensemble des Statuts et du Règlement Intérieur, la signification des termes suivants est définie ainsi qu'il suit :

« Pays membres » :

Pays qui ont été élus et inscrits au Bureau Central comme membres de la Commission Internationale des Grands Barrages.

A person appointed by a Member Country as one of their National Committee on Large Dams; also a person serving on Committees as provided in Section IX as a representative of the National Committee.

"Voting Member" :

The person selected by a National Committee to represent it at an Executive Meeting and to vote on its behalf.

"Delegate" :

A person appointed by a National Committee to attend at an Executive Meeting along with the Voting Member as a representative of the Member Country, but who is not entitled to vote.

"Participant" :

A member of a National Committee or other approved qualified person taking part in a Congress.

"Accompanying Persons" :

Persons who accompany anyone entitled under Section VIII to be present at an Executive Meeting or under Section X to be present at a Congress, but do not take any part in discussion. Such accompanying persons must be more than 16 years of age and must be immediate relatives or be normally resident in the household of those attending an Executive Meeting or a Congress who shall not bring more than three accompanying persons or such smaller number as decided by the host country. They shall pay a reduced registration free.

Section VI.

OFFICERS

(1) The Officers of the Commission shall be :

(a) President;
(b) Six Vice-Presidents;

Personne désignée par un pays membre pour faire partie de son Comité National des Grands Barrages.

Egalement, personne faisant partie des Comités visés au Chapitre IX en qualité de représentant du Comité National.

« Délégué Officiel » :

La personne désignée par un Comité National pour le représenter à une Réunion Exécutive et voter en son nom.

« Délégué » :

Personne désignée par un Comité National pour assister, aux côtés du Délégué Officiel, à une Réunion Exécutive comme représentant du pays membre, mais n'ayant pas le droit de vote.

« Participant » :

Membre d'un Comité National ou autre personne compétente agréée, qui prend part à un Congrès.

« Personnes accompagnantes » :

Personnes qui sans prendre part à aucune discussion, accompagnent quiconque autorisé au titre du Chapitre VIII des Statuts à assister à une Réunion Exécutive ou au titre du Chapitre X à participer à un Congrès. Ces personnes doivent être âgées de plus de seize ans et être des parents directs de ceux qui sont présents à une Réunion Exécutive ou participent à un Congrès ou habiter normalement chez eux, et ceux-ci ne pourront avoir plus de trois personnes accompagnantes, cette limite pouvant être abaissée par décision du pays invitant. Ces personnes devront payer un droit d'inscription réduit.

Chapitre VI.

BUREAU DE LA COMMISSION

(1) Le Bureau de la Commission sera constitué de la manière suivante :

(a) Un Président;
(b) Six Vice-Présidents;

(d) Treasurer.

All of whom shall be elected by the Commission. These elections shall take place during the course of the Executive Meetings the functioning of which is specified in Section VIII hereafter. The same person may be entrusted with the duties of the Secretary General and the Treasurer.

President.

(2) The term of office of the President shall normally be for three years (or from one Congress to the next Congress) a "year" being the period of time which elapses between two consecutive ordinary Executive Meetings. A special or extraordinary Executive Meeting shall not be taken into account in arriving at the term of office of the President.

(3) The election of a President shall whenever possible take place during the Executive Meeting of the year in which a public meeting or Congress will be held.

(4) The election of the President shall be by secret ballot and shall require a majority vote of the Voting Members present. A country represented by proxy as provided in Section VIII (7) is a voting member present. Invalid ballots do not affect the number of Voting Members present. The candidate receiving a number of votes greater than half the number of Voting Members present will be elected. If no candidate does obtain such a majority then a second ballot shall be held. For this second ballot the candidate receiving a majority vote over the combined votes of the other candidate will be elected. If no candidate does obtain such a majority then a last ballot will be held. For this last ballot, the candidate receiving the greatest number of votes will be elected. In the event of a tie the candidate who has attended the greatest number of Executive Meetings will be elected. In the case of candidates having attended the same number of Executive, Meetings, the older one will be elected.

(d) Un Trésorier.

Tous les membres de ce Bureau seront élus par la Commission. Ces élections auront lieu au cours des Réunions Exécutives dont le fonctionnement est exposé dans le Chapitre VIII, ci-après. La même personne peut être chargée des fonctions de Secrétaire Général et de celles de Trésorier.

Président.

(2) La durée du mandat du Président sera normalement de trois années (ou bien d'un Congrès au Congrès suivant), une « année » étant la période de temps qui s'écoule entre deux Réunions Exécutives ordinaires consécutives. Aucune Réunion Exécutive spéciale ou extraordinaire ne sera prise en considération dans le décompte de la durée du mandat du Président.

(3) L'élection d'un Président devra dans toute la mesure du possible avoir lieu lors de la Réunion Exécutive de l'année au cours de laquelle il sera tenu une Réunion Publique ou Congrès.

(4) L'élection du Président sera effectuée par vote secret, à la majorité des voix des délégués officiels présents. Un pays représenté par un délégué chargé d'une procuration, comme indiqué au chapitre VIII (7) est un délégué présent avec droit de vote. Les bulletins nuls n'affectent pas le nombre de délégués présents avec droit de vote. Le candidat qui obtiendra un nombre de voix plus grand que la moitié du nombre des délégués présents avec droit de vote sera élu. Si aucun candidat n'obtient une telle majorité, un deuxième scrutin devra avoir lieu. Si ce deuxième scrutin assure à l'un des candidats la majorité des voix par rapport à la somme des voix des autres candidats restants, il sera élu. Si aucun candidat n'obtient cette majorité de voix, il y aura un dernier scrutin. Le candidat qui réunira le plus grand nombre de voix au cours de ce dernier scrutin sera élu. En cas d'égalité de voix, le candidat qui aura assisté au plus grand nombre de Réunions Exécutives sera élu. Si ces candidats ont assisté au même

(5) A President on completion of his term of office shall not be eligible for re-election.

(6) The President shall represent the Commission and shall perform the usual duties pertaining to such office, as well as those entrusted to him by the Constitution, and by the Executive Meeting. He shall preside at all meetings of the Commission. As head of the Central Office he shall have general charge and management thereof, and in collaboration with the Secretary General he shall hire and supervise the employees, and be responsible to the Commission for the conduct of the affairs of the Central Office.

Vice-Presidents.

(7) The term of office of the six Vice-Presidents shall each be three years, the year being defined in Section VI, sub-section (2). Two of the Vice-Presidents shall be elected each year, the method of election being similar to that for the President, Section VI, sub-section (4). A Vice-President on completion of his term of office shall not be eligible for re-election as a Vice-President except as is provided in Section VI, sub-section (12). No person from his country may be elected to succeed him unless the next Congress is to be held in that country and there exists no other way in which it may benefit from a post of Vice-President in office at the time of the Congress. A Vice-President is eligible for nomination as President either during, or on completion of, his term of office.

(8) The distribution of the six Vice-Presidents between the different geographical zones shall be carried out in an equitable manner. The definition of the zones and the number of posts allocated to each of them shall be as determined by the By-Laws.

(9) Any one country shall not at the same time be represented by the President and a Vice-President.

sera élu.

(5) A l'expiration de son mandat, un Président ne sera pas rééligible.

(6) Le Président représentera la Commission et assumera toutes les fonctions habituelles relevant de ce titre, de même que les fonctions qui lui seront confiées du fait des Statuts et par la Réunion Exécutive. Il présidera toutes les réunions de la Commission. En tant que chef du Bureau Central, il en assumera la direction générale et la gestion, et, en collaboration avec le Secrétaire Général, il engagera et dirigera les employés et sera responsable devant la Commission de la conduite des affaires du Bureau Central.

Vice-Présidents.

(7) La durée du mandat de chacun des six Vice-Présidents sera de trois années – l'année étant définie au Chapitre VI, paragraphe (2). Deux des Vice-Présidents seront élus chaque année, suivant un mode d'élection semblable à celui qui est prévu pour le Président, Chapitre VI paragraphe (4). A l'expiration de son mandat un Vice-Président ne sera pas rééligible comme Vice-Président, excepté dans le cas prévu au Chapitre VI, paragraphe (12) ci-après. Aucune personne du même pays ne pourra être élue pour lui succéder à moins que le Congrès suivant ne doive se tenir dans ce pays et qu'il n'existe aucun autre moyen de faire bénéficier ce pays d'un poste de Vice-Président au moment du Congrès. Un Vice-Président est éligible comme Président soit pendant son mandat soit à l'expiration de celui-ci.

(8) La répartition des six Vice-Présidents entre les différentes zones géographiques devra être effectuée d'une manière équitable. La définition des zones et le nombre de postes attribués à chacune d'elles seront déterminés par le Règlement Intérieur.

(9) Aucun pays ne pourra être représenté en même temps par le Président et par un Vice-Président.

(10) In the unavoidable absence of the President, the Vice-President who has attended the greatest number of Executive Meetings, shall undertake his duties for the period required and if necessary until the next Executive Meeting.

(11) In the event of the death or retirement of a Vice-President he shall be replaced by the election at the next Executive Meeting of a person from his country who shall hold office only for the remaining part of the term of office of the replaced Vice-President.

(12) If a Vice-President is elected to the office of President before the expiry of his term of office as Vice-President, then the office of Vice-President shall at the next Executive Meeting be filled by the election, for the unexpired period, of a person from the same zone. A Vice-President who has completed such an unexpired period of office shall be eligible for subsequent nomination as a Vice-President.

Secretary General.

(13) The Secretary General shall be appointed at an Executive Meeting on terms to be agreed. He shall be responsible, under the general direction of the President, for the conduct of all correspondence of the Central Office, for the preparation and distribution of the agenda of the Executive Meetings, and for the preparation and maintenance of minutes of such meetings and of reports thereon. He shall also deal with any duties to be undertaken by the Central Office in connection with public meetings or Congresses, and perform any other service required by the Commission. The duration of the appointement will be defined in the terms of the Agreement.

Treasurer.

(14) The Treasurer shall be appointed at an Executive Meeting on terms to be agreed. The Treasurer shall be the custodian of the funds of the Commission and shall receive,

(10) En cas d'absence inévitable du Président, le Vice-Président qui a assisté au plus grand nombre de Réunions Exécutives assumera les fonctions du Président absent pour la période nécessaire et s'il le faut jusqu'à la Réunion Exécutive suivante.

(11) En cas de décès ou de démission d'un Vice-Président, celui-ci sera remplacé par l'élection, à la Réunion Exécutive suivante, d'une personne de son pays qui assumera ses fonctions dans la limite exclusive du temps restant à courir sur le mandat du Vice-Président remplacé.

(12) Si un Vice-Président est élu comme Président avant l'expiration de son mandat de Vice-Président, ce poste de Vice-Président sera pourvu, à la Réunion Exécutive suivante, par l'élection d'une personne de la même zone qui assumera ses fonctions pour la durée restante du mandat. Un Vice-Président qui aura exercé ses fonctions pendant cette période complémentaire sera rééligible.

Secrétaire général.

(13) Le Secrétaire Général sera désigné lors d'une Réunion Exécutive à des conditions à convenir. Il sera, sous la direction générale du Président, responsable de toute la correspondance du Bureau Central, de la préparation et de la distribution des ordres du jour des Réunions Exécutives ainsi que de la préparation et de la conservation des procès-verbaux de ces réunions et des rapports les concernant. Il devra également assumer toutes tâches qui incomberont au Bureau Central, en corrélation avec les Réunions Publiques ou Congrès; il devra également se charger de tous autres services à la requête de la Commission. La durée de ses fonctions sera définie par l'accord de désignation.

Trésorier.

(14) Le Trésorier sera désigné lors d'une Réunion Exécutive à des conditions à convenir. Il aura la garde des fonds de la Commission et encaissera toutes créances et contribu-

give receipts for and deposit all dues and contributions. The Treasurer shall disburse all moneys expended on account of the Commission. The Treasurer shall keep books of account of all moneys received and expended, and shall report annually, and at such other times as the Commission may direct, and prepare statements on the status of the funds and accounting of the Commission, and shall, on being requested, give an explanation of the expenses incurred. The Treasurer shall also give a bond or surety at the expense of the Commission if the Commission requests it. The duration of the appointment will be defined in the terms of the Agreement.

Section VII

CENTRAL OFFICE

(1) A Central Office shall be established and maintained in the City of Paris to deal with the business of the Commission. The Office shall be under the general direction of the President assisted by the Secretary General and Treasurer. Attached to the Central Office shall be secretaries, clerks, accountants and other employees necessary for the efficient working of the Office and as may be approved by the Commission.

(2) It shall be the duty of the Central Office to deal with all current business, to keep the accounts of the Commission, to prepare the annual budget of receipts and expenditure, to pay all necessary expenses on behalf of the Commission up to the limit of the approved budget, to issue annual demands to National Committees for the subscriptions due, to receive, deposit with an approved bank, and issue receipts for all dues and contributions received.

(3) The Central Office shall arrange for interchange of documentary and other information with and between National Committees; shall keep the archives of the Commission; shall prepare the agenda of all meetings

tions, en donnera quittance et les déposera. Il décaissera toute somme dépensée pour le compte de la Commission. Il tiendra la comptabilité des recettes et dépenses, en fera rapport chaque année, ainsi qu'à tout autre moment décidé par la Commission; il établira les relevés de l'état des fonds et des comptes de la Commission et fournira, sur demande, toutes justifications des dépenses effectuées. Le Trésorier devra également donner caution ou garantie pour le compte de la Commission si celle-ci le demande. La durée de ses fonctions sera définie par l'accord de désignation.

Chapitre VII.

BUREAU CENTRAL

(1) Un Bureau Central sera créé et géré à Paris pour traiter les affaires de la Commission. Ce bureau sera placé sous la direction générale du Président assisté par le Secrétaire Général et le Trésorier. Des secrétaires, comptables, commis et tous autres employés nécessaires à son bon fonctionnement seront attachés au Bureau Central, sous réserve de l'approbation par la Commission.

(2) Le Bureau Central sera chargé de l'expédition de toutes les affaires courantes, de la tenue des comptes de la Commission; de la préparation du budget annuel des recettes et dépenses; du paiement de toutes les dépenses nécessaires pour le compte de la Commission, dans la limite du budget approuvé; de l'appel annuel des cotisations dues par les Comités Nationaux, de l'encaissement et du dépôt de ces cotisations dans une banque agréée, ainsi que de l'établissement des reçus pour toutes les cotisations et contributions encaissées.

(3) Le Bureau Central prendra ses dispositions pour l'échange de renseignements et de documents avec et entre les Comités Nationaux; il assurera la garde des archives de la Commission; il préparera l'ordre du jour de

France
Italy
Korea (Rep. of)
Mexico
South Africa
U.K.

i.e. 8 countries

Group 9 : From 551 - 1 000 Dams

Canada
China*
India*
Spain
USSR*

i.e. 5 countries

Group 10 : + 1 000 Dams

Japan
USA

i.e. 2 countries

* according to the 80 % rule (Appendix IIIB).

Italie
Corée (Rép. de)
Mexique
Afrique du Sud
Grande-Bretagne

soit 8 pays

Groupe 9. De 551-1 000 barrages.

Canada
Chine *
Inde *
Espagne
URSS *

soit 5 pays

Groupe 10. + de 1 000 barrages.

Japon
Etats-Unis

soit 2 pays

* Application de la règle des 80 % (Annexe IIIB).

thereof and shall provide in French and English and send to the National Committees all such agenda and minutes of the meetings as well as papers, periodical bulletins, transactions, bulletins giving the Member Countries of the Commission and the composition of the National Committees of these countries, as well as any other papers, documents or publications approved by the Commission to be prepared.

Section VIII.

EXECUTIVE MEETINGS

(1) The ordinary Executive Meeting, which shall be called annually by the Central Office of the Commission, shall consist of the Officers of the Commission as defined in Section VI, sub-section (1) and of representatives from all the Member Countries. The total number of representatives from each country attending and taking part in the Executive Meeting shall not exceed four being one member with voting power and three delegates. Chairmen and Members of Technical, Administrative or Special Committees may attend the Executive Meeting but may not take part in its proceedings other than as provided for in the By-Laws.

(2) The Executive Meeting shall resolve all questions concerning organization and direction of studies, investigations and experiments, administration of all funds and properties, operation of the Central Office and any other relevant business of the Commission; it shall approve the budget of receipts and expenditure, appoint and organize all committees and elect new Member Countries.

(3) As long notice as possible shall be given by the Secretary General to each National Committee of the date and place for the next Executive Meeting. At the time that the notice is given, or as soon after that as is practicable, but not later than four months

conservera les procès-verbaux; il assurera l'établissement dans les langues française et anglaise et l'envoi aux Comités Nationaux de tous ordres du jour et procès-verbaux des réunions aussi bien que de rapports, bulletins périodiques, comptes rendus, bulletins indiquant les pays membres de la Commission et la composition des Comités Nationaux de ces pays, ainsi que de tous autres rapports, documents ou publications dont la Commission aura approuvé la préparation.

Chapitre VIII.

RÉUNIONS EXÉCUTIVES

(1) La Réunion Exécutive ordinaire qui sera convoquée annuellement par le Bureau Central de la Commission, sera constituée par le Bureau de la Commission, tel qu'il est défini au Chapitre VI, paragraphe (1), et par les représentants de tous les pays membres. Le nombre total des représentants de chaque pays prenant part à la Réunion Exécutive ne devra pas dépasser quatre (4) à raison d'un délégué officiel et de trois délégués. Les Présidents et les membres des Comités Techniques, Administratifs ou Spéciaux sont autorisés à assister à la Réunion Exécutive mais ne peuvent prendre part aux débats que conformément aux dispositions du Règlement Intérieur.

(2) La Réunion Exécutive devra résoudre toutes questions concernant : l'organisation et la direction des études, recherches et essais, l'administration de tous fonds et biens, le fonctionnement du Bureau Central et toute autre affaire intéressant la Commission; elle devra approuver le budget des recettes et dépenses; constituer et organiser tous Comités et élire les nouveaux pays membres.

(3) Aussi longtemps que possible à l'avance, le Secrétaire Général devra faire connaître à chaque Comité National la date et le lieu de la prochaine Réunion Exécutive. Au moment de cette notification, ou à une date aussi rapprochée que possible – mais jamais

before the Executive Meeting, the Secretary General shall circulate the outlines of a draft agenda for the Executive Meeting and shall invite the National Committees to propose any additional items for inclusion in the agenda. Any such additional items, including any nominations of candidates for the post of President or Vice-President, which must be submitted to the Central Office at least three months before the date of the Executive Meeting, shall be considered by the Secretary General in consultation with the President before the agenda for the Executive Meeting is issued. If, at least three months before an Executive Meeting, any additional item for the agenda is submitted by a National Committee with the written support of not less than three other National Committees, then this item must be included in the agenda.

(4) At least two months prior to the Executive Meeting the Secretary General shall send to each National Committee the final particulars of the date and place for the Executive Meeting, also the agenda setting out in detail the matters to be dealt with at the meeting. The principal categories of matters to be included in the agenda for an Executive meeting shall be as outlined in the By-laws.

(5) Any matter not on the agenda which a National Committee desires to raise at an Executive Meeting must be submitted in writing to the Secretary General and received by him not less than two weeks before the opening date of the Executive Meeting otherwise it shall not be considered. The President, in consultation with the Secretary General, shall decide whether the written communication is relevant to the business of the Commission. If so approved the President at the opening of the Executive Meeting shall announce the item of the agenda under which the communication will be considered. The matter raised, however, can only form the subject of a simple discussion unless a majority of the Voting Members present agree to its being put to a vote. In this event, the

moins de quatre mois avant la date fixée pour la Réunion Exécutive – le Secrétaire Général devra communiquer un projet d'ordre du jour de la Réunion Exécutive annoncée, et prier les Comités Nationaux de proposer toute question supplémentaire à inclure dans l'ordre du jour. Toutes ces questions supplémentaires y compris toute présentation de candidat pour un poste de Président ou de Vice-Président, qui doivent être soumises au Bureau Central au moins trois mois avant la date de la Réunion Exécutive, devront être examinées par le Secrétaire Général, en liaison avec le Président, avant la publication de l'ordre du jour de la Réunion Exécutive. Si, trois mois au moins avant la Réunion Exécutive, une question supplémentaire quelconque est proposée par un Comité National avec l'appui écrit d'au moins trois autres Comités Nationaux, ladite question devra être inscrite à l'ordre du jour.

(4) Au moins deux mois avant la Réunion Exécutive, le Secrétaire Général enverra à chaque Comité National les indications définitives concernant la date et le lieu de la réunion, ainsi que l'ordre du jour précisant d'une manière détaillée les questions qui doivent être traitées au cours de cette réunion. Les principales catégories de questions à inclure dans l'ordre du jour d'une Réunion Exécutive devront être conformes aux prescriptions du Règlement Intérieur.

(5) Toute question ne figurant pas à l'ordre du jour mais qu'un Comité National désire soulever lors d'une Réunion Exécutive, doit être soumise par écrit au Secrétaire Général et reçue par lui au plus tard deux semaines avant la date d'ouverture de la Réunion Exécutive, faute de quoi cette question ne serait pas prise en considération. Après en avoir conféré avec le Secrétaire Général, le Président décidera si la question écrite se rapporte bien aux affaires de la Commission. Dans l'affirmative, le Président annoncera, à l'ouverture de la Réunion Exécutive, la rubrique de l'ordre du jour sous laquelle la question sera examinée. La question ainsi soulevée ne peut toutefois faire l'objet que d'une simple discussion, à moins que la majorité des délégués officiels présents ne se déclare d'accord pour qu'elle

matter being proposed and seconded and formally put to the vote, then unless a unanimously favourable vote is cast by all the Voting Members present it shall be rejected. Any member abstaining from voting shall be recorded as having given an unfavourable vote.

(6) Any matter raised during an Executive Meeting which is not on the agenda and which has not been previously submitted in writing for approval (Section VIII, sub-section (5)) shall be ruled out of order and shall not be discussed or voted on at the Executive Meeting.

(7) Each National Committee upon receipt of the information in Section VIII, sub-section (3), shall notify the Secretary General of the name of its member with voting power and also the names of other representatives who will be present as delegates at the Executive Meeting. Any National Committee which will not have a representative at the meeting, may submit in writing to the Secretary General its opinion upon any item on the agenda, which opinion will be read at the meeting, but the country from which the documents are sent shall not be considered as represented at the meeting, and shall not be entitled to vote by proxy. Nevertheless the National Committee of any country whose Voting Member and delegates are prevented by the host country from attending shall be entitled to vote by proxy. The Voting Member of the country entrusted to vote by proxy shall be provided with an appropriate proxy power which he should hand to the President or Secretary General at the latest the day before the Executive Meeting. The President shall read such proxy power at the opening of the Executive Meeting. No Voting Member shall be entitled to represent more than one country in addition to his own.

(8) In the event of the Voting Member selected by a National Committee not being able, for any reason, to attend during an Executive Meeting, then a deputy Voting Member from that country can be chosen by

fasse l'objet d'un vote. Dans ce cas, la question étant proposée, appuyée et formellement mise aux voix, sera rejetée à moins d'obtenir un vote favorable à l'unanimité de tous les délégués officiels présents. Tout délégué officiel qui se sera abstenu sera réputé avoir émis un vote défavorable.

(6) Toute question soulevée au cours d'une Réunion Exécutive qui ne figure pas dans l'ordre du jour et qui n'a pas été préalablement présentée par écrit à l'approbation (Chapitre VIII, paragraphe 5) sera déclarée non recevable et ne pourra faire l'objet ni d'une discussion ni d'un vote au cours de la Réunion Exécutive.

(7) A la réception des indications dont il est question au Chapitre VIII, paragraphe (3), chaque Comité National devra notifier au Secrétaire Général le nom de celui de ses membres désigné comme délégué officiel ainsi que les noms des autres représentants qui assisteront comme délégués à la Réunion Exécutive. Tout Comité National qui n'aura pas de représentant à la réunion pourra soumettre par écrit au Secrétaire Général son opinion sur un point quelconque de l'ordre du jour ; cette opinion sera lue à la réunion mais le pays qui aura ainsi écrit ne sera pas considéré comme représenté à la réunion et ne sera pas habilité à voter par procuration. Toutefois, le Comité National d'un pays dont le délégué officiel et les délégués sont empêchés d'assister à la Réunion Exécutive du fait du pays invitant, aura le droit de voter par procuration. Le délégué officiel du pays chargé de la procuration devra être pourvu d'un pouvoir en bonne et due forme qu'il devra remettre au Président ou au Secrétaire Général au plus tard la veille de la Réunion Exécutive. Le Président en donnera connaissance à l'ouverture de la Réunion Exécutive. Un même délégué officiel ne pourra représenter plus d'un pays autre que le sien.

(8) Pour le cas où le délégué officiel désigné par un Comité National ne serait pas à même – pour quelque raison que ce soit – d'assister aux séances au cours d'une Réunion Exécutive, un délégué officiel suppléant de ce

the other delegates of the country. The name of the deputy shall be submitted to the Secretary General and announced by him at the Executive Meeting for the information of those present.

(9) For the valid constitution of an Executive Meeting at least one-third of the total number of National Committees should have a member present with voting powers, or represented by proxy as prescribed in Section VIII, sub-section (7).

(10) The conduct of an Executive Meeting by the President, the discussion of matters on the agenda, or of any amendments put forward by a proposer and seconder, shall be in accordance with normal committee practice and as set out in the By-laws.

(11) Provision shall be made for special or extraordinary Executive Meetings for any specific purpose provided two-thirds of the Voting Members present at an Executive Meeting are in favour. The President either on his own initiative or on the written request of not less than two-fifths of the National Committees may at any time propose a special Executive Meeting. In this event the Secretary General shall notify all National Committees in writing of the proposed date and place of the meeting and the matters to be discussed. A majority of all the National Committees must be in favour of the meeting before it can be called.

(12) Should any matter of importance arise which cannot be delayed until the next Executive Meeting then the President shall request the written approval of the National Committees to such a specific matter without calling an Executive Meeting. In this event full particulars shall be submitted to each National Committee and a majority postal vote of all the National Committees in favour of the proposal shall be necessary for the matter to be approved. If so approved then it does not require to be submitted for formal acceptance at the next Executive Meeting. Under conditions of urgency or other special

pays pourra être choisi par les autres délégués du pays en cause. Le nom du suppléant sera soumis au Secrétaire Général qui en donnera connaissance à la Réunion Exécutive pour l'information des délégués présents.

(9) Pour que la Réunion Exécutive soit valablement consituée, un tiers au moins du nombre total des Comités Nationaux doit y être représenté par un délégué officiel ou représenté par procuration comme prévu au Chapitre VIII, paragraphe (7).

(10) La conduite d'une Réunion Exécutive par le Président, la discussion des questions figurant à l'ordre du jour ou de tout amendement proposé et appuyé, seront conformes à la pratique habituelle des Commissions et aux prescriptions du Règlement Intérieur.

(11) Des Réunions Exécutives spéciales, ou extraordinaires, en vue d'un objet déterminé, pourront être prévues si les deux tiers des délégués officiels présents à une Réunion Exécutive y sont favorables. Le Président peut en tout temps proposer une Réunion Exécutive spéciale, soit de sa propre initiative, soit à la demande écrite d'un minimum des deux cinquièmes des Comités Nationaux. Dans cette éventualité, le Secrétaire Général enverra à tous les Comités Nationaux notification écrite de la date et du lieu proposés pour la réunion et des questions qui y seront discutées. Une majorité de tous les Comités Nationaux doit être favorable à la réunion pour qu'elle puisse être convoquée.

(12) S'il se présentait une question importante dont il ne soit pas possible de différer l'examen jusqu'à la prochaine Réunion Exécutive, le Président demandera l'approbation écrite des Comités Nationaux au sujet d'une telle question particulière, sans convoquer une réunion spéciale. Dans cette éventualité, des renseignements détaillés devront être fournis à chaque Comité National et un vote majoritaire par correspondance de tous les Comités Nationaux en faveur de la proposition sera nécessaire pour son approbation. Si cette proposition est ainsi approuvée, il ne sera pas nécessaire de la soumettre à la prochaine

working of the Commission, the President in consultation with the Secretary General shall be entrusted to take any action in the interest of the Commission subject to approval at the next Executive Meeting.

(13) All former Presidents and Vice-Presidents of the Commission shall be entitled to attend and take part in the meetings of the Commission but shall not be permitted to vote unless they have been appointed by their National Committee as a member with voting powers. All former Secretaries General and Treasurers are also entitled to attend and take part but without voting powers.

(14) The President is entitled to vote only when it is necessary to give a casting vote (Section VIII, sub-section (15)). The six Vice-Presidents during their term of office are not entitled to vote, unless they have been appointed by their National Committee as the member with voting powers. The Secretary General and Treasurer are not entitled to vote.

(15) Resolutions shall be adopted on the majority vote of the Voting Members present and represented by proxy as provided in Section VIII (7) except where otherwise specified. In the event of an equality of votes on any resolution the President shall have the casting vote. The number of votes for and against a resolution shall be recorded in the minutes as well as the decision taken.

Réunion Exécutive pour acceptation formelle.
En cas d'urgence ou d'autres circonstances spéciales qui mettent obstacle au fonctionnement normal de la Commission, le Président, après en avoir conféré avec le Secrétaire Général, sera chargé de prendre toute mesure nécessaire dans l'intérêt de la Commission sous réserve d'approbation par la Réunion Exécutive suivante.

(13) Tous les anciens Présidents et Vice-Présidents de la Commission auront le droit d'assister et de prendre part aux réunions de la Commission, mais ils ne seront pas admis à voter, à moins qu'ils n'aient été désignés par leur Comité National comme délégué officiel. Tous les anciens Secrétaires Généraux et Trésoriers ont aussi le droit d'assister aux Réunions et de prendre part aux débats mais sans droit de vote.

(14) Le Président n'a le droit de voter que lorsqu'il est nécessaire d'avoir recours à sa voix prépondérante (Chapitre VIII, paragraphe 15). Pendant la durée de leur mandat les six Vice-Présidents n'ont pas le droit de voter, à moins qu'ils n'aient été désignés par leur Comité National comme délégué officiel. Le Secrétaire Général et le Trésorier n'ont pas le droit de voter.

(15) Les résolutions seront adoptées par vote majoritaire des délégués officiels présents ou représentés par procuration, comme prévu au Chapitre VIII, paragraphe (7), sauf spécification contraire. En cas d'égalité des voix concernant une résolution quelconque, le Président aura voix prépondérante. Le nombre de voix pour et contre chaque résolution sera consigné dans le Procès-Verbal de même que la décision prise.

Section IX.

TECHNICAL COMMITTEES AND ADMINISTRATIVE OR SPECIAL COMMITTEES

(1) The Commission, whenever deemed convenient, may appoint Technical Committees and Administrative, Special or "ad hoc" Committees. Before such Committees are formally constituted the President, in consultation with the Secretary General, shall submit at an Executive Meeting his proposals for the size of the Committee, the names of the countries to be represented, and also should he so desire name the Chairman from one of these countries that he has selected. If approval is given at the Executive Meeting then the National Committees of the countries selected shall indicate the name of the member that they wish to represent them on the Committee. The National Committee of the country from which the Chairman has been selected will also be asked to approve the President's nomination of the Chairman. Any adjustements to membership of a Committee shall be submitted to an Executive Meeting by the President following consultation with the Secretary General and the Chairman of that Committee.

(2) As a general rule, a committee shall consist of not less than a Chairman and five other members as a minimum, and not more than a Chairman and twelve other members as a maximum. Any proposal to appoint less than five or more than twelve members for a given Committee must be approved at an Executive Meeting by a two-thirds majority of the voting members present.

(3) The Committees shall conduct their business by correspondence during the interval between Executive Meetings. Meetings of the Committees shall as a rule be held only at the time and place of the Executive Meeting. The Secretary General shall as far as possible arrange the times for the various Committee Meetings, held prior to the Executive Mee-

Chapitre IX.

COMITÉS TECHNIQUES ET COMITÉS ADMINISTRATIFS OU SPÉCIAUX

(1) Toutes les fois qu'elle le jugera opportun, la Commission pourra constituer des Comités Techniques, ainsi que des Comités Administratifs, Spéciaux ou « ad hoc ». Avant que de tels Comités ne soient formellement constitués, le Président – après en avoir délibéré avec le Secrétaire Général – présentera à une Réunion Exécutive ses propositions en ce qui concerne le nombre de membres du Comité, le nom des pays qui doivent y être représentés et aussi, s'il le désire, le nom du Président qu'il aura choisi dans un de ces pays. Si la Réunion Exécutive donne son accord sur ces propositions, les Comités Nationaux des pays choisis indiqueront les noms des membres qui les représenteront au sein du Comité. Le Comité National du pays dans lequel le Président du Comité aura été choisi par le Président sera appelé à donner son accord sur cette désignation. Toute modification apportée à la composition d'un Comité doit être soumise à une Réunion Exécutive par le Président après en avoir délibéré avec le Secrétaire Général et le Président du Comité.

(2) En règle générale, un Comité sera composé d'un Président et de cinq autres membres au minimum, d'un Président et de douze autres membres, au maximum. Toute proposition tendant à désigner moins de cinq membres ou plus de douze membres pour un Comité donné devra être approuvée par une Réunion Exécutive à la majorité des deux tiers des délégués officiels présents.

(3) Les travaux des Comités seront conduits par correspondance dans l'intervalle des Réunions Exécutives. En règle générale les réunions des Comités n'auront lieu qu'à la date et à l'endroit où se tiendront les Réunions Exécutives. Le Secrétaire Général devra autant que possible choisir les heures des diverses réunions de Comités tenues avant les

Committees do not find the meetings of their Committees being held at the same time. National Committees shall appoint a deputy when the appointed member is unable to conduct correspondence or to attend Committee Meetings.

(4) Under special conditions of urgency or other cause that may require a Committee to be set up before the next Executive Meeting, the President may select the Chairman and members of this Committee subject to approval by the National Committee of the member chosen. Formal approval of this action shall be required at the next Executive Meeting.

membre de deux ou plusieurs Comités ne se trouve en présence de réunions simultanées de ces Comités. Les Comités Nationaux devront désigner un suppléant lorsque le membre nommé ne sera pas en mesure de correspondre ou d'assister aux réunions du Comité.

(4) Dans des conditions spéciales d'urgence ou pour une autre cause exigeant la formation d'un Comité avant la prochaine Réunion Exécutive, le Président pourra nommer le Président et les membres de ce Comité, sous réserve de l'accord du Comité National de chacun des membres ainsi désignés. Cette décision devra être soumise à la Réunion Exécutive suivante pour approbation officielle.

Technical Committees.

(5) Every Committee shall comply with the terms of reference assigned to it by the Commission. Any major alteration of these terms of reference shall be submitted to an Executive Meeting by the President following consultation with the Secretary General and the Chairman of that Committee. However, slight modifications can be proposed by the Central Office and accepted by the Chairman of the Committee between two Executive Meetings.

(6) The Technical Committee thus appointed by the Commission shall be dissolved after having discharged the duties entrusted to it or at the latest after six years. At that date, if the Committee has not completed its studies and submitted a final report to the Commission, a new Committee may be appointed by the Commission to continue with and complete the work. If a Committee wishes to co-opt additional members for any specific reason it shall submit a request to the Central Office and the matter will be included in the agenda and a decision given at the next Executive Meeting. The Committee shall submit a Progress Report to the Commission at each Executive Meeting or more often if required.

Comités techniques.

(5) Chaque Comité devra se conformer à la mission qui lui aura été confiée par la Commission. Tout changement important à cette mission doit être soumis à une Réunion Exécutive par le Président après en avoir délibéré avec le Secrétaire Général et le Président de ce Comité. Cependant de légères modifications peuvent être proposées par le Bureau Central et acceptées par le Président du Comité entre deux Réunions Exécutives.

(6) Le Comité Technique ainsi constitué par la Commission, sera dissous lorsqu'il se sera acquitté de la tâche qui lui aura été confiée, ou, au plus tard, au bout de six ans. A cette date si le Comité n'a pas achevé ses études et soumis un rapport final à la Commission, un nouveau Comité pourra être constitué par la Commission, avec mission de poursuivre et d'achever le travail. Si, pour une raison particulière quelconque un Comité désire coopter des membres supplémentaires, il devra en présenter la demande au Bureau Central ; la question sera insérée dans l'ordre du jour et une décision sera prise lors de la Réunion Exécutive suivante. Le Comité devra présenter à la Commission un rapport d'avancement des travaux lors de chaque Réunion Exécutive, ou plus fréquemment s'il y est invité.

communicate their views to a Technical Committee, and the Chairman of that Committee after consultation with the President may invite a representative from any communicating National Committee to attend a meeting of the Technical Committee in order to assist in the deliberations.

(8) Unless special approval is given at an Executive Meeting, Technical Committees shall not be permitted to hold public meetings, public conferences, or public symposia, or take part in any such meetings as officially representing the Commission.

(9) The work of Technical Committees shall be carried out in accordance with the By-laws.

Administrative Committees.

(10) The duties of an Administrative Committee will be to deal with any matters assigned to it in connection with the general administration and activities of the Commission, except on technical matters which will be the responsibility of the Technical Committees. The various conditions set out in Section IX, sub-section (6) for the Technical Committees shall apply also to the Administrative Committees.

Special Committees.

(11) A special or "ad hoc" committee will be appointed by the Commission, Section IX, sub-section (1) when required to deal with a specific duty. In this case, however, the Chairman and the actual members of the Committee shall be selected by the President in consultation with the Secretary General and with the agreement of the National Committees from which the members have been chosen, before being submitted for approval at an Executive Meeting. The Chairman and members of the Committee will continue unchanged until it has submitted its report, and has discharged the duty laid upon it, and the dissolution of the Committee is approved at an Executive Meeting. The

communiquer leurs vues à un Comité Technique et le Président de ce Comité peut, après consultation du Président de la Commission, inviter un représentant de tout Comité National qui lui a communiqué ses vues à assister à une réunion du Comité Technique pour prendre part aux délibérations.

(8) Sauf autorisation spéciale donnée lors d'une Réunion Exécutive, il est interdit aux Comités Techniques de tenir des réunions publiques, des conférences publiques ou des symposia publics, et de prendre part en tant que représentants officiels de la Commission, à toute réunion de ce genre.

(9) Le travail d'un Comité Technique sera conduit en se conformant au Règlement Intérieur.

Comités administratifs.

(10) La tâche d'un Comité Administratif sera d'étudier toutes questions qui lui seront posées dans le domaine de l'administration générale et des activités de la Commission, à l'exception des questions techniques qui seront du ressort des Comités Techniques. Les différentes stipulations du Chapitre IX, paragraphe (6), concernant les Comités Techniques, s'appliqueront également aux Comités Administratifs.

Comités spéciaux.

(11) Un Comité Spécial ou un Comité « ad hoc » sera constitué par la Commission (Chapitre IX, paragraphe (1)) en vue de s'acquitter d'une tâche déterminée qui lui sera assignée. Dans ce cas, toutefois, le Président et les membres eux-mêmes du Comité seront choisis par le Président (de la CIGB) après délibération avec le Secrétaire Général et avec l'agrément des Comités Nationaux auxquels les membres choisis appartiennent, avant d'être soumis pour approbation à une Réunion Exécutive. Le Président et les membres du Comité demeureront inchangés jusqu'à ce qu'ils aient soumis leur rapport, qu'ils se soient acquittés de la mission qui leur a été confiée et que la dissolution du Comité ait été

Committee shall submit a Progress Report at each Executive Meeting. After six years, if the Committee has not completed its task, the Commission at the next Executive Meeting will decide whether the Committee should continue with its duties or else that it should be dissolved and a new Committee appointed to complete the work.

(12) Such funds as may be required for the operation of the Technical Committees and Administrative and Special Committees shall be budgeted for in co-ordination with the Treasurer and submitted to the Executive Meeting for approval. Annual accounting of expenses will be reported to the Central Office at such time as to permit inclusion in the Annual Financial Statement of the Commission.

approuvée à une Réunion Exécutive. Le Comité devra présenter un rapport d'avancement des travaux lors de chaque Réunion Exécutive. Au bout de six ans, si le Comité n'a pas achevé son travail, la Commission, à la Réunion Exécutive suivante, décidera si le Comité doit poursuivre sa tâche ou s'il doit être dissous et si un nouveau Comité doit être désigné pour achever les travaux.

(12) Les fonds qui peuvent être nécessaires pour le fonctionnement des Comités Techniques et des Comités Administratifs et Spéciaux, seront inscrits au Budget en accord avec le Trésorier, et présentés à l'approbation de la Réunion Exécutive. La comptabilisation annuelle des dépenses fera l'objet d'un rapport au Bureau Central, en temps opportun pour permettre son insertion dans le compte rendu annuel des comptes de la Commission.

Section X.

PUBLIC MEETINGS (CONGRESSES)

(1) The Commission shall from time to time arrange public meetings hereafter called "Congresses" for the presentation of papers or reports and for the general discussion of matters within the scope of the activities of the Commission. The Congresses shall normally take place every three years.

(2) The Congresses shall be held in such places and on such dates as will be determined by the Executive Meeting. The Commission may arrange if so desired and if practicable that such Congresses conveniently coordinate with meetings of other international organizations that deal with matters relating generally to the activities of the Commission.

(3) Any person who wishes to take part in a Congress as a "participant" must be introduced by the National Committee of his country or by the National Committee of the country in which he resides. The National

Chapitre X.

RÉUNIONS PUBLIQUES (CONGRÈS)

(1) La Commission organisera périodiquement des réunions publiques, désignées ci-après, sous le nom de « Congrès » en vue de la préparation de rapports ou comptes rendus et de la discussion générale de questions entrant dans le cadre des activités de la Commission. Les Congrès se tiendront normalement tous les trois ans.

(2) Les Congrès auront lieu en des endroits et à des dates qui seront fixés par la Réunion Exécutive. Si cela est désirable et réalisable, la Commission pourra tenter de coordonner convenablement ces Congrès avec les réunions d'autres organisations internationales qui traitent de questions présentant une certaine parenté avec les activités de la Commission.

(3) Toute personne désirant prendre part à un Congrès, comme participant, doit être présentée par le Comité National de son pays ou par le Comité National du pays dans lequel elle réside. Les Comités Nationaux doivent

Committees must ensure that all persons whose applications are sent to the Central Office have the necessary technical qualifications. In exceptional cases nationals of countries which do not possess a National Committee on Large Dams may participate in Congresses at the discretion of the Central Office, but only if in the opinion of the Central Office they have sufficient professional qualifications or are recommended by their Government or a recognized professional engineering body. Such persons, in addition to paying the normal registration fee for the Congress, shall pay a supplementary admission fee and shall also pay the full cost of the papers and documents which will be sent to them. Non-member countries shall not be permitted to present either reports or communications at a Congress even at their own expense.

(4) Resolutions, if any, presented and adopted at a Congress in accordance with the By-laws shall be considered as advisory only and must be submitted at an Executive Meeting for approval and action.

(5) It will be the duty of the National Committees to provide information about the Congress to technical journals, organizations, authorities and persons in their respective countries to ensure that full particulars of the Congress are known, and to encourage useful participation in its activities.

(6) The method of choosing the questions to be discussed at a Congress and the rules under which papers will be presented and discussed shall be determined in accordance with the By-laws.

s'assurer que toutes les personnes dont les demandes de participation sont envoyées au Bureau Central possèdent les qualifications techniques nécessaires. Dans des cas exceptionnels, les nationaux de pays qui ne possèdent pas de Comité National des Grands Barrages peuvent participer aux Congrès à la discrétion du Bureau Central mais seulement si, de l'avis du Bureau Central, ils possèdent des qualifications professionnelles suffisantes ou s'ils sont recommandés par leur Gouvernement ou par une organisation professionnelle d'ingénieurs dûment reconnue. Outre les droits normaux d'inscription au Congrès, ces personnes devront verser un droit supplémentaire d'admission et payer le prix intégral des rapports et documents qui leur seront envoyés. Les pays non-membres ne seront pas admis à présenter des rapports ou communications à un Congrès, fût-ce à leurs propres frais.

(4) Les résolutions éventuellement présentées et adoptées lors d'un Congrès, en conformité avec le Règlement Intérieur, seront considérées uniquement comme des avis ; elles devront être soumises à une Réunion Exécutive pour approbation et mise en œuvre.

(5) Il appartiendra aux Comités Nationaux de fournir toutes informations concernant le Congrès aux revues techniques, organismes, autorités et personnalités de leurs pays respectifs, afin d'assurer la diffusion de tous renseignements détaillés concernant le Congrès et d'encourager une participation efficace à ses activités.

(6) Le mode de sélection des questions qui seront discutées à un Congrès et les règles suivant lesquelles les rapports seront présentés et discutés sont déterminés conformément aux dispositions du Règlement Intérieur.

Section XI.

DEPOSITS, MEMBERSHIP FEES AND CONTRIBUTIONS

(1) For the purpose of meeting the expenses, capital costs and sundry financing of the Commission, the National Committees shall make an annual deposit, the amount of which shall be determined by the By-Laws.

(2) Every year, the Executive Meeting will approve the amount to be withdrawn from the deposit account of each member country to be transfered as membership fee to the Operating Account to balance it, or at least approximately.

(3) The National Committees will retain ownership of their deposits which shall be refunded in the event of dissolution of the Commission or resignation from membership. Only the part transferred as membership fee to the operating account according to the procedure defined in the By-Laws, will become the property of the Commission.

(4) These annual deposits are compulsory and cannot be used to settle other debts than membership fee.

(5) For each Congress, Central Office may fix individual registration fees for its account.

(6) Central Office shall be authorized to receive and handle as funds of the Commission, any contributions that may be made in the interests of research or of special investigations or experiments. The Central Office may give instructions for co-operative research or experimental work with properly qualified engineering bodies, governmental or private, or with technical societies or associations, or with other international organizations.

Chapitre XI.

DÉPOTS, COTISATIONS ET CONTRIBUTIONS

(1) Pour permettre à la Commission de faire face à ses dépenses, investissements et financements divers, les Comités Nationaux lui feront un dépôt annuel dont le calcul sera fixé par le Règlement Intérieur.

(2) Chaque année, la Réunion Exécutive approuvera le montant à prélever sur le compte de dépôt de chaque pays membre pour être versé en tant que cotisation au compte d'exploitation afin d'assurer ou approcher son équilibre.

(3) Les Comités Nationaux resteront propriétaires de ces dépôts, qui leur seront rétrocédés en cas de dissolution de la Commission ou de démission. Ne sera définitivement acquise à la CIGB, que la part virée au compte « Cotisations » suivant les modalités définies au Règlement Intérieur.

(4) Ces dépôts annuels sont obligatoires et ne peuvent servir à régler d'autres dettes que les cotisations.

(5) Pour chaque Congrès, le Bureau Central pourra fixer en sa faveur des droits individuels d'inscription.

(6) Le Bureau Central sera autorisé à recevoir, pour en disposer à titre de fonds de la Commission, toutes contributions qui pourraient être faites dans l'intérêt de recherches, d'investigations ou d'essais spéciaux. Le Bureau Central pourra donner les instructions nécessaires en vue de recherches ou de travaux expérimentaux effectués en coopération avec des organisations professionnelles d'ingénieurs dûment qualifiées, gouvernementales ou privées, ou avec des sociétés ou associations techniques ou bien avec d'autres organismes internationaux.

Section XII.

OFFICIAL LANGUAGES

(1) Discussions at Executive Meetings and Congresses shall take place in the official languages, French and English. However, at the Technical Sessions of Congresses, the delegates wishing to speak at a "prepared discussion" may do so in the language of the country organizing the Congress if the organizing Committee of the country so decides. In such a case, the organizing Committee shall be responsible for the simultaneous interpreting in French and English and shall meet all the expenses incurred by this procedure. French and English shall also be used, as appropriate, for correspondence to or issuing from the Central Office as well as for the preparation and presentation of papers and communications at a Congress.

Chapitre XII.

LANGUES OFFICIELLES

(1) Les discussions lors des Réunions Exécutives et des Congrès, auront lieu dans les langues officielles de la Commission : le français et l'anglais. Toutefois, dans les Séances Techniques des Congrès, les participants qui désirent intervenir dans une « discussion préparée » pourront s'exprimer dans la langue du pays organisateur du Congrès, si le Comité d'Organisation du pays en décide ainsi ; dans ce cas, le Comité organisateur aura la responsabilité d'effectuer la traduction simultanée en français et en anglais et prendra à sa charge tous les frais occasionnés par cette procédure. Le français ou l'anglais seront également employés dans la correspondance adressée au Bureau Central ou émanant de celui-ci ainsi que pour la préparation et la présentation de rapports et de communications à un Congrès.

Section XIII.

AMENDMENTS TO CONSTITUTION AND BY-LAWS

(1) Amendments to this Constitution may be proposed by any National Committee. Such amendments shall be submitted in writing to the Central Office and thereafter referred to a Special or "ad-hoc" Committee for report. The matter shall be discussed at a meeting of this Committee at the time of the next Executive Meeting. The report once finalized shall be circulated to all National Committees at least two months prior to the following Executive Meeting at which the amendments shall be placed on the Agenda. Adoption of such amendments will require representation at the meeting of at least half of the member countries and an affirmative vote of not less than four fifths of these member countries represented and entitled to vote.

(2) Amendments to the By-laws shall follow the procedure set out in Section XIII, sub-section (1) except that only an affirmative vote of three-fifths in favour of the amendments is required, instead of four-fifths as above.

Chapitre XIII.

AMENDEMENTS AUX STATUTS ET AU RÈGLEMENT INTÉRIEUR

(1) Des amendements aux présents Statuts pourront être proposés par tout Comité National. De tels amendements devront être présentés par écrit au Bureau Central puis transmis à un Comité Spécial ou « ad-hoc » en vue de l'établissement d'un rapport. Ces amendements devront être examinés en réunion de ce Comité à l'occasion de la prochaine Réunion Exécutive. Le rapport, une fois mis au point, sera soumis à tous les Comités Nationaux au moins deux mois avant la Réunion Exécutive suivante à l'Ordre du Jour de laquelle les amendements devront être inscrits. L'adoption de tels amendements exigera que la moitié au moins des pays membres soit représentée à la Réunion ; elle nécessitera un vote favorable des quatre cinquièmes au moins de ces pays membres représentés et ayant le droit de vote.

(2) Pour les amendements au Règlement Intérieur, on suivra la procédure indiquée au Chapitre XIII paragraphe (1), sauf qu'il suffira d'une majorité des trois cinquièmes en faveur de l'amendement au lieu des quatre cinquièmes comme ci-dessus.

Breakdown per group of member countries
(cf. Appendix IIIB)
1988 situation

Goup 1. From 1 - 5 Dams

Bangladesh
Bolivia
Costa Rica
Ecuador
Egypt
Ghana
Guatemala
Iraq
Jordan
Lebanon
Luxembourg
Nepal
Paraguay
Sudan
Urugay
Zambia

---

i.e. 16 countries

Group 2 : From 6 - 15 Dams

Belgium
Denmark
Dominican Rep.
Greece
Honduras
Iceland
Ireland
Kenya
Libya
Madagascar
Malaysia
Netherlands
Philippines
Syria

---

i.e. 14 countries

Group 3 : From 16 - 25 Dams

Algeria
Iran (Islamic Rep. of)
Ivory Coast
Poland

---

i.e. 4 countries

Répartition par groupes de pays membres
(cf. Annexe IIIB)
Situation en 1988

Groupe 1 : de 1-5 barrages

Bangladesh
Bolivie
Costa Rica
Equateur
Egypte
Ghana
Guatemala
Irak
Jordanie
Liban
Luxembourg
Népal
Paraguay
Soudan
Uruguay
Zambie

---

soit 16 pays

Groupe 2. De 6 à 15 barrages.

Belgique
Danemark
Rép. Dominicaine
Grèce
Honduras
Islande
Irlande
Kenya
Libye
Madagascar
Malaisie
Pays-Bas
Philippines
Syrie

---

soit 14 pays

Groupe 3. De 16 à 25 barrages.

Algérie
Iran (Rép. Islam. d')
Côte d'Ivoire
Pologne

---

soit 4 pays

Colombia
Indonesia
Morocco
Tunisia

---

i.e. 4 countries

Group 5 : From 36 - 50 Dams

Cyprus
Finland
Nigeria
Pakistan
Thailand

---

i.e. 5 countries

Group 6 : From 51 - 100 Dams

Albania
Argentina
Chile
German Dem. Rep.
Korea (Dem. People's Rep. of)
New Zealand
Peru
Portugal
Sri Lanka
Turkey
Venezuela
Zimbabwe

---

i.e. 12 countries

Group 7 : From 101 - 250 Dams

Austria
Bulgaria
Czechoslovakia
Germany (Fed. Rep. of)
Norway
Sweden
Switzerland
Yugoslavia

---

i.e. 8 countries

Group 8 : From 251 - 550 Dams

Australia
Brazil

Colombie
Indonésie
Maroc
Tunisie

---

soit 4 pays

Groupe 5. De 36 à 50 barrages.

Chypre
Finlande
Nigéria
Pakistan
Thailande

---

soit 5 pays

Groupe 6. De 51 à 100 barrages.

Albanie
Argentine
Chili
Rép. Dém. d'Allemagne
Corée (Rép. Pop. Dém. de)
Nouvelle-Zélande
Pérou
Portugal
Sri-Lanka
Turquie
Venezuela
Zimbabwe

---

soit 12 pays

Groupe 7. De 101 à 250 barrages.

Autriche
Bulgarie
Tchécoslovaquie
Rép. Féd. d'Allemagne
Norvège
Suède
Suisse
Yougoslavie

---

soit 8 pays

Groupe 8. De 251-550 barrages.

Australie
Brésil

Sedimentation problems at low dams in the Himalayas

By D. N. Bhargava, L. Narain, S. S. Tiagi and P. P. Gupta, Director, Research Officer, Assistant Research Officer and Resident Supervisor*

The rivers and tributaries of Ganga-Yamuna valley in India transport large quantities of sediment during the monsoons. The 60 m-high Ichari dam and 39 m-high Maneri dam became silted to the crest within a period of two years operation. As a result, the spillway discharge under free flow conditions was laden with sediment. The spillway profile, bucket and training walls at Maneri were subsequently severely damaged as a result. In some places, the concrete was completely eroded, and the foundation rock was exposed. The problem at Ichari was not as serious. Data collected over a period of eight years at this dam indicate satisfactory performance of the hydraulic system.

The rapid increase in both population and industrialization have caused acute power shortages in the state of Uttar Pradesh, resulting in severe power cuts; even essential factories and agricultural processes are affected. The development of the state therefore lags far behind others in India, although it is rich in natural resources. Immediate action is therefore required to accelerate hydro development in the state. In the Ganga-Yamuna valley, vast power potential exists in a mountainous region. A number of power and multipurpose projects are under construction or at an advanced stage of planning on perennial rivers and their tributaries. Some small projects have already been completed and commissioned. The large projects, however, are highly capital intensive and have long gestation periods.

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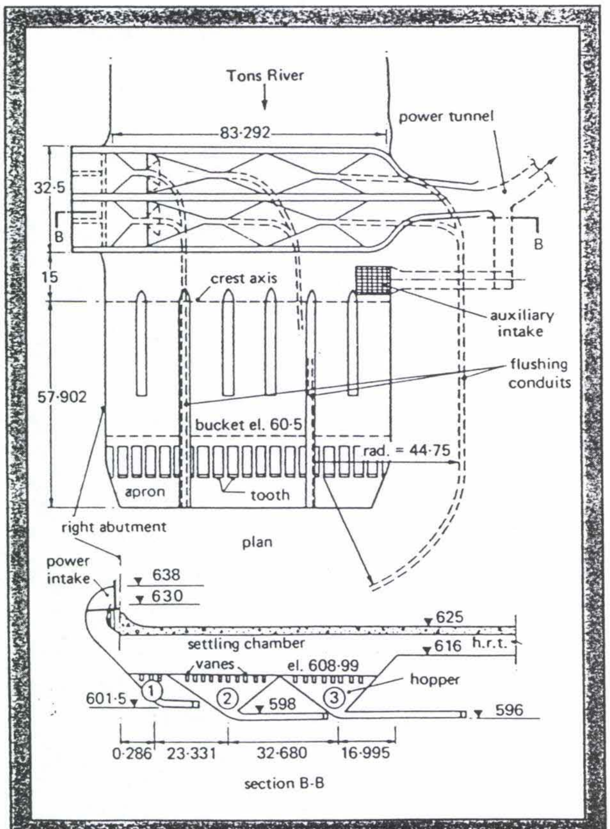

Fig. 1. Layout of the Ichari spillway.

In the Ganga valley, the Maneri dam and Garhwal-Chilla hydro scheme have now been completed and in the Yamuna valley the Ichari dam and the three-stage Yamuna hydroelectric scheme have been in operation for the last eight years. Systematic data have been collected at Ichari dam since its completion.

Ichari dam

This is a 60 m-high concrete gravity dam, constructed across the river Tons, a tributary of the Yamuna, to divert water to the Chibro underground powerhouse through a 7 m-diameter and 6.3 km-long tunnel. The dam provides a usable storage capacity of 4.7×10^6 m^3, so that the discharge may be regulated according to the diurnal variation of load demand. As the river flows in a narrow gorge at the dam site, an overflow section has been provided along the entire length. The spillway crest is at el. 628.8, and consists of seven bays of 9.5 m each. It has been designed for a flood of 14 800 m^3/s; the discharge at the spillway being 222.5 m^3/s per metre. Based on model studies, a roller bucket is provided below the spillway for energy dissipation. For the power intake, a goose neck entry followed by a closed settling chamber with automatic flushing conduits was constructed (Fig. 1). The hydraulic modelling was carried out at the Irrigation Research Institute, Uttar Pradesh.

Ichari dam was completed in 1972; it began operation in March 1975. Since then, various observations have been taken regularly[1]. Besides the meteorological and seismological observations, data are being collected on water and sediment inflow, water used and discharged, sedimentation of the reservoir, head losses in the water conductor system and the behaviour of the various underground structures. Only hydraulic and sediment data will be discussed in this article.

Water inflow, use and outflow

Four-hourly observations of water inflow and outflow (including that which escapes through the spillway or is used for flushing conduits) are regularly made at the dam site. The monthly flow is computed from the daily records. The cumulative figure for the year is then calculated. The data for the period 1976 to 1984 are given in Table I. The maximum inflow of 7825×10^6 m^3 was recorded during the year 1978-79. The peak discharge of the river and spillway was 6291 m^3/s and 6229 m^3/s respectively. In the remaining years the total inflow was of the order of 5000×10^6 m^3. The minimum total inflow of 3420×10^6 m^3 was recorded during the year 1979-80, the maximum spillway discharge being 773 m^3/s. The utilization of water for power generation varied from 46.2 per cent to 78.6 per cent of the total inflow.

Sediment survey

The reservoir survey conducted after one year of operation indicated that the silt had reached the crest level of the spillway. Since then it has been rising continuously (Fig. 2). The decrease in dead and live storage and the sediment trapped in various years are given in Table I. It can be seen how the sedimentation has affected the live storage.

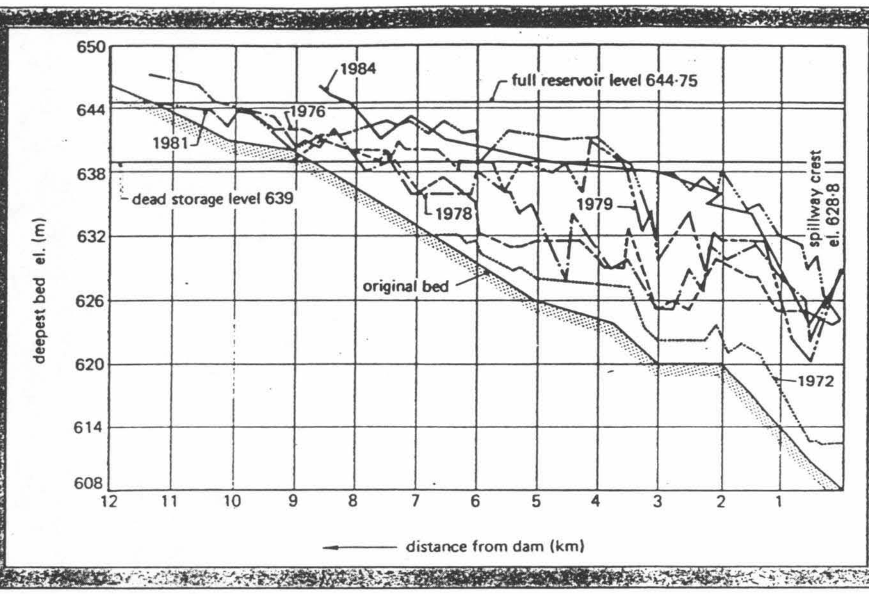

Fig. 2. L-section of the river Tons upstream of the dam axis.

The suspended load in the reservoir and at the spillway were also measured daily. The inflow sediment was classified in four categories:

- sediment trapped in the reservoir;
- bed load which was initially retained in the reservoir but was flushed through the spillway;
- residual suspended load carried away with the water through the intake and over the spillway; and,
- sediment rolling along the reservoir bed which eventually flowed over the spillway.

The total sediment transported by the river during a year has been calculated by adding the sediment of the four categories. The figures for various years are given in Table II. It can be seen that under the second mode of transportation most of the inflow sediment was flushed through the spillway. During the year 1978-79. 24.45×10^6 m^3 of sediment was flushed through the spillway, the value in the other three categories being of the order of 4.6×10^6 m^3. When the spillway was operated under free flow conditions one day in 1981, the sediment concentration on the spillway was of the order of 94 000 ppm.

Water conveying system

It has been observed that large pieces of wedge-shaped stone are caught in the trashrack of the intake structure during the monsoons. This indicates that pebbles and stones roll along the bed of the reservoir and pass over the spillway. To assess the efficiency of the sediment exclusion device, daily observations of suspended load are taken at the intake and in the draft tube gate slots of the Chibro powerhouse. The observations indicate that the mean efficiency of the devices varies from 50 to 90 per cent. However, its efficiency for particles larger than 0.06 mm is very high (about 85 per cent). The maximum particle size in suspension at the intake was 0.5 mm, whereas in draft tube slots it was 0.1 mm.

After the commissioning of the hydraulic works, the sedimentation chamber was inspected in November 1977 for the first time. No damage or choking of the hoppers was observed. In February 1984, the chamber was inspected again. It was found that a damaged trashrack was lying in hopper no. 1. Hopper no. 3 was completely clogged. About 1150 m^3 of sediment was extracted from this hopper. One wooden sleeper measuring $3.7 \times 0.15 \times 0.15$ m was also recovered from the hopper. The neoprene paint which was applied in the chamber during its construction was found to have a surface covered in bubbles filled with water.

The clogging of the hopper could have been caused by damage to the trashrack allowing the entry of a wooden sleeper into the sedimentation chamber. Also, the apple crop of Himachal Pradesh, which was destroyed in the monsoons of 1983, was swept into the intake. After saturation, the rotten apples settled in the hopper and consequently clogged it.

The rugosity coefficient has also been worked out from the observed water levels. It has been found that the value is of the order of 0.011 during monsoon. In the non-monsoon period the value is slightly higher. There is no definite trend in the values for different years.

Spillway and bucket

The spillway profile has been treated with neoprene paint. The teeth are protected at the edges with angleiron, which measures

Table I—Annual inflow and outflow data for the Ichari dam

Year (June to May)	Total Inflow: Water (10^6 m^3)	Total Inflow: Sediment (10^6 m^3)	Peak river discharge (m^3/s)	Peak spillway discharge (m^3/s)	Peak sediment concentration on spillway (1000 ppm)	Dead storage (10^6 m^3)	Live storage (10^6 m^3)	Sediment trapped (10^6 m^3)
1976	(n/a)	(n/a)	(n/a)	(n/a)	(n/a)	3.93	5	2.62
1976-77	5049	1.63	1639	1673	(n/a)	3.4	4.92	0.61
1977-78	6455	3.71	2144	2299	25	3.4	4.8	0.12
1978-79	7825	29.02	6291	6229	80	2.09	4.25	1.86
1979-80	3420	2.07	1103	773	(n/a)	1.6	3.6	1.14
1980-81	4585	4.8	1572	1623	47	1.14	3.46	0.6
1981-82	5445	1.09	1218	1292	94	1.08	3.93	0.41
1982-83	4716	0.49	(n/a)	(n/a)	(n/a)	1.08	3.58	0.35
1983-84	5148	2.43	1246	1194	88	1.2	3.23	0.23

Table II—Sedimentation data for the Ichari dam

Year (June to May)	Sediment trapped (10^6 m^3)	Sediment flushed through spillway with gates up (10^6 m^3)	Residual suspended load passed with water (10^6 m^3)	Rolling sediment along the bed (10^6 m^3)	Total quantity of sediment transported (10^6 m^3)
1976	2.62	(n/a)	(n/a)	(n/a)	(n/a)
1976-77	0.61	0.45	0.57	(n/a)	1.63
1977-78	0.12	2.52	0.32	0.25	[illegible]
1978-79	1.36	24.5	1.32	0.89	29.02
1979-80	1.14	0.25	0.55	[illegible]	2.07
1980-81	0.82	2.51	0.14	[illegible]	[illegible]
1981-82	0.37	0.1	0.55	[illegible]	1.09
1982-83	0.15	0.18	0.26	[illegible]	[illegible]
1983-84	0.66	0.77	0.6	[illegible]	[illegible]

150 × 150 × 50 mm. Steel plates 150 × 100 mm have been anchored at the edge of the bucket lip. Flap valves have been fitted at the outlets, at the downstream face of the teeth.

The bucket was dewatered and inspected in May 1984. There was a little localised abrasion on the spillway face. However, the teeth were badly damaged. The iron on some of the teeth was also damaged and in some cases had been washed away. Concrete was eroded from the top surface of all the teeth. A maximum amount of erosion of 160 mm was observed in one tooth, and on the downstream surface cavities had formed in all the teeth (the maximum cavity size being 13.6 m^2 with a depth of 700 mm). A 30 m length of steel plate, fitted on the lip of the bucket, was washed away. The concrete at the lip had eroded, exposing the reinforcement. In the middle bay, the damaged area and its maximum depth were 35.3 m^2 and 300 mm respectively. Almost all the flaps of drainage pipe were damaged and washed away, and cavities had formed in the training walls. The downstream hill slopes, treated with shotcrete, were badly damaged, and several cracks had developed and deep cavities had formed in the hill slope.

The damage to the teeth and lip of bucket can be attributed to the impact of shingle and pebbles, which rolled over the spillway after siltation of the reservoir. It was reported that pebbles of 15 cm to 20 cm were recovered from the riverbed downstream of the bucket. The cause of the cavities which formed on the downstream face of the teeth was the churning of heavy sediment carried with the flow.

The river bed conditions as observed after the floods of 1975, 1978 and 1984 are shown in Fig. 3. It can be seen that there is no scour in the 20 m reach just below the bucket. The condition of the river bed near the bucket indicates that ground rollers formed at site. Beyond this reach, the river scoured up to el. 603 almost every year.

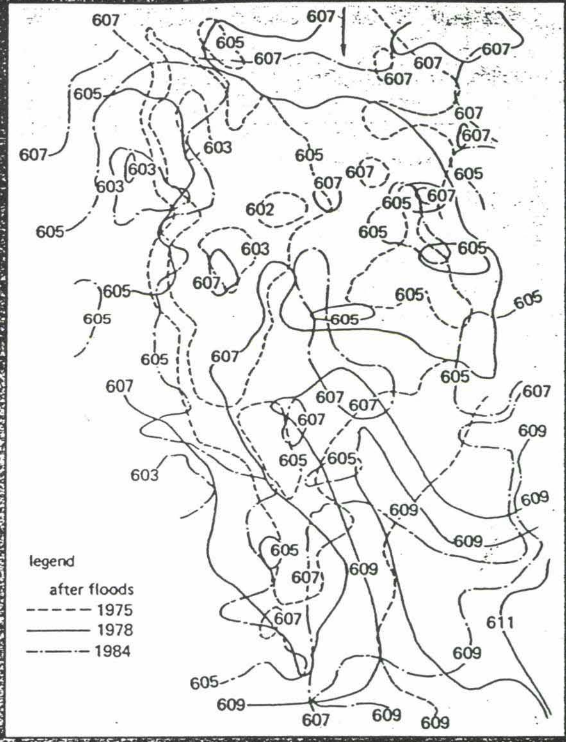

Fig. 3. Riverbed conditions downstream of the Ichari dam.

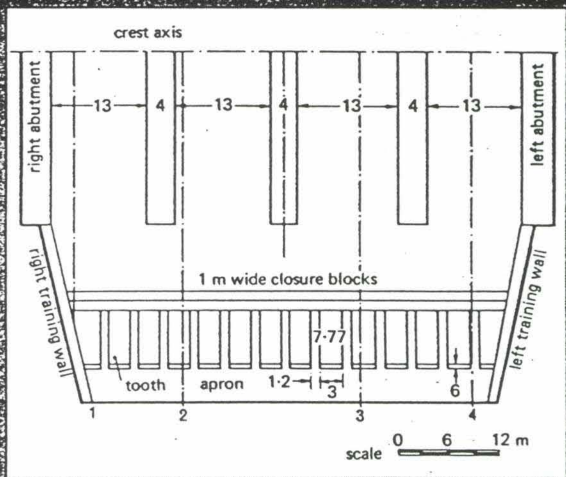

Fig. 4. Layout of the Maneri spillway.

Maneri dam

This is a 39 m-high concrete dam on the river Bhagi-rathi; it diverts flow to the Uttarkashi powerhouse through a 4.75 m-diameter, 8.66 km-long tunnel. The spillway has four 13 m-wide bays separated by 4 m thick piers (Fig. 4). A slotted roller bucket has been provided for energy dissipation below the spillway. The spillway has been designed for a flood discharge of 5000 m^3/s. A settling chamber with hoppers followed by flushing conduits similar to that at Ichari has been provided to keep sediment out of the power intake.

The dam was completed in 1978, and it began impounding in September 1984. The first unit in the powerhouse was commissioned the following month.

An unprecedented flash flood of about 4600 m^3/s was caused by landslides in the upper valley in August 1978. A discharge of about 4000 m^3/s passed over the spillway and the balance through diversion tunnel. The movement of enormous quantity of heavy boulders and rolling debris over the spillway resulting from the siltation of the reservoir caused abrasive damage to its face.

The spillway of Maneri dam was damaged further in the floods of 1979 and 1980. As the river was flowing through bay no. 1 the extent of damage could not be ascertained in 1981. However, the flow pattern indicated considerable damage there. Reinforcement bars were exposed at the spillway face in bay no. 2. A cunnette of 50 cm width and 30 cm depth formed along the right side pier of the bay[2]. The concrete around the sill beams of the stoplogs and radial gates was eroded and the beams were damaged. In bays 3 and 4, the spillway concrete was eroded to a depth of 5 cm to 15 cm.

Protection up to the end of the stoplog gate grooves was absolutely essential because with the damage in the sill beam or seal seat of the stoplogs, the repairs were only possible after drawing down the reservoir and ceasing power generation. The downstream damage could be repaired afterwards without shutting down the powerhouse. After carrying out technical and economic studies, the damaged portion was repaired with grade A 20 M 35 concrete mixed with steel fibre. A steel liner 20 mm thick was provided at the crest extending from 1 m along the upstream slope to 2 m downstream of the radial gate sill.

The dewatering of the bucket took place in November 1984 after the commissioning of the powerhouse. It was found that the bucket had filled with sand, shingle and boulders. When this material was removed it was observed that the concrete had been damaged over the entire area (Fig. 5). The teeth of the bucket were found to be badly affected[3]. The concrete along with the reinforcement and edging angleirons had been eroded and washed away. The depth of erosion was found to vary from 0.1 m to 5.57 m. At two points the concrete was completely eroded and the foundation rock was exposed.

A cavity had formed on the spillway face in bay no. 1. The cavity was filled with debris. When this material was removed from the cavity it was found to be dome-shaped. The depth of the cavity was so large that all the concrete was eroded, along with some foundation rock. The foundation rock was encountered in this area at about 1.2 m below the original rock level where the dam concrete was laid.

The concrete of both training walls had also been eroded to some extent. At some points the reinforcement was worn out and had been washed away. On the right training wall, the maximum damage was observed near the cavity and at end of the pier, whereas in left training wall the erosion was more pronounced near the end. The maximum erosion extended to a depth of 1.37 m.

The damage at Maneri dam may have been caused by the onslaught of pebbles and boulders passing over the spillway with the flow, since the reservoir was filled up to the crest in the first monsoon. The pot hole would have been initiated by the impact of heavy boulders which passed over the spillway in the flood of August 1978. In subsequent years, the cavity would have trapped boulders from the flow. The churning of these boulders in the cavity could have enlarged it to the shape of a pot hole.

The repair works at Maneri dam were completed before the monsoons of 1985. The eroded and damaged portions of the bucket and spillway were repaired with well bonded dense concrete after reinforcement had been provided at sections where material was washed away. The spillway profile and bucket, including its teeth, were provided with 20 mm-thick steel cladding after the damaged portion had been concreted to the required profile. Single V-joints were provided for fixing the steel plates with anchored steel bars.

After the floods of 1985, it was found that the steel cladding which was visible above water, was intact. However, a few steel plates have been seen lying under water in the river downstream of the spillway. As the lower portion of the spillway is submerged because of the tailwater depth,it is not possible to tell exactly where these plates have come from. It is likely that they became detached as a result of failure of the anchor joints resulting from vibrations caused by the onslaught of boulders.

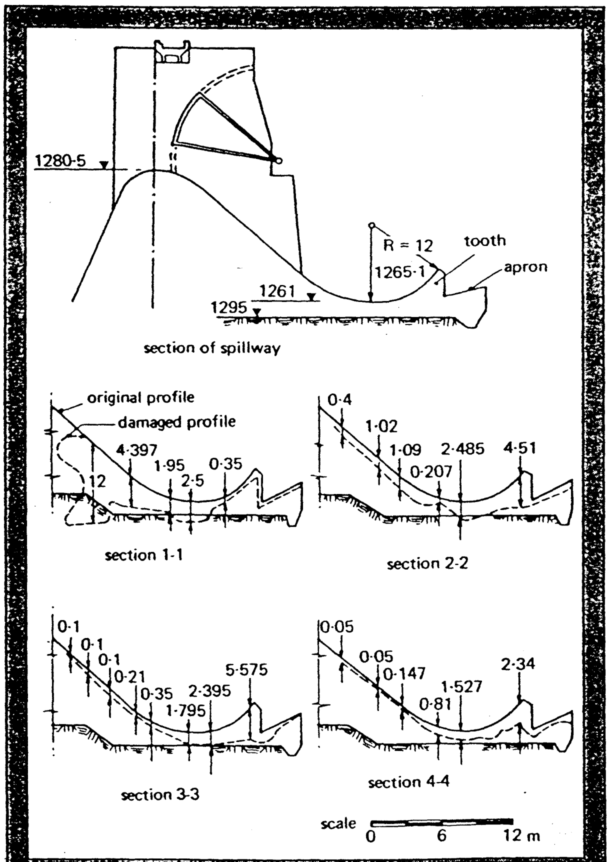

Fig. 5 Damage to the Maneri spillway.

Conclusions

The rivers and tributaries of the Ganga-Yamuna valley transport large quantities of sediment during monsoons. A total volume of 29.02×10^6 m^3 of sediment was transported by the 7825×10^6 m^3 water inflow at Ichari dam during the period 1978-79. Low dams are likely to be silted up to the crest within a short time, as happened at the Ichari and Maneri dams. Heavy sediment passing over the spillway may cause serious erosion in the stilling basin, roller bucket and also on the spillway face. If small areas of erosion are not repaired quickly, severe damage may result in subsequent years.

The experience of the damage at Maneri underlines the necessity of providing anchored steel cladding or erosion-resistant epoxy coating on the spillway face and bucket. In cases where the anchoring of steel bars or welding with cladding through double V-joints are difficult, an I-section may be fixed on the spillway face longitudinally and laterally, to form 1×1 m squares. The intermediate space may be provided with steel fibrous concrete. □

Acknowledgement

The authors are grateful to Sri R. K. Jain Chief Engineer (Dams), Irrigation Design Organisation, Roorkee, for valuable suggestions offered.

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APPENDIX L

CONCLUSIONS FROM THE DUSER SOIL EROSION PROJECT IN TANZANIA

BY ANDERS RAPP

Department of Physical Geography, University of Uppsala

The 15 papers of this volume form an integrated geographical study of soil erosion and sedimentation in some tropical environments under heavy human influence. The main approach of the project is geomorphological and hydrological. Surface runoff, erosion, and sedimentation were documented in a number of catchment basins. The catchment studies are supplemented by earlier data from erosion plots, either collected from unpublished reports in Tanzanian archives or compiled from published papers. To widen the perspective in time and space, the history of land use and soil conservation has been reconstructed as far as possible. Furthermore, a number of papers in the volume deal with special studies—rainfall over Tanzania, soils on Mt. Meru, and sediment transport of the Rufiji river—thus widening the perspective also in a methodological sense.

The most important message that this volume contains is about the necessity to observe critically the reactions of the environment upon exploitation, and to draw rational conclusions for a better land use from these observations. Every land development scheme should to some extent also be a research project. As such it should from the planning stage be designed to allow scientific observations, comparisons, and conclusions concerning its impact on environment and man. In other words, for long-term success, development schemes must be combined with accurate documentation, so that through later comparisons, initial mistakes can be recognized and corrected. Schemes of water and soil conservation must be provided with reliable maps, profiles, reference photographs, and descriptions documenting the situation before the project, so that accurate and inexpensive evaluation of environmental changes during the progress of the work can be made (e.g. changes in erosion, reservoir sedimentation, afforestation, grassland reclamation, stock numbers, and human population).

Any environment under heavy human influence is nevertheless to a certain extent under the control of natural structures and processes.

This is quite evident in the two types of marginal tropical lands—deforested mountains and overgrazed semi-arid grasslands—which we have studied in this project. However, both in the industrialized world and in developing countries man has increasingly neglected the limits of the environment and tried to conquer instead of cooperate with nature. Hence the world of to-day is facing a global ecological crisis. One part of this world-wide pattern is the crisis of land use in the developing countries, another is that of pollution in the industrialized world.

We have in the DUSER project made a particular effort to present carefully documented and illustrated cases, which we hope are understandable and convincing, not only to scientists, but also to decision makers, planners, and farmers. We have in the cases studied tried to document the kind and rate of erosion and sedimentation. On the basis of our diagnosis of the illness of the catchments, we have also recommended methods for their continued observation and treatment. However, we have intentionally avoided going deeply into the details of the cures, because such details should be further discussed with agronomists, foresters, conservationists, water development planners, and economists before being transformed into actual development schemes.

Two important points have been stressed in our approach to catchment studies: (1) the spatial interaction of landscape factors such as relief, soils, and vegetation, and (2) the importance of long-term variations in processes, particularly rainfall extremes, and floods.

The selected study areas represent two different ecological zones: (1) steep, cultivated mountain slopes with perennial stream flow, and (2) semi-arid savanna plains with a long, dry season, severe shortage of water, and seasonal streamflow.

Mountain areas

The studies of the catchments at Morogoro and Mgeta show that small landslides and mudflows triggered by extremely intense rainstorms are important processes affecting steep cultivated slopes in the western Ulugurus. The case study of a rainstorm at Mgeta showed an average landslide denudation of 14 mm over an area of 20 km^2 from this single storm. Erosion by landslides and mudflows is also active under forest and woodland, but is greatly accelerated on deforested slopes, as the data from Mgeta show. The recurrence interval of such events on deforested slopes in the Ulugurus is probably one to a few decades, judging from analyses of records of rainfall intensity.

The "normal" annual erosion from splash and sheet wash in the Morogoro catchment corresponds to a general denudation of 0.26 mm or 260 m^3/km^2. A tenfold higher intensity of denudation by slopewash is likely on the 10 % of area that is under cultivation within the catchment. This conclusion is supported by erosion plot records from Mfumbwe in the Ulugurus. Further information concerning the erosion and runoff on slopes in areas of high rainfall is provided from soil erosion tests in plots at Lyamungu and Tengeru in northern Tanzania.

The most feasible means of controlling landslide erosion on such mountain slopes would be shelter belts of forest planted below ridge crests, along road cuts and along stream sides, to stabilize the soil and regolith with tree roots. Slopewash can be considerably diminished by use of cover plants, mulching, reduced burning, and change to perennial instead of annual crops.

In summary, we recommend continued and extended studies of water and sediment budget in mountain catchments of small size (1—20 km^2). Such studies are necessary as a basis for better knowledge of the following problems:

a) The loss of water, soil and plant nutrients from areas under different type of cultivation or grazing, as compared to forested catchments.
b) The importance of catastrophic erosional events due to heavy, infrequent rainstorms, as compared to average annual erosion losses; the so-called magnitude-and-frequency problem.
c) The time needed for recovery of soil, vegetation and economy after severe erosion.
d) The best inexpensive conservation practices, their implementation, and maintenance in a long term perspective.

Semi-arid savanna lands

The rate of soil erosion and reservoir sedimentation is very high in the four catchments investigated near Dodoma and the one near Arusha. Reservoir sedimentation rates in the cases investigated correspond to annual sediment yields of 200—730 m^3/km^2 averaged over the longest periods of available records. The figures of sediment yield decrease with increasing drainage area, due to sedimentation in the catchment. Therefore sediment yields from small catchment basins, a few km^2 in area, reflect most closely the erosion in the catchment. The suspended sediment transport in the Rufiji river at Stiegler's gorge amounts to 15—20 million tons/year with the highest concentrations in the beginning of the rainy season, which is characterized by marked fluctuations in discharge, due to flash floods in the different tributaries.

The most important process of erosion in the Dodoma and Arusha catchments is sheet wash from overgrazed land and unprotected cultivations. Gully erosion is spectacular in some areas but a clear understanding of the mechanism and frequency of gully cutting could not be obtained during the short time of the DUSER project. Gully cutting is probably connected with rare and extremely intense rainstorms. Studies of when and how gullies are cut and how they function as drainage lines for water and sediment should continue and provide a basis for the establishment of efficient methods of gully control.

Judging from our studies the life lengths of reservoirs in the Dodoma and Arusha areas are very short due to rapid sedimentation. Reservoir surveys to document the rate and type of sedimentation and to establish the remaining life length of reservoirs should be undertaken as standard practice for all existing and planned reservoirs in semi-arid areas. Reservoir maps and profiles should be made, and sedimentation pegs established when a development project starts, so that through later comparisons one can determine how the project has affected the area.

Improved grass management in the semi-arid catchments is the best general method of decreasing soil erosion and increasing the life-length of the reservoirs.

In summary we recommend continued and extended studies of the water and sediment budget in catchments of all sizes in semi-arid regions. Such studies will provide a basis for better knowledge of the following problems:

a) The range of losses of water, soil and plant nutrients from areas under different types of land use, as compared to good grassland management.
b) The importance of catastrophic erosional events due to heavy infrequent rainstorms in comparison with average annual losses. Particular emphasis should be placed on the problems of gully erosion in relation to sheet erosion.
c) The time needed for recovery of soil, vegetation, and economy after excessive erosion.
d) The best and least expensive conservation practices in semi-arid lands, their implementation and maintenance in a long term perspective.
e) The rate of reservoir sedimentation and the distribution, texture, and structure of the deposits. Such studies provide important information for many purposes such as erosion in the catchment, prognosis of life-length of reservoir, and possible use of sand-filled reservoirs for ground-water storage.

APPENDIX M

DAM SAFETY AND SEDIMENTATION MONITORING IN TANZANIA

1. Introduction:

Tracing back the history of dam construction in Tanzania it is noted that it started after the creation of the Department of Water Development and Irrigation in the late 1940s, for public use. There were however a few smaller dams, before this period constructed for private use - eg. in sisal estates, Mwadui Mines etc.

In the late 1950 dams with increased water capacity continued to be constructed priority of which were given to arid districts/provincies. In the early 1960's the biggest dam in the country, water capacity wise (Nyumba ya Mungu) was constructed as a multipurpose dam (hydropower, Irrigation, fishery).

2. Operation and Maintenance:

Most of the public dams in the rural areas(consructed under (MAJI) supervision were maintained by the Water Department. At the each dam, there was a dam attendant, amongst the duties included cutting grass on the embankment, repairs of minor erroded parts of the embankment, see to it that livestock drink at the water throughs not from the reservoir not(upstream) of the embankment. Sometimes the same dam attendants were used as gauge readers (water levels and rainfall records) at the dam site.

At the Provincial/Regional Water Officers there were Water Inspectors/ Technicians who were carrying out routinal inspection "safaries", say twice or thriee per annual one inspection safari covering all the districts back to the office a report was prepared, detailing the field observations and recommendations, for repair etc.

After Nyumba ya Mungu dam was completed, the Ministry appointed a Senior Officer (ex-Regional Water Engineer) as a Resident Dam Superintendent who had assistants under him, all resident at the dam site. The post existed up fill 1972, after decentralization, either there is an officer in-charge, but the functions of overseeing the activities have "slowed down" after decentralization, may be because the administration of the dam (operations/ maintenance), showly changed hands between the Ministry, Region, District and TANESCO. In the other dams we have had no such a post of a dam superintendent. It was suggested to have such officers for all big dams during the 17th ANSC Meeting in Morogoro, November, 1992.

2.1 Safety in Particular to Nyumba ya Mungu Dam:

The have been reports of see page through the dam embankment. Minor studies have been carried out without and/no solutions or activities have been done to arrest the situation. Other areas including the spill way also need civil work rehabilitation.

Reports for other dams in the country like Minda dam in Morogoro, Mwamapuli dam, in Tabora, Ning'wa dam in Shinyanga, and many others, seepage is a common feature. Unfortunately no studies have been carried out.

3.0 Data on suspended Sediment:

Records indicate that from 1960 onwards some efforts were done to procure data on suspended sediment transport for some rivers. But due to lack of enough samplers it became difficult to get a complete relationship between flows and parallel suspended discharges covering the whole range. It was noted however that in Central Regions and Southern Coastal Region large amounts of sediments are transported annually. Also in the internal drainage basin (semi-arid) overgrazing increases sheet erosion in upstream catchments hence sedimentation increases in downstream areas.

Instruments used for sampling included Integrated Suspended Sediment Sampler types USD-49 and DH-48. Also in most perennial rivers, boats are necessary to survey cross-sections at different points. For such data collection it is important to have enough instruments and camp equipment, transport and not forgetting sufficient funds to carry out a continuous programme, especially during the rainy season. It is proposed that to start such a programme now, the first thing to do is to prepare and inventory of existing dams, prepare short reports on their conditions and prepare budgets for rehabilitation, instrument and transport procurement budgets. Either, the programme could be implemented by zoning the country - so that a team stationed at one Zonal Office can monitor - sediment load in a number of Regions within the zone for rivers lakes and reservoirs (dams). Dams of national interest, economy-wise eg. for hydropower/irrigation/industries should be given first priority.

The programme should include among others studies on source of sediments, erosion control measures on the sources, quantitative yield of each principal sediment sources.

4.0 Dam Safety:

Other minor works on maintenance of dams can be shared between the villagers, district councils/(Local Government) and Central Government. Such works include the following, as tabulated.

No.	Type of Work	Responsible	Strategy	COST	
				Activity	T.Sh.
1	Prohibit farming in catchment areas	Villagers/ Local Government	-Villagers to guard -Catchment guards -Fencing	-Beneficiries contribution -Guards -Fencing	
2	Construct cattle troughs -D/S of dam	as above	-Cattle troughs -Rehabilitate -watchmen	-Cattle troughs -watchmen	
3	Embankment grass tree-clearing	as above	-Villagers -employ labourers	-Beneficiries contribution -Labourers	
4	Rehabilitate spillway or embankment	as above	-Remove logs -Rehabilitate enoded areas	-Beneficivies -Labourers	
5	Fumigate and destroy antihills	as above	-Fumigation	-Fumigation expert	
				Total	

The Central Government to assist if heavy plants/equipment is required in case the Local Councils cannot hire or pay for such plants from their own fund - resources.

4.1 Sediment Pollution:

So far there are no dam safety rules or requlations in the country. However any activities, lake farming near or down to water source banks may cause erosion and sediment can easily be carried to water source (sediment pollution). Such defaulters can be taken to task and be prosecuted under Act. No.42 of 1974 and 10 of 1981 - Water utilization (Control and Regulation).

S.G. Mkuchu,
PRINCIPAL WATER OFFICER 3/5/1993

APPENDIX N

THE UNITED REPUBLIC OF TANZANIA
MINISTRY OF WATER

RESERVOIR SEDIMENTATION STUDY

(STUDY PROPOSAL)

repared for:

MINISTRY OF WATER
DAR-ES-SALAAM

Prepared by:

Hydrology Section
Water Research Division
Ministry of Water
DAR ES SALAAM

Jan 1990.

PROJECT PROPOSAL

COUNTRY: UNITED REPUBLIC OF TANZANIA

TITLE OF PROJECT: RESERVOIR SEDIMENTATION STUDY

SCOPE:

This project is aimed at undertaking reservoir sedimentation surveys of at least 50 existing reservoirs of varying capacities from below 0.2×10^6 cubic meters to over 40.0×10^6 cubic meters.

The work will involve the following activities.

(i) Determining volume and distribution of sediments in the reservoirs.

(ii) Determining the densities of the sediments.

(iii) Investigation of sediment in the rivers (inflowing and outflowing) associated with the reservoirs.

(iv) Based on collected data derive relationships for estimating sediment yield from ungauged catchments.

0 BACKGROUND INFORMATION:

Tanzania is a tropical country where arid and semi-arid conditions prevail over half of the territory namely, Dodoma, Singida, Shinyanga, Tabora and parts of Mwanza, Mara, Tanga and Arusha regions. In these regions surface water streams are either ephemeral or intermittent.

In order to satisfy water demand for various uses, the Ministry of Water has constructed several dams to store water during the dry season to supplement groundwater sources. Unfortunately due to indiscriminate cutting of trees, high population and animal pressure on land and poor land management might have led to high erosion rate which prevail. This has led to deposition of large quantities of sediment into these reservoirs resulting in possible loss of useful storage volume, and thus threatening to deprive the people their ... of water.

Some of the reservoirs were surveyed about 10 years ago but no system was established to permit a repeatition of survey. Despite these few surveys very little is known about the rate at which these capacities have been reduced due to sedimentation.

JUSTIFICATION:

Most of the reservoirs in Tanzania were constructed to satisfy water demand for various uses. The Government has thus invested millions of shillings into constructing them. Land use patterns have changed considerably especially in the semi-arid regions where most of the reservoirs exist. Erosion process seems to be accellarated and thus greatly contributes to sedimentation of the reservoirs which, consequently, depletes their useful storage capacity and thus reduces their useful life.

There is no established system of monitoring sedimentation of the reservoirs, as such the current capacities are unknown. With increase in population, agricultural, livestock industrial and other development activities the demand on water supply is increasing, but where the actual volume available is unknown. In this regard it is difficult to offer legal Water Rights for the various uses or to make reallocations of water where appropriate.

Further, more reservoirs are being planned in these areas to satify increased water demand. Therefore knowledge of existing sedimentation rate will assist in the planning and design of new reservoirs as well as assisting in finding ways of minimizing sedimentation of the reservoirs.

Therefore it is important to undertake reservoir sedimentation surveys in order to realise the set objectives.

.0 RESPONSIBLE GOVERNMENT AGENCY:

Hydrology Section of the Ministry of Water.

Address: MAJI UBUNGO

P.O. BOX 35066

DAR ES SALAAM

UNITED REPUBLIC OF TANZANIA.

7.0 INSTITUTIONAL SUPPORT:

(i) The Regional Offices of the Ministry of Water are responsible for operation and maintenance of the reservoirs.

(ii) The Hydrological section headquarters is responsible for providing expertise, supervision and analysis of data.

8.0 DURATION OF PROJECT:

18 months.

9.0 STARTING DATE:

July 1990.

10.0 ESTIMATED COST:

US $ 148,000.00

11.0 GOVERNMENT INPUT:

(i) Personnel

Hydrologists 2 From Hydrology Section Headquaters

Technician 1 From Hydrology Section Headquaters.

Existing hydrological staff from eight Regional Offices involved.

Each region will provide one Hydrologist and three technicians.

(ii) Equipment and Supplies:

Theodolites, Maps, Stationery, office space, and Graph papers.

(iii) Funds:

T.Shs. 657,260/= (US $ 8,676) SALARIES

T.Shs. 440,000/= (US $ 2,303) STATIONERY + HIRE OF THEODOLITE

TOTAL TSHS.

2,097,260/= (US $ 10,979).

EXTERNAL INPUTS:

(i) Personnel:

Expert on Erosion and sedimentation to assist in planning and undertaking of the reservoir sedimentation survey, processing analysis and interpretation of results.

- To provide training for counterpart staff.
- Preparation of technical report.

Duration: 3 months at the beginning of the project.

3 months before the end of the project.

(ii) Equipment and Supplies:

ITEM	UNITS REQUIRED	ESTIMATED UNIT PRICE (TSHS)	ESTIMATED TOTAL PRICE (TSHS)
Echo sounders with stationery and batteries.	3	900,000	2,700,000
Surveying sextants	3	165,000	495,000
Alluminium boats 4-4.5m long	3	150,000	450,000
Boat engine 15hp	6	350,000	2,100,000
Inflatable boats	3	75,000	225,000
Two way radio communication	3 sets	60,000	180,000
Rain coats	20 pairs	4,000	80,000
Life jackets	20 sets	6,000	120,000
Gumboots	20 pairs	5,000	100,000
Vehicles (4 wheel drive)	3	4,000,000	12,000,000
Sediment samplers			
- Suspended	3	150,000	450,000
- Bed material	3	100,000	300,000
- Corers	3	100,000	300,000
		TOTAL	19,500,000
		Approx:	US $97,500

(iii) Funds:

(a) US $ 97,500

- For the purchase of equipment and supplies listed in Section 12.0 (ii).

(b) US $ 28,500

- Night out and travel allowance for local staff at the following rates:-
  TShs. 1000/= per night for small towns.
  TShs. 1500/= per night for district towns.
  TShs. 2000/= per night for regional headquaters.
  TShs. 2500/= per night for municipalities.

(c) US $ 11,000

- For the purchase of fuel and maintenance of vehicles.

(d) Experts salaries and allowances, travel expenses. (not budgeted).

13.0 OUTPUTS:

(i) Annual sediment yield of the watersheds will be determined.

(ii) Re-evaluation of the existing storage capacity and thus useful life of the reservoirs will be established.

(iii) Relationship between volume of sediment and some catchment characteristics will be established. This will assist in the design of new reservoirs in areas with similar hydrologic, climatic and physiographic characteristics.

(iv) Suggestions and recommendations on the operation of the reservoirs and protection of the catchment in order to minimise the sediment problem.

14.0 GOVERNMENT PRIORITY AND COMMITMENT:

Though the project is not included in Government development plan, it has good support in view of Government's commitment to the water sector, and considering the amount of investment made into constructing the reservoirs. More reservoirs are being and will be constructed in the future.