MATHEMATICAL MODELLING FOR REAL-TIME FLOOD FORECASTING AND FLOOD CONTROL IN CENTRAL AMERICA

PLAN OF ACTIVITIES FOR 1995

COSTA RICA

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1. INTRODUCTION

Within the present project Mathematical modelling for real time flood forecasting and flood control in Central America, modelling technology is being transferred to the six participating countries, including Costa Rica. In 1993 and 1994 the main project activities have been an Inception Phase from January to July 1993 followed by a Data Collection and Training Phase from July 1993 to December 1994. The main activities have been data collection in the case study areas, regional workshops, two oversees training courses and transfer and installation of hard- and software to the participating Institutions. In January 1995 the project is entering into its application and consolidation phase with a duration of two years.

The objective of the present document is to describe project activities during the application and consolidation phase with special emphasis on project status, targets for 1995, identification of activities required to achieve these targets and a scheduling of the necessary inputs.

The document has been prepared by DHI in cooperation with Jorge Granados Calderon (ICE), José Alberto Zuñiga (ICE), Juan Carlos Fallas (IMN) and Marco Antonio Jaubert (UCR). In addition, the role of CNE has been discussed with Ing. Rafael Oreamuno Vega, director of the operative sector of CNE.

2. PROJECT STATUS

Below is given a short status of the project as per January 1995.

2.1 Institutional Framework

In the recently finalized data collection and training phase three institutions have been the main participants:

Instituto Costarricence de Electricidad (ICE)

ICE is the national power and telecommunication institution responsible for power production and telecommunication in Costa Rica. ICE operates approximately 50 % of the meteorological stations and the far majority of river gauging stations in Costa Rica and complements the meteorological services provided by IMN. In addition ICE makes sediment sampling at a large

number of their hydrometric stations.

The results of this hydrometeorological data collection programme is published in a yearbook which is widely distributed. All data are stored in a data base system well organized and easy to access. Data are available for other projects and organisations free of cost, the latter likely to be changed in the near future.

The Hydrological Division, responsible for the hydrometeorological network including data management executes a number of hydrological studies every year and intends to apply the MIKE 11 modelling system as a standard tool for these studies. It is persons from the Hydrological Study Unit who have participated in the oversees training courses in Denmark.

The Hydraulic Division of ICE, responsible for design and construction of structures related to the hydro power production also intends to apply the MIKE 11 modelling system as a general design tool for their studies as well as utilising the calibrated Reventazon river model in connection with the construction of the Augustin reservoir.

Instituto Meteorologico National (IMN)

IMN is the national meteorological institute. IMN operates approximately 240 meteorological stations in Costa Rica and is by law given the responsibility for issuing of forecasts and warnings about meteorological hazards such as hurricanes and severe storms causing heavy rainfall, floods and storm surges. IMN operates a well established data receiving and storage system and has by law access to all meteorological data in Costa Rica.

IMN has formed a warning group comprising four staff members which in case of a meterological hazards reports directly to CNE, see below. To be able to issue not only meterological forecasts but in addition flood warnings, IMN joined this project and one person from the Information Department participated in the training in Denmark.

Universidad de Costa Rica (UCR)

UCR is far the largest national university. The civil engineering faculty (Escuela de Ingeniera Civil, Facultad de Ingeniera) teaches around 650 students each semester and has a professional staff of approximately 45 persons. Courses in hydrology and hydraulics are given at medium and high level.

UCR will play an important role in securing the project sustainability in the long term perspective. From the second semester of 1995 UCR will gradually include mathematical modelling at advanced level courses in hydraulics as well as applying it for thesis work.

Together with CNE, UCR will define the flood hazard simulations to be carried out applying the calibrated Reventazon model and there is no doubt that UCR will play an important role defining new applications, identifying new model areas and together with ICE/IMN carry out the studies.

It is expected that the framework with ICE, IMN and UCR as actively involved institutions will continue also in the application and consolidation phase with an additional involvement of:

Comisión National de Emergencia (CNE).

CNE is the national disaster organisation and has the overall coordinating role in case of a natural disaster. For the purpose of coordinating work related to hydrometeorological hazards a sub-committee has been formed with representation from ICE, IMN, UCR, the water supply organization and Ministry of Public Work (MOPT).

CNE/the Committee has only limited staff resources to carry out technical analyses in the field of hydrology and hydraulics and has not been directly involved in the data collection and training phase, but will play an important role in the application phase defining scenarios to be modelled and as a disseminator of results to other related organisations. The national representative of Costa Rica is from CNE.

Other end-users:

Minesterio de Obras Públicas y Transportes (MOPT).

MOPT (Ministry of Public Work) is responsible for design, construction and maintenance of river embankments and other river training activities. MOPT has shown an interest as a potential end-user of the established model(s).

Via CNE contacts has been made to JAPDEVA (Developing of the Atlantic Region and Administration of Ports and Coastal Areas). JAPDEVA is a potential end-user of the Reventazon model as well as of other models of rivers in the atlantic zone.

It is indisputable that CNE as an important end-user organisation of the results must play an active role defining the applications of the calibrated models with respect to flood mitigation measures. The other end-user organisations mentioned above will probably not play an active role in the modelling works, but interrelate with the project via CNE.

2.2 Counterpart staff

In total four counterparts have attended the 6 months overseas training course in Denmark:

* Ing. Jorge Granados Calderon (ICE), who is a hydraulic engineer in the hydrological department

* Ing. José Alberto Zuñiga (ICE), who is a hydraulic engineer in the hydrological department

* Lic. Juan Carlos Fallas (IMN), who is meteorologist and Sub. chief of Information.

* Ing. Marco Antonio Jaubert (UCR), who is civil engineer and teacher at the civil engineering faculty.

In addition to these persons additional staff members has been introduced to and operated the modelling system.

At ICE Ing Carlos Rodrigues Mesa who is a hydraulic engineer at the hydrological department has been introduced to MIKE11 by Jorge Granados and has carried out data entry and analysing procedures and HBV simulation.

Training of additional staff in operating the system has been discussed with ICE, IMN and UCR. At present it is anticipated that through the coming two years approximately ten additional staff members will be frequent users of the modelling system given they will receive the necessary training.

From ICE most of the staff in the hydrological and one or two staff members of the hydraulics department will be frequent users of the modelling system.

At IMN MSc Rosario Alfaro Ocampo, already familiarly with the HBV module will be involved in operating the modelling system in 1995. In 1996 one additional person not yet identified will be attached to the project.

At UCR Ing. Rafael Murillo, Civil engineer at faculty of civil engineering and Ing. Antonio Sanchez, Head of the hydraulic and environmental department will be involved in the project.

2.3 Hardware and software installation

In total four hardware installations have been made, each consisting of a 486 based personal computer, a 17" colour monitor, a laser printer and an UPS. Two systems have been installed at ICE, one at IMN and one at UCR.

Computers installed after the first training courses were all supplied with a 450 Mb harddisk. It has been found that institutions carrying out intensive modelling activities experiences disk capacity problems and it has been decided to upgrade these computers with an additional 500 Mb harddisk.

The MIKE 11 version 3.11 for MS-Windows has been installed on all computers. The HIS module at present under transfer to Windows but still operated under DOS has been installed in addition. Backup procedures of system software and data files has been discussed and established. No virus problems has been detected on the computers installed in June 1994, but anti-virus software has been supplied and installed on all computers.

At ICE two additional MIKE 11 installations have been made after a request. Both the installations are in the hydrological department but it is anticipated that one of the installations will be transferred to the hydraulics dep. At UCR one additional installation has been made.

These additional software installations have all been made on computers provided by the receiving institutions and are presently made available for the users for the duration of the ongoing project.

Based upon experiences from participating institutions installing unauthorised software on the supplied computers, is must be strongly recommended NOT to initiate any kind of software updating on the provided computers without consulting DHI in advance.

2.4 The Rio Reventazon case study.

The Rio Reventazon basin is situated in the central area of Costa Rica. The river system drains approximately 3,000 km2 with an altitude varying from 3,432 m.a.s.l. in the south to m.s.l at the outflow to the Atlantic Ocean in the north. The annual precipitation varies between 1200 and 8000 mm.

As the hydro power stations in the Reventazon catchment of which the Cachi station is by far the largest, produce a major part of the hydroelectric energy in Costa Rica, this river basin is of great importance for the country. The Cachi reservoir is located in the upstream part of the catchment where high precipitation rates results in frequent flash floods causing loss of lives and damages on roads, embankments and transmissions installation structures. A related problem in

the upstream areas is frequent landslides provoking high rates of sediment erosion and transport causing siltation in the downstream reservoirs. In the lower and coastal areas the river system now and then inundates the floodplains effecting important settlements and agricultural areas.

The selection of the Reventazon basin as case study area was based upon the possibilities to undertake the following applications:

- To develop and implement a flood warning system enabling authorities to warn people being effected and to protect properties threatened by floods.
- To develop a management tool for the dam operations based on real-time flow forecasts to maximize power production and to minimize inundations downstream the reservoirs.
- To prepare flood hazards maps and assess possibilities for flood control schemes.
- To assess areas of risk downstream of the Cachi reservoir in case of a dam failure.

At present ICE is carrying out a data collection programme in connection with planning and design of two additional reservoirs and hydro power plants downstream the Cachi reservoir. Three hydrometric gauging stations with radio based data transmission have been established and this network will be further developed in the near future.

Obviously the Reventazon model is a potential tool for analysing the consequences this project with respect to design of spillways, changes of river discharges generating erosion and/or siltation and coordinated dam operation.

Following the two training courses in Denmark a HBV and HD models covering the entire Reventazon basin has been established. During the first overseas training course model work was concentrated around the model setup and initial calibration. During the second training period the Parismina submodel was included in the setup and calibration was carried out both in Costa Rica and in Denmark. Referring to the final report of the second Overseas Training Course the calibration of the Reventazon model as per January 1995 can be summarised as below:

Analyses of double mass curves and duration curves has not been completed. Mainly due to memory limitations in the DOS operating system. Will be completed when the HIS is operational under Windows. A review of rating curves is also pending.

The Parismina river basin submodel was established but due to lack of hydrometeorological information a calibration could not be carried out.

Compare HBV calibrations obtained by first and second group, including water balance, peak runoff and dry season flow.

As the respond time of the basin is less than 24 hours the final calibration of the HVB and the HD models must be based on hourly precipitation and water level and runoff data.

3. PROJECT TARGETS

The general immediate objectives of the present project has been defined as follows:

- to enhance the capability of the countries to plan, design and operate flood mitigation measures.
- to contribute to the improvement of flood preparedness programs by improving flood forecasts methods and increase lead times.

Through discussions with the institutions and counter parts involved in the project in Costa Rica these objectives have been further detailed in more specific long and short term targets reflecting the needs and possibilities. The short term targets to be accomplished within 1995 are listed below:

3.1 Specific targets for 1995

- Establish two new water level gauges in the downstream reaches of Rio Reventazon
- Exchange of data, results and experiences between counterparts from the first and second overseas training courses.
- Update time series data bases in MIKE 11 with latest available hydrometeorological data.
- Analyze double mass and duration curves; review rating curves.
- Refine the Reventazon model with flood plain data to be able to represent the upstream flash floods and to simulate the extend of the inundations of the floodplains in the lowland.
- Finalize the calibration of the Cachi reservoir
- Run and calibrate the HBV and the HD model using available hourly precipitation and water level data.

- o Application simulations (flood hazard simulations, flood control simulations, Dambreak simulations, Dam operation simulations)
- o Assess possible improvements in flood warnings procedures combining the calibrated models with a telemetric system.
- o Initiate setup of new models including identification of model areas (flooding problems or/and hydro power production), investigation of data availability (cross-sections and hydrometeorological data) and schematisation and setup.
- o Plan and execute a 2 weeks training course in San Jose to introduce potential end-user organisations to and to train additional counterpart staff from participating institutions in operating the modelling system.
- o To participate in a one month Regional Training Course.
- o Introduce the modelling system in courses at UCR
- o Preparation of course material and computer exercises for UCR.

4. PROJECT ACTIVITIES

4.1 The Rio Reventazon case study

4.1.1 Updating of the MIKE 11 data bases.

As it is the intention to keep the MIKE 11 data bases "up to date" latest records of precipitation, water level and discharge data must be entered into the time series data bases. Exchange of new and modified data between counterparts must be ensured. To minimise this work and to maximize the data security it is recommendable to establish a "field data directory" where all observed data are stored in MIKE 11 format.

4.1.2 Data Analysing.

4.1.3 Final model calibration

From simulations carried out at ICE after installation of the latest version of MIKE 11 utilising the possibilities of an improved bed-friction description it was found that the problems regarding calibration of the Cachi reservoir was reduced and identified as an irregularity in the level versus

surface area description. This will be evaluated and long term calibration simulations (one year) carried out. These runs can be based on daily values.

To be able to reproduce flash flood events often with a duration of a few hours it is necessary to calibrate the model using time series with hourly observations as boundaries in the upper branches and catchments. This calibration will be evaluated based on its capability to reproduce the peak water levels of the individual events (floods). Both rainfall-runoff (HBV) and river routing simulations will be based on hourly data, but to eliminate as many uncertain parameters as possible the HD calibration simulations should utilise upstream **measured** inflow where possible.

It is expected that the final calibration of the Reventazon model will be carried out by the counterpart staff in Costa Rica. Backup from the Consultant will be given to the extend possible and the results will be discussed and evaluated in May where DHI staff will visit Costa Rica.

It is expected that the calibration will be finalised by June 1995.

4.1.4 Application of the Reventazon model

Application of the calibrated model of the Reventazon basin will be finally decided at the visit in May. The following applications wave been discussed

- Flood Hazard Simulations.
  Such simulations are of particular interest of the Committee. Scenarios to be simulated and methods to present the results will be discussed and decided by CNE, UCR and IMN.

- Flood Control Simulations
  Evaluation of proposed flood control measures to protect against or to minimize the damages of flooding will be of the interest of MOPT.

- Dambreak simulations
  With the additional planned reservoirs in mind the need for an overall assessment of the risk in case of a dam failure will be stressed.

- Dam Operation Simulations
  It is anticipated that the power production can be increased by optimising the operation of reservoirs and dams at high flow situations but also during drought situations. The effect of proposed policies can easily be tested by applying the model.

In connection with the planned visit in May final discussions will be held regarding applications.

4.2 Training

4.2.1 Local training course

A 2 weeks training course with class activities four hours each day will bee arranged in Costa Rica. The purpose of this course is to **introduce** additional counterpart staffs and potential end-user organisations to the modelling system and to provide staff members operating the system with the necessary knowledge to do so. The course will be arranged by the Technology Transfer Centre of Civil Engineer School of UCR. Principal instructors will be the four trained counterparts. DHI will supply the necessary number of software installations and manuals to execute the course.

4.2.2 Regional training course.

A one months training course will be held in the region, probably in November. Three to five persons nominated among the new "additional staff members", see chapter 2.1, will here have a chance to get a deeper knowledge about the modelling system, data requirements, model schematisation and set-up, calibration techniques and application simulations. The counterparts having received training in Denmark will be requested to provide their support to this course as instructors together with persons from DHI/SMHI. DHI will forward requests in this respect in May.

Participants in the above course will be selected by a committee comprising the counterparts having served as instructors on the national training courses, the national Representative and a representative from DHI.

4.2.3 Support to UCR

As a support to the integration of the modelling technology at UCR the Consultant will assist in preparing lecture notes and computer exercises. A one week regional seminar will be arranged in July/August with participants from the consultant and the involved universities. The purpose will be exchange of ideas and experiences in teaching the subjects.

4.3 Model setup and applications in new areas.

4.3.1 Areas of interest.

After discussion with the direct involved institutions (ICE, IMN, UCR and CNE) the following 5 basins have been identified as of general interest with respect to flooding problems and/or hydro power production.

Atlantic side:

- The Sixaola Basin with a catchment area of 2336 Km2
- The Estrella Basin with a catchment area of 1006 KM2
- The Chirripo/Matina Basin with a catchment area of 1420 Km3

Pacific side:

- The Parrita basin with a catchment area of 1276 km2
- The Grande de Terraba basin with a catchment area of 5085 Km2.

It is expected that modelling activities will be **initiated** in these areas within 1995, and a priority list should be established and data availability identified during the first visit of the Consultant.

5. Activity schedule and staff input (Costa Rica)