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

PLAN OF ACTIVITIES FOR 1995

NICARAGUA

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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 Nicaragua. 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.

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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 two institutions have been the main participants:

Instituto Nicaragüense de Estudios Territoriales (INETER)

INETER is a technical-scientific institution responsible for the inventory, classification and studies of the natural resources in Nicaragua as well as the planning of their exploration and conservation. Direccion de Recursos Hidricos (DRH), one of five directions of INETER, operates sections for hydrology, hydrogeology and meteorology with a total staff of about 45 of which 18 have an university degree.

INETER´s tasks includes operation and maintenance of the national network of meteorological and hydrological stations and investigations related to the water resources. The hydro- and

meteorological network was seriously effected by the political instabilities in the country from 1979 to 1989/90. The meteorological network was reduced from 400 to only 90 stations and the hydrometric network from 60 to 11. Under a programme assisted by FINNIDA 11 meteorological stations in the Escondido basin have been rehabilitated since 1990.

It is persons from the Water Resources Department who have participated in the overseas training in Denmark.

Universidad National de Ingenieria (UNI)

At UNI the Building Technology Faculty teaches around 600 students each semester with a professional staff of approximately 40 persons. Courses in basic and medium level hydraulics and hydrology are offered by the Hydraulic Department (six teachers). The Programma de Investigation y Docencia en Media Ambiente (PIDMA) at UNI is however offering courses at the advanced level along with research and provision for external services in the fields of water supply and waste water treatment.

UNI/PIDMA will gradually introduce the modelling technology in courses at medium and advanced level as well as applying it for thesis, technology transfer courses and external services. By interacting with INETER and INE, PIDMA will be able to provide students and research personals with actual field data.

The person from UNI who has received training in Denmark has a function as teacher at the hydraulic department and as research assistant at PIDMA.

The Institute for planing of Energy and Hydropower production in Nicaragua (INE) has exposed an interest for participating in the project. In agreement with the decision made at the 4th Steering Committee Meeting, the project is currently in the process of entering into an operating agreement over their participation. This agreement is expected to be finalised and signed in March 1995.

In December 1994 the energy sector was separated into two organisations each with their different obligations:

Instituto Nicaragüense de Energia (INE)

INE is the national Institute for Energy and has the authorization to explore, regulate and manage the energy sector which at present includes conventional energy (oil, gas and coal), hydropower and geothermic energy and alternative energy sources. In addition, INE is authorized to plan and regulate the utilisation of surface water foe energy purposes and responsible for the environmental effects related to this.

INE is executing a number of hydrological studies every year and intends to apply the MIKE 11 modelling system for these studies, such as the Rio Viejo catchment where a master plan study recently has been initiated. INE is also interested in applying the system in the Rio Escondido catchment where they within the next five years are supposed to execute two feasibility studies.

Other end-users:

In the **application and consolidation** phase it is expected that the following organizations will be involved in the project in the role of end-users of the calibrated models, defining applications or as coordinator of dissemination of model results.

Estado mayor de Defenca Civil.

Defenca Civil is the national disaster organization and has an overall coordinating role in case of a natural disaster. Defenca Civil has no staff to carry out technical analyses or assessments and will not be directly involved in the modelling work. They have an interest following the project as an observer and as a user of a real-time flood forecasting system if such is established.

La Empresa Nicaraguense de Energia (ENEL)

ENEL, separated from INE has the responsibilities of production, transmission and trading of energy. This includes optimisation of the operation of reservoirs and sluices and as so they have an interest in applying the calibrated models of the Escondido and the Rio Viejo basins when available.

2.2 Counterpart staff

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

* Ing. Luis Sandor Palacios (INETER), who is technical director of the water resources direction.

* Ing. Fernando Martines Martinez (INETER), who is head of the hydrological analyses section of the water resources direction.

* Ing. Isaías Montoya Blanco (INETER) , who is head of hydrological department of the

water resources direction.

* Ing. Miguel Blanco Chavez (UNI), who is civil engineer, teacher at the hydraulic department and research assistant at PIDMA.

No additional staff members has until now been trained or introduced to the modelling system, but training of additional staff in operating the system has been discussed with INETER, UNI and INE.

At present it is anticipated that through the coming two to four years approximately ten additional staff members (three from INETER, three from UNI and four from INE) will be frequent users of the modelling system given they will receive the necessary training.

From INETER Ing. Augustin Centeno Garcia, Ing. Ramon Davila Lopez and technical ass. Winkler Fonseca Trejos all staff members of the hydrological section of DRH will be involved in operating the software.

From UNI the new counterpart staff will be employees from PIDMA and from the Hydraulic department under the Engineering Faculty.

INE is presently in the process of entering into the project. Four staff members, some already familiar with the HBV module of MIKE 11, are expected to be involved in the project but it is evident that the lack of trained counterparts must be compensated by a substantial input from the already trained counterparts and the Consultants. UNI has indicated that they are prepared to support this training of INE staff.

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. Three systems have been installed at INETER and one at UNI.

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 are having 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. During the visit in May the HIS module for Windows will bee installed. WordPerfect

6.0, Quadro Pro 4.0, Lahey F77 Fortran compiler and ArcSolo tape backup system have been supplied and installed.

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 UNI two additional MIKE 11 installations have been made after a request. Both at PIDMA. These additional software installations have been made on computers provided by the receiving institution and are made available for the user for the duration of the ongoing project.

A request for 3 installations at INE have been made during the visit of the Consultant in January. These installations will be made on computers provided by INE and will be forwarded immediately after the agreement over INE's involvement in the project has been concluded.

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 Escondido case study.

The Rio Escondida basin is situated in the southeastern part of Nicaragua and consists of the four main rivers Rio Siquia, Rio Mico, Rio Rama and most downstream Rio Secondido. The river system drains approximately 11,560 KM2 with a highest altitude of 800 m.a.s.l. The annual precipitation varies between 4,000 mm near the coast to 2,500 mm in the mountain areas.

Farming, mining and forestry are important activities in the basin. Downstream of Rama, fishery becomes important as well as navigation.

Extreme flooding have been observed in Rio Escondido downstream of the inflow of Rio Rama often generated by a combination of high sea level and extreme precipitation events.

In connection with two to three hydro-electrical projects in the Escondido basin planned to start operating in the beginning of next decade, INE will execute several studies during the coming five years.

In summary the selection of the Rio Escondido basin as a case study area was based upon the possibilities to undertake the following applications:

- To develop a flood forecast and warning system enabling the authorities to warn people being effected by the inundation and to protect properties by advance emergency operations.

- To prepare flood hazards maps for the Rama area and investigate flood control possibilities.

- To study the effect of river dredging downstream Rama with respect to hydraulic capacity, erosion and sedimentation and the interaction with flood control measures.

Following the two training courses in Denmark a HBV/HD model covering Escondido basin upstream Rama has been established.

To calibrate the HBV model the basin was divided into 7 subcatchment out of which four were calibrated using measured catchment runoff. Two catchments using data from a period of 10 years, two catchments where the data coverage was limited to one and two years. Three catchment has not been calibrated due to no hydrometrical data. These catchments have been represented using parameters from neighbouring catchments.

It is obvious that the quality of the calibration has suffered from limited amount of available data, but also the quality of available data was found to be inadequate. Homogeneity tests revealed inconsistencies and a comprehensive evaluation of the data basis has to be carried out in the very near future.

The HD model established during the first training course included 166 km of the Rio Siquia with only three cross-sections available, 179 km of the Rio Mico described by only four sections and 129 km of Rio Rama where ten cross-sections were available mainly in the lower part.

Despite the ambition to add new topographical data during the second training course it came out to be impossible.

The HD model has been calibrated using available observed water level and discharge data from only three gauging stations. During a period of two years (1983 and 1984) data from all boundary and calibration points are available, which has been used for the calibration.

Considering the limited amount and quality of available topographical and hydrometeorological data the HD calibration must be considered to be relative good. But even that the HD model is able to reproduce the conditions at the gauging stations, the needs of additional topographical information must be stressed.

The entire model setup was transferred into FF mode and forecasts on experimental basis have been tested. The conclusion after these simulations stresses the necessity to improve the data quality and quantity.

Additional information regarding available data and the quality of these, model setup's and calibration and recommendations can be found in the training reports prepared by the Counterparts.

3. PROJECT TARGETS

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

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

Through discussions with the institutions and counterparts involved in the project in Nicaragua 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

INETER:

- o Exchange of data, results and experiences between counterparts from the first and second overseas training courses.
- o Update time series data bases in MIKE 11 when rehabilitated stations starts to report.
- o Evaluate/improve data collection procedures and data quality assurance.
- o Review existing hydrometeorological data to reduce sources of errors in the calibration process.
- o Survey of new river cross-sections in the upstream branches and flood plains downstream Rama.
- o Process available hourly precipitation and water level data from 1983/84
- o Examine correlation between hourly and daily precipitation data.

- Recalibrate the HBV and HD model following the review of all hydrometeorological data and rating curves.

- Run and calibrate the HBV and the HD model based upon hourly data.

- Application simulations (Flood forecast simulations, Flood hazard simulations, flood control simulations)

- Assess possible improvements in flood warnings procedures combining the calibrated models with a telemetric system. This includes the development and design of a telemetric network.

- Training of three additional staff members from INETER.

- To participate in a Regional Training Course.

UNI:

- General introduction of the modelling software and training of additional professionals from UNI and INE.

- Prepare and carry our courses for persons from other organisations than INETER and UNI.

- Apply MIKE 11 as a general tool in research and thesis work at PIDMA.

- Preparation of course material and computer exercises for UNI.

INE:

- Participate in training sessions being arranged and initiate model setup for Rio Viejo.

4. PROJECT ACTIVITIES

4.1 The Rio Escondido case study

4.1.1 Updating of the MIKE 11 data bases.

As it is the intension to keep the MIKE 11 data bases "up to date" , 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.

When the two renovated gauging stations mentioned in chapter 2.1 starts reporting these data must be entered into the MIKE 11 data base together with precipitation data from the catchments.

4.1.2 Data Processing.

Quality:
At present all field data collected by INETER are stored in an internal data base system WITHOUT undertaking any kind of data quality assurance checking. Such procedures should immediately be established. If necessary in cooperation with the Consultant.

Rating curves used in the calibration must be revised, and in cases where they are based on data outside the calibration period they shall be reestablished.

Cross-sections:
It is expected that funds necessary to launch a survey program during the dry season of 1995 (before June) is available. This program shall include river sections upstream Rama and flood plain sections of the flood prone areas downstream of Rama.

Hourly data:
Precipitation data from 6 and water level records from 5 stations are available but only as hard copies. These data should be processed ie digitized and entered into the MIKE 11 time series data base.

Based on processed hourly and daily precipitation data an exercise correlating daily data in space followed by a correlation of hourly and daily records in time and space must be undertaken. This exercise will be done in close collaboration with the Consultant.

4.1.3 Final model calibration

Following the completion of the above outlined data checking both the HBV and afterwards the HD model must be recalibrated. This recalibration will be based upon daily data and shall include:

Calibration of the HBV model over a period of say 5 years (if possible) evaluating yearly water balance, peak runoff including max values and recession and dry season flows.

Calibrate the HD model over a period say one to two years focusing on the capability to represent min, mean and max flow situations.

To be able to reproduce flash flood events in the upstream branches often with a duration of 6 to 12 hours, it is necessary also to calibrate the model using time series of hourly observations as boundaries in the upper branches and catchments. This calibration will be evaluated on its capability to reproduce the peak water levels of the individual events (floods). Both rainfall-runoff (HBV) and river routing simulations must 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 Escondido model will be carried out by the counterpart staff in Nicaragua. Calibration based on mean daily data is expected to be finalised in July and the final calibration around December 1995.

Backup from the Consultant will be given to the extend possible and the results will be discussed and evaluated during the visit in May and August according to the enclosed schedule.

4.1.4 Application of the Escondido model

In the light of the intensive data checking and calibration work still pending it is uncertain when the application simulations in this catchment will be initiated, but the following have been initially discussed:

- Flood Hazard Simulations with the aim to prepare inundations maps of the Escondido flood-plains downstream Rama.
- Flood control simulations to evaluate the effect and consequences of proposed flood control measures to protect against or to minimize the damages from flooding.

Such simulations are can be carried out applying the model calibrated on daily data.

Scenarios to be simulated and methods to present the results will be discussed in May/August.

4.2 Training

4.2.1 Local training course

Training of additional counterparts at INETER will be initiated in March and be executed as a combination of minor introduction lectures and on the job training. Training of additional counterpart staff from participating institutions and interested end-user organizations will also be arranged.

UNI/PIDMA:
After a 1 to 1½ months planning and "technology familiarising" period PIDMA will launch an internal training program with a duration of approximately three months with the purpose of training university teachers and research staff. During this period setup of cases outside the Rio Escondido basin will be initiated.

After this internal training UNI is expected to be in a position to offer courses for people from other organisations, potential end-users, students.

It must be stressed that PIDMA and INETER makes every effort to involve INE in their internal training programme.

The possibility of a national training course say of two to four weeks with half day classes has been discussed and should be considered among the involved institutions. The purpose of such a course would be to **introduce** additional counterpart staffs to the modelling system and to provide these staff members the necessary knowledge to operate the system. Such a course could be arranged at PIDMA. Principal instructors should be the four trained counterparts. DHI would supply the necessary number of software installations, manuals and computer exercises 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 UNI

As a support to the integration of the modelling technology at UNI 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 The Rio Viejo Basin

Rio Viejo is situated in an area with a dense population. It drains into the Managua Lake and has a lengths of approximately 170 km.

Two hydropower plants each with a capacity of 50 MW was constructed in 1965 and in 1972 respectively. Surface water is also needed in connection with irrigation schemes important for the agricultural areas. INE is in the process of finalising a feasibility study of a sub catchment 2.5 km upstream of the confluence of Rio Viejo and Rio Trinidad.

It is the intension to setup HBV and HD model of the entire Rio Viejo and apply this model as a general planning tool for the overall utilisation of the surface water.

5.1 Activity schedule and staff input (Nicaragua)