Final Report to CIDA

Snow and Ice Hydrology (Pakistan)

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Acronyms

ADB	Asian Development Bank
BCHIL	British Columbia Hydro International Limited
CIDA	Canadian International Development Agency
DCP	Data Collection Platform
DFG	Deutsche Forschungsgemeinschaft
FFC	Federal Flood Commission
FPSP	Flood Protection Sector Project
GTZ	Deutsche Gesellschaft füer Technische
H&RD	Hydrology and Research Directorate
IDRC	International Development Research Centre
IRSA	Indus River System Authority
LFA	Logical Framework Analysis
MAF	Million Acre-Feet
MASc	Masters of Applied Sciences Degree (in Engineering)
MCC	Meteor Communications Corporation
MEng	Masters of Engineering Degree
NDP	National Drainage Program
NPCC	National Power Control Centre (WAPDA)
PMD	Pakistan Meteorological Department
SIHP-II	Snow and Ice Hydrology Project — Phase II
SSARR	Streamflow Synthesis and Reservoir Regulation
SUPARCO	Space and Upper Atmosphere Research Organization
SWE	Snow–Water Equivalent
SWH	Surface Water Hydrology Office
TOEFL	Test of English as a Foreign Language
UBC	University of British Columbia
UIB	Upper Indus Basin
USAID	United States Agency for International Development
VCC	Vancouver Community College
VHF	Very High Frequency
WAPDA	Water and Power Development Authority of Pakistan
WBS	Work Breakdown Structure
WMO	World Meteorological Organization

Section 1: Introduction

Purpose

This report outlines the status of the Snow and Ice Hydrology Project - Phase II (SIHP-II) at completion.

Background

This project was funded by the Canadian International Development Agency (CIDA) and implemented by the International Development Research Centre (IDRC). IDRC's main contractor was British Columbia Hydro International Limited (BCHIL), which conducted the main activities of project management, technical assistance, procurement, and training. A Training Advisor assisted BCHIL with the implementation of the Training Plan. Specialist consultants were employed as required for various activities such as training and evaluation.

The project was activated on 3 January 1991 with the signature of a contribution agreement between CIDA and IDRC, which became effective on 1 October 1990. IDRC then signed a commercial contract with BCHIL and a Memorandum of Grant Conditions with the project beneficiary, the Water and Power Development Authority of Pakistan (WAPDA). The cost of a preparatory field mission by BCHIL and IDRC in October 1990 was covered by the commercial contract, but no work was effectively carried out by BCHIL until after 18 February 1991.

During 1994, an 18-month time extension was approved by CIDA (12 months for the project itself and 6 months for final evaluation and other administrative wrap-up procedures in Canada). In December 1996, at WAPDA's request, a second extension (time only) was approved by IDRC and CIDA. The project completion date was therefore 30 June 1997.

Scope

Section 2 presents the background to the project. Section 3 outlines results through analysis of project objectives and the logical framework analysis (LFA). Section 4 discusses efforts made to maximize the benefits from the project. Section 5 reviews problems that were encountered during the project. Section 6 reviews the project schedule. Section 7 presents budget highlights at completion. Section 8 documents lessons learned and recommendations that will help during the implementation of future projects. Finally, Section 9 presents the conclusion. The six appendices present additional details about the project.

Section 2: Background

Among the large nations of the world, Pakistan is one of the most dependent on a single river system. The water from the Indus River and its tributaries provides the bulk of the agricultural water supply for 140 million people. Forty-five percent of the electrical energy of Pakistan is produced by hydroelectric dams on the main stem and tributaries of the Indus River.

This river, with an 860 000 km^2 drainage basin and 2880 km length, is one of the largest rivers in South Asia (see Appendix C). The river and many of its tributaries originate in the Karakoram and Hindu Kush regions on the north and northeastern borders of Pakistan and descend south toward the Arabian Sea. An average annual volume of 38.7×10^9 m^3 (31.37 million acre-feet, MAF) is discharged past the Tarbela dam.

The climate of the Indus Basin varies from subtropical arid and semi-arid in the southern and central lowlands of Punjab and Sind provinces to temperate sub-humid/humid and alpine in the mountainous highlands of the north. Annual precipitation ranges from between 100 and 500 mm in the lowlands to a maximum of 2000 mm (water equivalent) on some mountain slopes. Condensation of the warm air occurs at high altitudes (above 3000 m) where temperatures are colder. The active hydrologic zone lies between elevations of 2500 m and 5500 m, and snowfall in the mountains accounts for a large proportion of the total runoff into the river.

The two major storage dams on the Indus River system, Tarbela on the main stem of the Indus and Mangla on the tributary Jhelum River, have a combined storage capacity of less than 16% of the total annual flow. A third dam, Chasma, provides nominal storage, and is intended for flow regulation. There are long-term plans to build additional storage dams on the Indus to capture more water for irrigation and flood control and to improve regulation for power generation.

It is estimated that 80% of the inflow to the Tarbela reservoir originates from snow and glacial melt; whereas, between 40% and 70% of the inflow to the Mangla reservoir is from snow melt. Snow accumulates between elevations of 2500 m and 5500 m, and the zone of maximum snow accumulation is at approximately 5000 to 5500 m. However, prior to this project, almost no useful data from high elevations (above 3000 m) were being used to help estimate the inflows to these two reservoirs and thus ensure optimum water usage.

The Indus River and its tributaries provide nearly 90% of the water used for irrigation. Most of the remainder is groundwater that is recharged by various basin streams. The Indus is also the main source of domestic and industrial water both at the city and village levels. It is estimated that at least 80% of all water consumption comes from streams, canals, reservoirs, and wells recharged by the river or its tributaries. As the population increases, there are increasing demands for water for irrigation, domestic, and industrial use. Massive urbanization in recent years has also increased pressure to enhance both energy production and water availability for urban areas.

Agriculture on irrigated land accounts for 85% of cereal-grain production (mainly rice and wheat), all sugar production, and most of the cotton production. Most of these products are used both for internal consumption and for export. Rice, cotton, sugar, and wheat exports provide the bulk of the foreign-exchange revenues of the country.

The complexity and extent of the irrigation network in Pakistan, the largest contiguous system in the world, requires an efficient management system based on accurate forecasting of water availability as far in advance as possible.

In addition to irrigation and domestic and industrial water supply, the Indus waters are used for hydroelectric power generation. Because by law, water supply for irrigation for food production is the first priority, water is often released in excess of turbine capacity. This means that the opportunity is lost to generate valuable energy for the country, which lowers the overall utilization ratio of the electric turbines.

At present, estimates of inflows to the major reservoirs are based on statistical analyzes of historical data. These estimates are used in conjunction with the indents (irrigation demands of the water districts) and existing reservoir levels to determine the releases from Tarbela and Mangla reservoirs.

A major operating problem is uncertainty about the estimates of short-term and seasonal inflows. Because of insufficient data, releases from the reservoirs are often delayed until inflows have increased sufficiently to raise reservoir levels. Because of this delay in increasing outflows, valuable water is later spilled. This uncertainty in the inflow estimates can be reduced by improved data gathering and improved prediction models, along with improvements in the short-term weather forecasts that are required in part by the short-term prediction models. The uncertainty in the inflow estimates must be considered in the optimization of water-use strategies.

Forecasts of snowmelt runoff and the resulting river flow can be used in various scenarios that are linked to key water-management decisions and allow water use at Mangla and Tarbela dams to be optimized. With the addition of more storage reservoirs on the Indus, flow forecasting for water management will become even more critical.

The project discussed in this report was developed from an earlier research project carried out jointly between staff of WAPDA and Wilfred Laurier University. This project was funded by IDRC and its intent was to increase understanding, particularly by Pakistan, of the snow and glacier melt phenomena that take place in the upper Indus region of Northern Pakistan. It was expected that the output from this project would assist Pakistan to develop an inflow-forecasting system. The results of the research carried out in this earlier project are presented in a report prepared by Dr. K. Hewitt and entitled Snow and Ice Hydrology Project, Final Report 1989 (Canadian Centre) Wilfred Laurier University.

Prior to completion of the above project, a Project Identification Report was prepared in 1988 for CIDA by Nanuk Engineering Limited of Calgary. It recommended a project to establish an operational system for monitoring and forecasting runoff from ice and snowmelt in the Upper

Indus Basin (UIB). This basin is defined as the Indus River above Tarbela, the Jhelum River above Mangla, and the Kabul River above its confluence with the Indus River (see Appendix C). The report proposed a potential monitoring and forecasting system consisting of:

- Up to 30 remote sensors of precipitation (snow and rain), air temperature, snow depth and density, and river discharge to be installed in the snow-accumulation zone (2500–5500 m) in the Himalaya and Karakoram mountains in the UIB.

- Remote telemetry to transmit the data from the remote sensors to a central processing centre near Lahore. These data would be used in conjunction with data from the existing flood-forecasting network.

- Calibration of a hydrologic model (such as the UBC Watershed Model) to predict inflow to Mangla and Tarbela dams.

- Satellite imagery to augment the ground-based network by providing information on the snow-covered area, the area of glaciers, the extent of debris cover on glaciers, and the cloud cover.

The present project was designed to carry out these objectives. However, the satellite imagery was to be used only if a technical review showed that it would provide information useful to the project.

Following subsequent discussions with CIDA, it was agreed that IDRC would act as the Canadian Executing Agency. BCHIL was selected as the Canadian Implementing Agency because of its considerable experience in the operation of remote data-gathering networks in mountainous areas.

Section 3: Results

This section outlines project results first by examining whether the goals and objectives were achieved and second by discussing the results and key assumptions within the context of the Logical Framework Analysis (LFA).

3.1 Goals and Objectives

The goal of this project was to improve living conditions in Pakistan by increasing energy production and farm output through improved water management. The overall objective was to strengthen the water-resources management capability of WAPDA by improving their ability to forecast the flows from the Upper Indus Basin.

All of the systems that were to be installed in Pakistan to meet the overall objective are in place and can be operated (and modified, if required) by WAPDA staff. However, to become fully operational and to provide reliable forecasts, a database is required of 6–8 years of data from the remote stations that were installed as part of the project. This requirement was understood at the outset of the project. Therefore, it will be about 3 more years before the project is fully operational. In addition, the strategies developed for reservoir operation by the project were only intended to be preliminary and should be upgraded.

The achievement of the overall project goal — increased energy production and farm output depends on the development of an operational flow-forecasting system. But, it also depends on a number of other factors, including use by, and collaboration between, water-management agencies in Pakistan. Following the signing of the water-apportionment accord in 1991, which governs the use of water from the Indus River by the provinces in Pakistan, the Indus River System Authority (IRSA) was established to implement the accord. Decision-making on reservoir releases shifted from WAPDA to IRSA. As discussed later in this report, despite efforts, it is unclear whether all IRSA members understand the value of the model.

To meet the overall goal, several specific objectives were set out in the contract between BCHIL and IDRC. All of the objectives given in Section 3.0 of the contract were met.

Objective: "provide a team of scientific and technical personnel from Canada to work with WAPDA in Pakistan on the Project;"

BCHIL provided eight key staff members who worked both in Canada and Pakistan. The expertise of the staff members was augmented by that of staff from a Vancouver-based remote data gathering network installation and maintenance company (Via-Sat); staff from the University of British Columbia; and three Vancouver-based training development companies, Nutec Training, Johnson Management, and Lamoureux and Associates.

Objective: "procure items as agents for and on behalf of the centre in accordance with IDRC's procurement guidelines...;"

One and a half million dollars worth of equipment was purchased for the project in Canada, the United States, and Pakistan. The major purchases were the Meteor Burst signal transmission system (master station and remote terminals); sensors (snowpack, precipitation temperature, and relative humidity, wind speed and direction, and solar radiation); five Toyota vehicles; and computers. Where possible, equipment was purchased in Pakistan either to develop sources for future equipment replacement or to ensure local availability of spare parts.

Objective: "provide technical assistance and training to WAPDA:"

Technical assistance was provided for all phases of the project. BCHIL concentrated their efforts on working with WAPDA staff to accomplish the tasks rather than on carrying out tasks for WAPDA.

Training was provided through three main techniques; on-the-job training, short courses, and university training. Training included:

- system design;
- installation, maintenance, and operation for the master and remote stations;
- equipment repair;
- data handling and quality control;
- hydrologic modelling;
- inflow forecasting; and
- determination of operation strategies.

The university training included fundamentals of hydrology and hydrologic modelling and research into flow routing, effect of snow avalanches on runoff, and optimal reservoir operation. This research was directly applicable to the project goals.

Objective: "provide all resources necessary to ensure effective and efficient project and financial management;"

Initially there were some difficulties with project management — mainly in the area of reporting. These were overcome by adding a Project Management Assistant, which also allowed the Project Manager to make more efficient use of his time in technical areas. A financial accounting system was set up for the project using a commercial software package. The project was audited twice and no significant problems were uncovered.

Objective: "cooperate with and provide assistance to the IDRC-appointed Canadian Project Manager and/or Evaluator;"

BCHIL staff and IDRC staff developed a strong collaborative working relationship that greatly assisted the project in reaching its goals. BCHIL staff provided all requested input to the Midterm and Final Evaluations.

Objective: "participate in the Project Review Committee...;"

BCHIL staff participated actively in all six Project Review Committee meetings and presented, jointly with WAPDA, the Annual Work Plans and Progress Reports.

Objective: "determine the stream flow forecasting needs for the Upper Indus Basin;"

A project report entitled "Project Direction and Review Report" examined the forecasting needs for the Upper Indus Basin and identified approximately 20 million dollars annual net benefits (1992) that could be realized by the provision of seasonal and short-term forecasts using remote data-gathering and hydrologic modelling. This report was reviewed for IDRC by Dr. Geoff Kyte of the Canadian National Hydrology Research Institute, who agreed with its findings.

Objective: "After review of all relevant past work for the Upper Indus Basin, examine known and potential seasonal and short term forecasting systems as a function of WAPDA's operational needs;"

During and subsequent to preparation of the Project Direction and Review Report, key inflow-forecasting system components were examined jointly with WAPDA staff. These included:

- remote-data requirements;
- alternative systems for signal transmission to retrieve data from remote, high-altitude stations;
- data-handling and quality-control procedures and software;
- hydrologic models; and
- forecast systems.

These reviews are summarized in various project reports and memos.

Objective: "select the optimal solution(s) for stream flow forecasting requirements."

The system selected with the input of WAPDA staff included: up to 24 remote stations, accessed by a Meteor Burst communication system; a data-handling and quality-control system based on CLICOM software, developed and supported by the World Meteorological Organization (WMO), with additional project-developed software; the UBC Watershed runoff model and a UBC flow-routing model developed as part of this project; and an inflow-forecasting system developed by project staff in Pakistan and later refined at B.C.Hydro.

Objective: "depending on the results of the above, and as directed by the Centre;"

"Expand the existing hydrometeorological network to the high altitude snow covered and glaciated area;"

Twenty of the twenty-four remote hydrometeorological stations planned during design have been installed at elevations between 2100 and 4800 m and are operating. Four planned stations could not be installed because the landscape was so rugged that siting requirements could not be met. Two additional unplanned stations were installed at lower elevations to provide real-time discharge and weather data for forecast system updating and operation.

"Install, after proper testing, a communications system for rapid and reliable transmission of mountain hydrometeorological data to operational runoff forecasting centre(s);"

The Meteor Burst signal system radio was installed in 1993 and has been operated and maintained since then by WAPDA. Reliability of the signal-transmission system, excluding sensors, has been better than 99.7% when power has been available from the WAPDA transmission grid or the back-up diesel generator. Because diesel fuel is expensive, and data can be stored at the remote site for 2–3 days, the back-up diesel generator is only operated when the power from the transmission grid has been off for a day or more. The system has only operated about 77% of the year. For a discussion of sensor reliability (see Appendix B, WBS 214).

"Upon determination of positive benefits, install equipment necessary for reception and analysis of remotely sensed data for runoff forecasting purposes;"

A review of the benefits of obtaining and using satellite imagery showed that it would be costly to operate and maintain such a system and the associated additional benefits would be doubtful. A decision was made that no further action would be taken on this aspect of the project.

"Establish procedures for the estimation of seasonal runoff due to snowmelt, glacier-ice melt and rainfall;"

The procedures established to estimate runoff are based on the use of the UBC watershed and flow models that used actual data to the date of the forecast and 15 years of historical weather sequences to provide a range of possible future weather and hence inflows.

"Estimate the seasonal and short term runoff volumes arising from snow-melt, ice-melt and rainfall by calibrating and testing computer models of the catchment upstream of the mouth of the Kabul River, the Indus River at Tarbela, and the Jhelum River at Mangla:"

The UBC watershed and flow-routing models have been calibrated for the above basins (divided into appropriate sub-basins). For areas outside of Pakistan in India and Afghanistan, it has been necessary to correlate flows with flows from other basins in Pakistan. A total of 12 sub-basins have been calibrated. Generally, calibrations have ranged from good to excellent.

"Continue some of the applied hydrological research activities initiated within a previous project funded by the Centre, called Snow and Ice (Pakistan), in the area for their integration into the proposed forecasting system;"

Originally, it was proposed to continue some glacier ablation, flow, and sediment measurements carried out in the previous project; however, this was not done because of project work pressures on WAPDA staff combined with the lack of benefits of the work in relation to flow forecasting. In many respects, the whole project was a research project in the fields of high-altitude data gathering and hydrologic modelling of glacier- and avalanche-prone areas. WAPDA staff produced three Master of Applied Science theses and the project has likely produced the largest hydrometeorological database in the world for the highest average elevation (approximately 3500 m), over the largest area (approximately 300 000 km^2), for the longest continuous period (over 6 years at some stations).

"Train WAPDA personnel in all phases of the project so that upon completion they may capably operate, maintain and modify the system, as required, without outside assistance;"

The project evaluation report considers that this objective has been met and the project is sustainable as long as WAPDA provides adequate funding. WAPDA staff were trained in all phases of the project including design.

"Establish strategies for reservoir operation as a function of schemes developed by the hydrologic model;"

WAPDA staff have developed preliminary operating strategies for different sets of constraints.

Objective: "provide all reports as stipulated...."

All reports have been provided as required.

3.2 Logical Framework Analysis

Appendix D shows the Logical Framework Analysis with the column headed "Results" replacing the original column "Means of Verification." Although the results indicate some significant delays and their reasons, all required work was completed.

For the Project Goal (Program Purpose) no "Important Assumptions" were listed. However, there were two inherent assumptions that had to have been made to justify proceeding with the project. These were:

- Pakistan water agencies had the capability to use the forecasts and optimal water-use strategies when they were made available; and

- These agencies would use the forecasts and optimal water-use strategies produced by the project.

For the latter assumption to be valid, the former must be valid. In fact, not all members of the key water-management agency in Pakistan (IRSA) fully understand the nature of the forecasts (the probabilistic aspects), appreciate its benefits, and can apply them in their negotiations with the provinces over irrigation allotments. The flow forecasts produced by the project must be shown to be sufficiently reliable to compel the water-management agencies to incorporate the forecasts with their water-management practices. There will still likely be a need to train the key staff of the various provincial irrigation departments, and possibly WAPDA's power wing, in the best use and limitations of the information to be provided by the outputs of this project. Both these issues affect the project's sustainability because, unless there are knowledgeable users of project outputs, it will difficult to maintain long-term financial support.

All the important assumptions for the Project's Objectives and Outputs proved to be valid except that there was a delay in project approval. This caused significant schedule disruptions. In addition, three important assumptions that were made "subconsciously" but not listed did have significant effects the project. Those were:

- "A radio licence could be obtained for the Meteor Burst system in 1–2 months."

  In fact, it was almost 1 year before the licence request was approved. This delay was mainly caused because the frequencies required were in a band allocated to the military. This had adverse cost, schedule, and data-loss consequences.

- "Data required from other agencies for hydrologic and flow-model calibration would be available."

This assumption was significantly in error. Other agencies (Surface Water Hydrology Directorate of WAPDA and Pakistan Meteorological Department) that were expected to supply data, had large backlogs of unprocessed data (over 10 years in one case). Because the priorities of this project were not necessarily the same as those of the agencies responsible for providing these data, this diverted significant effort of WAPDA staff to process the data for other agencies at the expense of the project. The result was significant delays in hydrologic model calibration.

- "Real-time stream flow (water level) and weather data from key stations required for forecast-model updating would be available"

This assumption was also significantly in error and has ultimately resulted in a delay in implementing real-time tests of the forecast system. Over the life of the project, WAPDA tried several means to obtain data on surface-water hydrology, either in near real-time (radio) or within several days (mail). Neither were successful, either as a result of seasonal factors (radios were only available at some stations during flood season) or the mail was unreliable. To circumvent these problems, additional Meteor Burst remote terminals were supplied so that key stream-flow and weather data could be obtained in real-time. This work was beyond the scope of the project.

Section 4: Maximizing Project Benefits

This section summarizes the activities undertaken by IDRC to ensure that the research results of the project were used and that Pakistan realized the potential project benefits. Over the last 3-years of the project (1995–1997), in addition to its role as implementing agency, IDRC focussed its efforts on ensuring that the potential benefits of the flow-forecasting model would be understood and that the model would be used in Pakistan. This was accomplished by reviewing the project benefits, including benefits that were not envisaged at the start of the project, outlining the obstacles which could prevent achievement of those benefits, and taking the steps necessary to counter those obstacles. The benefits and obstacles are described below. The needs, scope, and partners for a follow-up project are also outlined as are the efforts that have been made to disseminate project findings.

4.1 Benefits

During SIHP-II, a study was made of how the Tarbela and Mangla Reservoirs could have been operated had a deterministic model been available to decision-makers. Generally, for the period studied (1986–1990), the difference between actual and simulated operation was that reservoir outflow increased in the simulation during the low-flow period at the end of winter and the start of the summer, and decreased during the high-flow period during the middle of the summer. All irrigation demands would have been met using this optimal operation — in fact the irrigation deficit of 11 MAF (million acre-feet) that occurred with the actual outflows would have been eliminated. As well, 870 million kWh of additional energy could have been generated annually. The value of this modified operation was conservatively estimated as $21 million annually (1992 Canadian dollars) (Project Direction and Review Report, BCHIL, February 1993). Other benefits, such as increased energy production from planned hydroelectric stations downstream of the Tarbela reservoir and improved flood control, were not quantified.

After the model is calibrated, these economic benefits would allow for the project to pay for itself three times over, in only 1 year. However, IDRC believes that the most important benefit may have been overlooked at project inception. After the model is calibrated, Pakistan will be able to allocate water to different sectors (agriculture, industry, and domestic) at a national level. No other country in the world the size of Pakistan possesses this ability. Pakistan will be able to allocate water at a national level due to three unique factors:

- concentration of water supply (Tarbela, Mangla, and Chasma);
- the largest contiguous distribution system in the world; and
- an accurate reservoir inflow-forecasting system.

Despite the many problems that Pakistan faces in the water sector (e.g., waterlogging and salinisation), this ability to allocate water will enable Pakistan to meet the challenges that are faced by water-scarce countries throughout the world — for example, the diversion of water from agriculture to cities for industrial and domestic use. These decisions will be faced by all industrializing developing countries in the coming century. Massive urbanization in the developing world (and Pakistan's urban growth rates are among the highest in the world), combined with the much higher economic value of water in industry and for domestic use (about 16 times higher than in agriculture), will make such decisions increasingly important.

4.2 Obstacles

However, realization of these potential benefits by Pakistan are threatened by four major factors:

- changes in the water-management regime within Pakistan;
- weak institutional linkages among water-management agencies;
- model-calibration period (and associated loss of project support if it is not perceived as immediately beneficial); and
- poor fiscal situation in Pakistan (loss of project operation and maintenance funds).

At the outset of the project in 1990, WAPDA had responsibility for deciding on releases from the reservoirs. This changed in 1991 when a water-apportionment accord was signed to govern the use of water from the Indus System by all provinces. The Indus River System Authority (IRSA) was established by the government to implement the accord. IRSA, which has one member from each province, and one from the Federal Government, now has final authority for reservoir outflows and directs WAPDA on when to make releases.

The creation of IRSA and the water apportionment accord were very positive developments for Pakistan. In addition to the three unique technical factors described in the previous section, the existence of one national water management decision-making body, informed by other agencies and levels of government, is necessary for effective, national water management.

However, unless IRSA is fully informed, it will not be fully effective. In 1995, most IRSA members were still unaware of the SIHP-II project, which could provide a tool to help them with their work — a reflection of the weak linkages between water-management agencies. In addition, numerical models and their need for calibration and new to IRSA and some other Pakistani water-management agencies.

IDRC felt that the best way to counter these obstacles was to ensure that the project outputs and benefits were disseminated in Pakistan to IRSA and other water-management agencies. In addition, in concert with WAPDA and BCHIL, the scope and partners for a follow-up project were established.

4.3 Dissemination

To ensure that the outputs of the model were understood and used by Pakistani water-management agencies, the following activities were carried out in the last 3 years of the project.

Meeting with IRSA (October, 1995)
IDRC and WAPDA met with the General Manager and some of the permanent members of IRSA to introduce SIHP-II and to discuss the need for, and scope of, a follow-up project. IRSA members were invited on a project field trip to see first-hand what the project could do. (IRSA members were ultimately unable to attend the field trip).

Seminar on project outputs (September 1996)
This seminar was designed to disseminate project results within WAPDA (outside of the Hydrology and Research Directorate). Participants included representatives of the Power Wing, which will be the chief beneficiaries of the project, and the Chief Engineers for both the Tarbela and Mangla reservoirs. IDRC and BCHIL representatives also attended the seminar.

Seminar on project outputs (February 1997)
This seminar was used to disseminate project results among water-management agencies in Pakistan. Participants included representatives from the IRSA, Pakistan Planning Commission, Ministry of Water and Power, Federal Flood Commission, Provincial Irrigation Departments, and Pakistan Meteorological stations. Representatives from CIDA, IDRC, and WAPDA also attended.

Meeting with IRSA (February 1997)
To further emphasize the importance of the model as a tool for IRSA, IDRC and WAPDA again met with the IRSA Chairman and several provincial members.

Although most Pakistani agencies now understand the benefits of SIHP-II, it is unclear whether all IRSA members do. At least one IRSA member questioned whether the sophisticated flow-forecasting system, which measures many physical variables to define the complex snow and ice melt and runoff relationship, was superior to simply measuring alpine temperatures, to estimate snow and ice volumes.

Another IRSA member suggested that the system was flawed because satellites were not used for data transmission. Satellite transmission was rejected early on in the project because it demonstrated no advantage over the meteor-burst system, and the reception fees were considered an unnecessary burden for Pakistan. In fact, the meteor burst transmission system is working exceptionally well, is used on other projects in Pakistan, and is an effective, integrated part of the flow forecasting system.

4.4 Follow-up Project

Beginning in 1995, IDRC held a series of meetings with various officials within WAPDA, the Pakistan Planning Commission, the Pakistan Meteorological Department, the Federal Flood Commission, and the Indus River System Authority to discuss the need for, and scope, of a follow-up project.

On the basis of these discussions, and the obstacles to project benefits listed above, it was felt that a follow-up project was needed first and foremost to:

- strengthen linkages between water-management agencies in Pakistan; and
- ensure that the project was financially supported during the crucial period of model calibration.

The proposed follow-up project is described in "Water Optimization in Pakistan, IDRC-WAPDA-BCHIL Project Concept Paper," Draft 21, March 1996.

Overall, the goals of the follow-up project are to strengthen capabilities in water-resources management in Pakistan by reinforcing institutional linkages and human-resource development, continuing to improve flow forecasting, and enhancing planning and operating methodologies.

The expected outputs from this follow-up project would include:

- clarification of key points in decision-making about water management;
- strengthened links between water-management agencies;
- clear lines of communications between official agencies, as well as between those agencies and water users;
- recommendations to assist with the application of existing water polices, or if relevant, to change existing policies;
- a fully calibrated and enhanced steam-flow forecasting system for the Upper Indus Basin;
- recommendations for water optimization; and
- clearly defined operating strategies for existing Upper Indus reservoirs (including conjunctive management) that meet the needs of competing stakeholders.

While preparing the concept paper, IDRC looked at what other donors were doing in Pakistan, to build on complementary projects.

During the implementation of SIHP-II, several related externally funded projects began:

- The National Power Plan Project, funded by CIDA, which included a review of water availability as it relates to future power needs.
- The Culture Area Karakoram Project, funded by Deutsche Forschungsgemeinschaft (DFG) for 6 years starting in 1989, which collected extensive local meteorological data in the Karakoram mountains.

- The Mini Hydro Power Assessment, funded by Deutsche Gesellschaft füer Technische (GTZ), which collected flow and weather data in many UIB sub-basins to assess the potential for mini hydroelectric stations in the Northwest Frontier Province and the Northern Areas.
- The National Drainage Program, funded by the Asian Development Bank (ADB) and the World Bank, which is aimed at improving drainage in the country, with an emphasis on beneficiary (farmer) participation.
- The National Irrigation Project, which proposes decentralizing irrigation management through autonomous water boards and local water-users associations.
- The ADB-funded Flood Sector Improvement Project (FSIP), which is to establish an Indus flood-forecasting system through the development of models of rainfall, runoff, and river-flows and a decision-support system for reservoir operations.

Upon review of these projects, it was clear that the ADB projects were closely-related to SIHP-II. At CIDA's request, IDRC tried to develop a multi-donor coalition, composed of CIDA, the ADB, and IDRC, to fund the follow-up project.

The two current ADB-supported projects in Pakistan include:
- National Drainage Program (NDP) (Jointly supported with World Bank); and
- Flood Protection Sector Project (FPSP-II).

Like the proposed Water Optimization in Pakistan project, the overall goal of both of these projects is improved water management in Pakistan. Key complementarities between these projects and the proposed follow-up project to SIHP-II include:

Water-Management Policy

A specific goal of the NDP program is an improved water-management policy in Pakistan. The inflow-forecasting model developed under SIHP-II is a powerful tool that can be used to conduct simulation and dynamic programming analyses that can optimize benefits to the national economy as a whole. In fact, these analyses were conducted during the last months of the project and would continue during the follow-up project.

Flood Forecasting

The flood-forecasting model being developed under the FPSP can build on and use the information available through the SIHP-II project. Moreover, with the addition of a few additional DCPs and minor modification to the model timestep, the UBC model could also be used as a point of comparison to the models developed under the FPSP for the catchment area upstream of Mangla and Tarbela.

Successful and Consistent Technology Transfer

The Meteor Burst Communication technology first introduced to WAPDA for the SIHP-II project has been well-received and is being installed on the remote stations for flood forecasting under the FPSP and for the flow-gauging and telemetry system under the NDP.

Same Players

Whether at a managerial level or an operational level, CIDA, IDRC, and the ADB are working with the same individuals within WAPDA, the FFC, IRSA, PMD, and the Ministry Water and Power. For example, the same team within the Hydrology and Research Directorate trained by SIHP-II to install, adapt, and maintain the system will benefit from increased responsibility under the two ADB-financed projects.

Similar Challenges and Recommendations

Because each project has the same overall goal of improved water management, similar, if not identical challenges are faced by the donor agencies, foreign consultants, and Pakistani team-members of the various projects. For example, institutional strengthening has been recommended by SIHP-II, NDP, and FPSP. Also, the flow-routing and flood-forecasting models developed under the FPSP require the same need for calibration as the UBC Watershed Model — and the same expectation of instant and accurate results.

Through coordination, and combined funding of a follow-up project, the donor agencies can share information and strategies to synergize efforts. The collective weight of the common recommendations of several donors will carry more weight and bear more fruit within Pakistan.

As a result of several meetings between the IDRC and the ADB, and the complementaries in the projects, the ADB agreed to encompass all aspects of the IDRC–WAPDA follow-up project, in a one form or another, into the ADB-funded FPSP-II. This decision was contingent on CIDA contributing funds to that aspect of the project. IDRC also committed to providing funds to the project. Ultimately, however, because of budget constraints and due to lack of an official request from the Government of Pakistan (GOP), CIDA decided not to contribute funds to the multi-donor initiative. Due to CIDA's decision, and because it also did not receive an official GOP request, the ADB also decided not to fund the follow-up project, although IDRC was still willing to contribute to a bi-donor initiative.

Because development funds are limited, multi-lateral and bilateral donor agencies depend upon the recipient government to help them prioritize aid requests. (This is not the case for IDRC, which responds directly to requests from research institutions and NGOs, generally bypassing the government). For the ADB, official government requests are essential because they represent a government commitment to loan repayment. For CIDA, government requests are important for projects with government agency involvement, although CIDA also directly funds NGOs.

The lack of an official GOP request is significant, and emphasizes the challenge that WAPDA, other Pakistani water management agencies, and external donors face. Representatives of the Federal Finance Ministry make official requests on behalf of the GOP. They, and the political leadership must be convinced by the internal agency promoting the project, in this case WAPDA, of its validity. But WAPDA has lost much political power recently, has experienced severe budget cuts, and has had some of its duties transferred to other agencies. (For instance, reservoir release authority shifted from WAPDA to IRSA). And as noted, some members of IRSA are unconvinced of the benefits of the inflow-forecasting model. Given the political and fiscal turmoil WAPDA faces, it is not surprising that it was unable to convince the GOP to make an official request. And as ADB and CIDA noted, the GOP, like some other developing countries, still places the highest priority on infrastructure projects. It will be absolutely essential for those within Pakistan who recognize the potential of the inflow-forecasting model to continue to promote it strongly internally, to ensure the model is calibrated, and that it is ultimately used.

The challenge for external donor agencies is to propose funding a project, as they sometimes do, which the recipient government has not itself requested, because the donor sees the value in doing so. This is particularly true for computer model projects, which are new to many developing nations. Unlike infrastructure projects, or even some social sector projects, the benefits of the development of a computer model are not evident, until it is complete. Only when the model will be fully calibrated, will its benefits be realized, and will it gain recognition of its importance and corresponding financial support. Ironically, the financial support is more crucial now than it will be later.

Section 5: Snow-Pillow Interface Problem

Throughout the project, there was a problem interfacing the data from the snow-pillow shaft encoder to the Meteor Burst datalogger/transmitter. This caused the snow-pillow data that were transmitted from the remote sites to inexplicably "jump" and to produce cumulative readings that made no sense. Attempts were made to study the problem by using a "remote" station that was set up at the electronic office to analyze equipment problems, particularly the snow-pillow problem. Although some of these "jumps" occurred at the Lahore station, their cause could not be determined. In 1994, all of the interface units were modified. More resistors were added to limit the currents that were causing key components of the interface to burn out. Initially, these modifications appeared to be successful, but most of the interface units failed again in 1994–1995.

In late 1996, Meteor Communications supplied an "up-down" counter from Campbell Scientific Ltd. to replace the interface supplied by MCC. There was some question as to whether this worked, and in June 1997, a provisional decision was made to attach a precision potentiometer to the shaft encoder to provide the water-level output. Although this solution was only tested at one remote station (Shogran) for the 1996–1997 winter, it was tested previously at two stream-gauge sites (Murala and Kohala) for two summers during tests of the Meteor Burst System carried out by WAPDA for the Federal Flood Commission. As a result of the success of these tests, MCC offered to supply (at no charge to the project) the potentiometers and related spare parts (gears) that were needed to convert the shaft encoders from a digital output to an analog. These modifications will be made by WAPDA staff, who developed this potential solution.

In August 1997, WAPDA submitted data from the Shogran site for review by BCHIL before making the modifications. This evaluation was complicated by other factors such as ice bridging and a possible rupture of the snow pillow. As a result of this review, BCHIL requested additional data, in particular an examination of the snow pillow, to check if it may have been damaged and therefore lost fluid. This information was needed to try to explain some unusually rapid decreases in the snow-water equivalent indicated by the snow-pillow sensor. To date (November 1997) WAPDA has not responded to this request. It is believed that the modification of the shaft encoders to a potentiometer will solve the problem, but this cannot yet be confirmed.

Snow-pillow data are not directly used by the UBC watershed model for flow forecasting. Therefore, this problem has not delayed implementation of the forecast system (it uses precipitation and temperature data to estimate snow volumes). However, during the snow-accumulation phase, data from the snow pillow serve to check the performance of both the precipitation gauge (which is highly correlated to the snow pillow) and the estimates of snow made by the model. These snow-pillow data can be reconstructed based on correlations with precipitation-gauge readings after 2–3 years of reliable snow-pillow data have been obtained. During the snow-depletion phase, the snow pillow provides valuable data on the state of the snow pack and a further check on the performance of the hydrologic model.

However, there is a strong perception in Pakistan that the collection of snow-pack data is one of the main purposes of the project and, prior to model calibration, the snow-pack data are valuable. These data (where available) are currently being used to provide information regarding early Spring flows, which are critical for the Kharif crop. Timely presentation of this information is important to the project's reputation in Pakistan.

The project made every attempt to use tested and proven equipment to avoid the added difficulties (to an already challenging project) of trying to solve the inevitable problems associated with equipment development. However, just because each component is tested and proven does not mean that all the components will work together as a system. This was the case with the shaft encoder for the snow pillow and the Meteor Burst remote terminal. Although the interface was included in the bench-testing of the equipment, there was no indication of the problems that later occurred. This suggests that not only must the individual system components be tested and proven, but they must have a history of working together. In the present case, this might have resulted in either specifying a different type of shaft encoder (potentiometer type) or using a pressure cell.

After WAPDA is able to examine the snow pillow in the field (summer of 1998), further attempts will be made to solve the problem.

Section 6: Schedule

Although all the proposed work was accomplished by the time the project was completed, several factors resulted in delays to the work and resulted in schedule revisions. The key factors and their effects on the schedule are described below. Detailed discussion of the schedule for each year is given in the annual progress reports of the project.

6.1 Delayed Project Approval

Project approval was originally expected to be given in late 1990. Instead, it was not received until late February 1991 (and back-dated to include an inception mission in October 1990). This resulted in a very compressed 1991 construction and work schedule. Had the delay been any longer, the test installations made in 1991 would have been delayed 1 year.

6.2 Delayed Approval in Pakistan of the Required Radio License

This delayed purchase of the Meteor Burst equipment and its installation in the field by 1 year. This not only reduced the length of the database by 1 year for some stations but also reduced the time available to deal with a problem that arose between the signal from the shaft encoder used with the snow pillows and its interface to the Meteor Burst datalogger/transmitter. Finally, the delay added about 10% to the cost of the Meteor Burst equipment because the Canadian dollar dropped about 10% in value against the US dollar prior to purchase.

6.3 Sectarian Violence in Northern Pakistan in 1992 and 1993

This resulted in last minute revisions to reconnaissance and construction work and delayed some planned reconnaissance from 1992 to 1993. As a result, WAPDA staff had to make significant extra efforts to complete construction of the number of scheduled sites in these years.

6.4 Problems in Identifying and Approving Students for University Training in Canada

The three major problems that occurred were: the failure of one proposed student to pass the TOEFL test of English language proficiency with the required marks; the falsification of his marks by a second student; and delays in identifying students (often related to government rules to ensure equality of opportunity from all sources). These occurrences led to delays of 1 year for each of the first two students and 2 years for the third student in commencing their studies in Canada. These delays translated into delays in hydrologic model calibrations (particularly for avalanche-prone sub-basins) and delays in developing preliminary optimal operating strategies. Both these tasks were completed by project end.

6.5 Provision of a Training Supplement for the Project

This allowed the project schedule to be extended 1 year, which helped overcome some of the effects of the delays in students commencing their university studies. More importantly, it allowed for an additional year of site presence by a BCHIL Modelling Specialist. This presence was of significant benefit to the training of WAPDA staff.

6.6 Snow-Pillow Interface Problem

As noted in Section 5, there is a problem in interfacing the data from the snow-pillow shaft encoder to the Meteor Burst datalogger/transmitter. This problem was partially solved in 1995, and snow accumulation and depletion data were obtained from some stations. The problem was not fully resolved at project completion because WAPDA were questioning the readings from a test site and further review was required. Although this did not directly delay project work, it did result in the loss of up to 4 years of snow-pillow data at some stations. A failure to solve this problem before the end of 1996 was one of the reasons the project was extended into the first 6 months of 1997.

6.7 Difficulty in Obtaining Data from Other Sources in Pakistan

In designing the project it was expected that any stream-flow and low-elevation data required by the project would be available, and, if required, could be made available in real-time. This assumption was incorrect. This meant that WAPDA staff had to spend a great deal of unplanned effort in assisting other agencies to update stream-gauge rating curves and/or quality-control data. Furthermore, the lack of some real-time flow data required to update the hydrologic model meant that the project had to purchase, and that WAPDA staff had to install, additional remote transmitters at key stream-gauge sites. WAPDA staff also had to develop a "punch-in device" so that gauge readers could enter data into the system. Some spare hydrometeorological sensors were also installed at these stations to provide required real-time data. In addition to the requirement for extra funds for equipment, these data problems diverted effort from hydrologic model calibration and delayed WAPDA staff almost 1 year in their practising of inflow forecasting under real-time (as opposed to simulated) conditions.

6.8 Delays Due to Weather

Delays in completing project work as a result of storms are always a potential problem for a remote data-gathering system. The only significant delay was in the installation of a station at Arundu (later moved to Dassu) due to road washouts in 2 successive years. Although other weather-related delays did occur, they were not significant. The consequence of this delay was a loss of 2 years of data at this location.

Section 7: Budget and Final Costs

Budget details are reported in each of the Annual Reports of the project. The final project budget and costs will be detailed in the final IDRC financial report to CIDA, which will be produced after all final costs are accounted, including production of this final report. The project will be slightly (about $40,000 depending on final costs) under budget. Internally, some reallocation of the budget between IDRC and BCHIL was necessary. This included the $23,000 approved for BCHIL in 1997 to cover additional equipment, a final mission to Pakistan, and miscellaneous cleanup. The funds were approved using part of the GST refund that IDRC held as a small contingency fund. It is notable that the 15% project contingency that CIDA set aside at the beginning of the project, because of the uncertainty of building an operational flow-forecasting system in the most difficult and highest terrain in the world, remains untouched.

The most important cost differences within individual budget line, items are give below:

Salaries
Approximately $137,000 of the $354,000 increase from the original budget is related to the additional time spent by the Site Manager in Pakistan and additional training in Canada and Pakistan that were part of the training supplement. Another $130,000 is related to fees for training consultants, additional training in Meteor Burst equipment repair, and a final mission to Pakistan to install an updated inflow-forecasting system. These were not included in the original budget. The remainder can be attributed to the underestimation of administrative costs — particularly financial.

Equipment
The major portion of the $238,000 cost increase over the initial budget resulted from higher than budgeted costs for the Meteor Burst equipment combined with an adverse change in the Canada–US dollar exchange rate and inflation. There were also additional equipment purchases beyond those provided for in the budget. These were partly offset by savings in vehicle costs and mountain equipment.

Expenses
The major cost reduction of $186,000 in this category was due to the reallocation of approximately $215,000 for field expenses to the equipment category. This reduction was partly offset by additional funds required for accommodations because of the extended presence of the Site Manager and Modelling Specialist (from training supplement) and much higher than expected communications and reproduction expenses.

Travel
The small cost increase here was mainly due to additional, unbudgeted trips and inflation in airfares. This was partially offset by savings in using the Site Manager's house as a guest house.

Training

The additional costs here were the result of the extra training provided by the training supplement. Training costs were high for both BCHIL and IDRC.

Section 8: Discussion and Recommendations

The following section highlights areas where improvements could have been made to the project and discusses successes that could benefit other projects.

8.1 Management

To be successful, given the difficulties faced by the project, this project required good, dedicated personnel from all sides. Not only did all sides supply very capable, dedicated, and hardworking staff who were willing to work hard to overcome the project challenges, but, these staff stayed with the project for its duration. Without this dedication, the project would not have been a success.

A good working relationship was developed at all levels and both Canadians and Pakistanis learned to work with the different management styles of WAPDA and BCHIL. The only management areas where there were problems were the identification of students for training and financial accounting.

As described in WBS 163, Project Administration, there was a definite difference in the management styles of WAPDA and BCHIL. In fact, it was noted by WAPDA staff in the Final Evaluation Report that "the Canadian Model of vocal participation was encouraged without any guidelines as to the limitations of the model." This difference in management styles and productivity between BCHIL and Hydrology and Research Directorate (H&RD) staff needed to be kept in perspective. From a Canadian perspective, productivity of H&RD staff could have been greater and more initiative could have been shown by H&RD staff. However, by WAPDA standards, H&RD staff had to make sacrifices without extra rewards for going to the field. The sacrifices were not required of most other WAPDA personnel. In addition, H&RD staff had to do some of the work of the Surface Water Hydrology Directorate of WAPDA and the Pakistan Meteorological Department, in addition to their own work, to process data required for hydrologic model calibration. By WAPDA standards, they may have been considered much more productive than average. The differences in management styles and productivity should be more clearly recognized in future projects of this type.

In a sense, some of the management problems that arose when WAPDA took over Site Management in the last 2 years can be considered beneficial. During project negotiations in 1988, WAPDA wanted a longer BCHIL site presence. IDRC, fearing that the presence would curb WAPDA initiative, wanted a shorter presence. This is consistent with IDRC's philosophy of helping aid recipients to solve their own problems. In the end, IDRC supported a Site Manager, who was instructed to work with, rather than for, WAPDA, as long as the Site Manager was phased-out before the end of the project. The transition from BCHIL site management to WAPDA site management was challenging and revealed some problems related to the use of monthly status reports as a management tool. Although the problems were not beneficial, it is natural that they occurred, and it was good that they occurred before the end of the project. The 2-year WAPDA self-management period gave BCHIL and IDRC the opportunity to help WAPDA with these problems prior to the end of the project. This assistance included producing status-report templates for WAPDA and making suggestions about human-resource management.

A key element in the success of this project was the informal agreement between BCHIL and WAPDA to maintain continuity of staff on the project. Both sides upheld this agreement. For WAPDA, this meant "bending" many standard procedures regarding personal movement. The result for WAPDA was that it allowed the development of a core of staff familiar with the project. From the BCHIL side, continuity of staffing resulted in a better understanding of WAPDA staff and project needs.

The identification of students for training ran into three problems: identifying potential students; language requirements; and academic requirements. Required academic standards are the easiest to identify. These should be checked early so that those identifying potential students know the requirements that must be met. The students should be identified as soon as possible with a back-up, in case the first choice does not meet the language requirements. In the case of this project, only one student was identified at a time and sometimes well past scheduled times. When one failed the language requirements, this further delayed progress. Finally, everyone needs to be clear on the language requirements. In Pakistan there was confusion between a TOEFL test administered by USAID and the official TOEFL test, which was the only one the university would accept. This also delayed acceptance of students.

There was a continuing problem with approval and payment of expense accounts by WAPDA. The BCHIL bookkeeper noted that in the final evaluation, even drivers and peons were acknowledged but no administrative staff (although the BCHIL bookkeeper took part in the evaluation). It was suggested that had some of the financial administration staff received training and been made to feel part of the WAPDA team then they might have helped, rather than hindered financial approval. On a similar vein, training of some of the secretarial staff, particularly in word processing, would have helped the WAPDA engineers who sometimes had to do typing of correspondence to obtain good copies from the computer printer, rather than from the mechanical typewriters used by the WAPDA secretaries.

The use of the Site Manager's house as a guest house worked well and resulted in significant savings to the project. One of the reasons that worked well was that the missions from Canada were neither too frequent nor too long, thus the visitors were more like guests and not seen as a significant burden.

8.2 Technical Assistance

The direct involvement of WAPDA staff in the review and planning of the project helped give them ownership of the project and also transferred technology. This was all part of the "work with WAPDA" strategy that required continuous involvement by WAPDA as opposed to the often used "work for WAPDA" approach. The former approach, which reflects IDRC's philosophy of project management, is much more effective for technology transfer.

The inclusion of WAPDA staff in the design, in addition to aiding technology transfer, provided valuable input regarding local terrain, customs, and potential problems that would not otherwise have been easily available to the designer.

The selection of the Meteor Burst signal transmission system was clearly the correct decision. The acceptance of this system is demonstrated by its selection for a flood-forecasting system by the Flood Forecasting Centre and for a canal-monitoring system by WAPDA. In addition to cost, and no ongoing requirement for foreign exchange, the advantages of the system include two-way communication and the fact that no other agencies are required to be involved in the data-transfer process.

Selection of remote sites was difficult. Office studies were hampered by poor, and sometimes no mapping. Although there is probably better mapping today than when the project started (e.g., US satellite mapping) in projects such as this, the difficulties of locating potential sites based on mapping cannot be underestimated. The fact that potential sites may not be feasible and alternatives may be required must be considered. Although the "Remote Site Selection" (WBS 221) did have some alternatives, field reconnaissance sometimes showed that even these were not always sufficient.

The project made every attempt to use tested and proven equipment to avoid the added difficulties (to an already challenging project) of trying to solve the inevitable problems associated with equipment development. However, just because each component is tested and proven does not mean that all the components will work together as a system. This was the case with the shaft encoder for the snow pillow and the Meteor Burst remote terminal. Although the interface was included in the bench testing of equipment, there was no indication of the problems that later occurred. This suggests that not only must the individual system components be tested and proven, but they must have a history of working together. In the present case, this might have resulted in either specifying a different type of shaft encoder (potentiometer type) or using a pressure cell.

The data-acquisition interface was hampered by the fact that the CLICOM program, although well supported by WMO, is cumbersome and based on the use of out-of-date software. It likely would have been a better solution to purchase an up-to-date commercial program (CLICOM is free) and provide some additional funds for annual fees and maintenance. This would have resulted in faster progress with the data handling and quality control. Nevertheless, in spite of the problem, CLICOM does do the required job.

The UBC Watershed Model was the best model choice. It has been demonstrated to be very robust, and much better than expected calibrations using low-elevation data have been obtained. Most importantly, because the WAPDA students could obtain their academic training at UBC under the guidance of the model's designer, they were able to obtain a better understanding of the design, strengths, and limitation of the model than they would have with most other models. They were also able to participate in the design of modifications and additions to the model, thus helping to give them a feeling of ownership.

The extent of the problems in obtaining quality-controlled data from other agencies for model calibration and real-time data for model updating for forecasting was not recognized in the design of the project. This resulted in extra work for WAPDA staff and significant delays in model calibration. It also prevented real-time testing of the forecasting procedures. In the design of future similar projects, the status of data quality control by the responsible agencies and the availability of real-time data (and its likely quality) should be examined closely. The project should then include an allowance for appropriate solutions to these problems. In the case of this project, this would have meant including some funds for automating some stream gauges and some low-level meteorological sites as well as allowing time and human resources for the additional data-processing work. The data processing might also have started earlier.

The delay in the approval of the students delayed the development of an operating strategy; however, the approach using dynamic programming appears to be a feasible methodology. Further development beyond the scope of this project (which was only to develop a preliminary strategy) to include probabilistic estimates of inflows into the strategy would be worthwhile.

Although WAPDA now has the capability to produce inflow forecasts on a seasonal and 10-day basis to Mangla and Tarbela reservoirs, the project is not fully operational because:

- at present real-time data from some stream-flow and low-elevation meteorological stations required for hydrologic model updating are not available (see WBS 256 and Section 3.0); and
- there is not a sufficiently long high-elevation database to provide reliable hydrologic model calibrations.

The former problem was not clearly recognized until part way into the project. The latter point was recognized prior to project inception – it was known that there would not be a sufficiently long high-elevation database at the end of the project. When real-time data from the stream gauge sites and low-elevation meteorological stations are available, it will be possible to make forecasts using low-elevation data, but their reliability will not be as good as with the addition of the high-elevation data. Therefore, it is recommended that forecasts based solely on low-elevation data not be used for operational purposes. In the meantime, H&RD staff can continue developing the forecast system, practising forecasting, and developing an optimal water-use strategy. Given the funding problems for projects in Pakistan, particularly when they are not fully operational, it would be worthwhile to provide some form of continued funding and technical assistance until the project is fully operational and can demonstrate its financial benefits.

8.3 Procurement

Surprisingly, there were few problems with procurement. The major problem was the delay caused by the problems in obtaining a radio licence. The radio licence problem occurred because the range of frequencies within which the Meteor Burst system can operate was within a band of frequencies allocated to the military. Possibly several months of the delay might have been avoided if the application for a licence had proceeded immediately after the preliminary selection of the Meteor Burst system in 1991; however, given the length of time for the licencing to take place, and, seasonal construction limitations, the effect on the schedule may not have been any different. Future projects that involve radio technology have the potential for both normal licencing delays and additional delays because the required frequencies may be allocated to the military or other government organizations.

8.4 Training

The provision of the training supplement and resulting additional site presence were valuable additions to the project. IDRC originally was not in favour of even a 2-year site presence because of their fear that it would reduce WAPDA initiative and ownership of the project. The additional site presence worked because of the project philosophy of BCHIL "working with WAPDA"; thus, unless WAPDA took responsibility for their project tasks, there would be no progress. BCHIL was not going to do the work for WAPDA. The "work with" philosophy was a successful approach that should be used in future projects. (In fact, it is the basis of IDRC philosophy but not necessarily the philosophy of international consultants. IDRC projects are typically structured so that Canadian experts work with experts in the host country to solve local problems and to transfer technology.)

Training Plan development was expensive and not as useful as it could have been, particularly the attempts to individualize the training. WAPDA should have been more involved in the assessment of training needs and requirements with BCHIL and that there should have been less involvement of training consultants. While the identification of required training in the Nutec report was not as balanced as it should have been (see WBS 148 and 443), it was a necessary first step. At this point, WAPDA staff could have been identified to receive the training in their area and in turn, identified what training they required. The training to be given, the methodology, and approximate schedule could then have been developed with much less expense. (In fact, almost in spite of some of the training plans, this is the process that developed.) Evaluation of the success of training was on the basis of the ability to perform individual tasks (as in the case of installation and maintenance) or more "rolled up" tasks, as in the case of hydrologic modelling. Although part of the objection to the Nutec training plan was its philosophy of competency-based training, this is to some extent what evolved, albeit the competencies were not always at a simple level but instead at a summary (they can calibrate a model) level.

The final step in training evaluation, the introduction of "Training Evaluation Workshops" was a very valuable and useful addition because it transferred the responsibility for learning to the learners, and helped to identify knowledge gaps that could be filled in and build confidence. These should definitely be considered in the design of future projects and training plans. Further benefit might be gained by introducing them earlier, not only for training evaluation and planning but also for team building.

In future projects, care should be taken that there is not unnecessary effort spent on training plans. They must be simple, easily understood, and practical. The transfer from teacher-centred training, based on identified required knowledge, to learner-centred training should begin early in the project, but, initially it is the teachers who must guide while at the end it will be up to the learners.

Training-of-Trainers was a very useful process for both WAPDA staff and BCHIL staff. It might have been more effective if it had been given earlier in the project and then reinforced, possibly in joint WAPDA–BCHIL sessions. The purpose would have been not only to improve training skills, but also help the teacher–learner relationship as both BCHIL and WAPDA would have had a better understanding of each other's teaching and learning methods. As noted in WBS 446, it would also have helped WAPDA staff understand each other's project outputs and needs.

The academic training provided by the project was originally intended to be at the M.Eng level (i.e., no thesis). The extension to the MASc level was a positive change as each of the three theses was directly applicable to the project outputs. The value of this approach should be considered for future projects.

Finally, a project such as this is difficult to plan in advance. No matter how good the original plan (and given the available knowledge, the plan for this project worked amazingly well) there needs to be flexibility to adapt to changing situations. In addition, in a project such as this, there are seasonal constraints that do not allow a great deal of time for approvals to changes in the program. This requires that a great deal of trust exist between the executing agency (IDRC) and the implementing agency (BCHIL) and also between BCHIL and WAPDA. The willingness of IDRC to trust BCHIL's judgement and to provide fast responses to requests for change, significantly aided the progress (as did BCHIL's trust of WAPDA).

8.5 Sustainability

As noted in the Final Evaluation Report on the Project, there is a trained core of WAPDA staff capable of carrying out all the tasks required to obtain and process data, to prepare and issue forecasts, and update the hydrologic model. However, the evaluation notes that there are several potential obstacles to sustainability such as:

- ongoing funding;

- staff incentives for field work and encouraging responsibility and accountability among H&RD staff;
- the small size of the cadre of trained staff; and
- the need to develop a core of users of the project outputs.

These can be partially overcome by the demonstrated dedication to the project of key WAPDA staff, but there would be a significant benefit to sustainability by further external support to the project until such time as forecasts are being used and the benefits to the economy can be demonstrated. Such support could also include training and development of users of the forecasts to ensure that maximum benefits are realized from the project.

The use of the Meteor Burst system for the flood-forecasting system (underway) and for canal monitoring (proposed) will help sustain the infrastructure supplied by this project.

Section 9: Conclusion

Overall, SIHP-II was a successful project. Almost all of the infrastructure that was identified in the initial planning has been successfully transferred to Pakistan. Currently, 22 Data Collection Platform (DCP) Stations are installed. The Meteor Burst communication system is functioning reliably and is consistently transmitting data to the master station in Lahore. The data-management system is in place and is producing seasonal and 10-day flow forecasts. The Pakistani personnel within the project are trained and capable of technically supporting the Project. No operational flow-forecasting system has been developed anywhere in the world at such high altitudes and in such difficult terrain as is found in the Upper Indus Basin.

All aspects of all 10 project objectives were fulfilled, except for one component related to the DCP Stations. At project completion, the interface between the snow-pillow shaft encoder and the Meteor Burst system was still not operating satisfactorily. To solve the problem, pending snow-pillow data from the field in the summer of 1998, MCC will supply (at no charge to the project) potentiometers and related spare parts (gears) to convert the shaft encoders from a digital to an analog output. The modifications will be made by WAPDA staff, who developed this potential solution.

Other than the snow-pillow problem, SIHP-II faces three major challenges to its success and sustainability. The first is the conditional nature of its sustainability. Sustainability of SIHP-II is predicated on WAPDA's willingness to support and use the ongoing efforts of SIHP-II when the project's ability to produce reliable forecasts increases as more inflow data are acquired. The second challenge is maintenance of the trained SIHP-II personnel. For the duration of the project, the personnel remained constant. Now, however, the personnel are open to transfer, and the importance of adequately training new staff, by those who are leaving, cannot be overemphasized. The third challenge is to have the inflow forecasts used within the water-management structure of Pakistan, especially by IRSA. Work began in the last year of the project on practice forecasts and reservoir management. Until the model is fully calibrated, the practice forecasts should be disseminated and used very carefully.

To ensure that SIHP-II can meet these challenges, a follow-up project is recommended to:

- strengthen the links between water-management agencies in Pakistan; and
- ensure that the project is financially supported during the crucial period of model calibration.

The overall goals of the follow-up project would be to strengthen capabilities in water-resources management in Pakistan by: reinforcing institutional linkages and human-resource development; continuing to improve flow forecasting; and enhancing planning and operating methodologies.

SIHP-II was a dynamic and viable project built on the motivation and commitment of the individuals and organizations involved in the project. Given that the primary objectives have been met successfully, to enjoy its potential benefits, the positive outcomes of the project must be used and incorporated into the water-management strategies of Pakistan.

Appendix A: Detailed Workplan

The original Work Breakdown Structure (WBS) was given in the Project Inception Report. This WBS was revised in the 1992 Annual Work Plan and modified still further in the 1993 Annual Work Plan. The final WBS is outlined on Appendix E. Final progress against the WBS is given below.

A.1 100 Management

140 BCHIL Management

141 Administration: This was an ongoing activity that included providing human resources, supervising all project activities, and ensuring timely completion of activities within the established budget. The activity was carried out by the Project Manager, assisted by a Project Management Assistant, and the Site Manager for activities in Pakistan. It required close coordination with the WAPDA Project Director.

The Project Manager was also responsible for ensuring that ongoing reviews of project training needs and WAPDA staff progress were conducted. A detailed training plan was to be reviewed as part of this activity by B.C.Hydro Manpower Development staff.

All required personnel resources were supplied as required. A total of 8 BCHIL employees worked on the project. A Site Manager and a Modelling Specialist were on site for periods of 2.2 years and 1 year, respectively. Eleven external consultants were also employed on the project as required (see WBS 149). Work was carried out within overall budget allowances. The project was extended 1.5 years as a result of the training supplement and another 0.5 year to resolve problems with remote-data acquisition (snow pillow, see WBS 214) and obtaining data from Pakistan sources (see WBS 253).

Annual work plans were prepared with WAPDA input. Three training plans were prepared: a preliminary plan by BCHIL; a plan by Nutec Training, which was not accepted by the IDRC Training Consultant; and a plan by Johnson Management Inc., which, although accepted, was not used directly (see WBS 148 and WBS 443).

142 Supervision: This activity included review of all work plans, memoranda, specifications, and reports produced under Technical Assistance, Procurement, and Training activities. The BCHIL Project Manager or his designate carried out this review.

143 Reporting: The draft of the Project Inception Report was completed and reviewed by WAPDA, IDRC, and CIDA. The report was issued in January 1992 along with a letter noting that it should be read in conjunction with the Annual Work Plan.

Annual Work Plans: The draft Annual Work Plans for each year were prepared for the Project Review Meeting in September–October of the previous year and finalized in

October–November. These reports included a status report of work accomplished up to the time the plan was prepared. The reports were prepared under the direction of the Project Manager assisted by the WAPDA Project Director and the BCHIL Site Manager.

Progress Reports: Preparation of financial and progress reports was carried out under the direction of the Project Manager assisted by the BCHIL Site Manager and B.C.Hydro Administrative Services Staff.

- The semi-annual progress reports were prepared with input, review, and comments from WAPDA staff and issued by July–August to IDRC and WAPDA.
- Financial reports and budget forecasts for the remaining quarters of the year were issued within approximately 20 days from the end of each quarter and copies were forwarded to IDRC and WAPDA.
- A monthly summary highlight activity report requested by IDRC and CIDA along with relevant correspondence was issued. For the last 2 years of the project, these reports were prepared by WAPDA.

Management and Accounting Information: This on-going activity included the preparation and archiving of financial and progress information for reporting purposes and future auditing. A commercial software package (Accpac-Bedford) was used for accounting. Scheduling was done manually. These activities were carried out by B.C.Hydro Administrative Services staff.

145 **Liaise with other Institutions:** This was an ongoing activity that ensured cooperation among institutions involved in work related to this project. It included liaison with Wilfred Laurier University (Dr. Hewitt), University of British Columbia (Drs. Quick and Casselton), University of Engineering Technology in Lahore (Dr. Shah), and the German GTZ project (Dr. Lopez). It was carried out principally by the Project Manager assisted by the BCHIL Site Manager and the WAPDA Project Director.

146 **Participate in Project Review Meetings:** The Project Manager travelled to Lahore in September–October of each year to participate in the Project Review Meeting. He was assisted by the BCHIL Site Manager. Site visits to remote-sensing stations in the Khagan Valley, Swat Valley, and Deosai Plain were also carried out at the time of the meetings. A draft Annual Work Plan was completed prior to the meetings.

147 **Identify Research Needs:** Originally it was intended to continue some of the research in the earlier Snow and Ice Project. However, this proved to be impractical given the work load on the WAPDA staff. Most of the research carried out as part this project was done by the three WAPDA staff who obtained MASc Degrees. The students and their research topics were:
Mr. Danyal Hashmi: "Flow Routing Model for the Upper Indus River (Pakistan)" December 1993 (BCHIL Report No 028).

Mr. Inam Ullah Khan: "The Effects of Snow Avalanches on the Hydrologic Regime of the Kunhar River, Western Himalayan Pakistan: Analysis and Application to River Flow Forecasting" April 1996 (BCHIL Report No. 047).
Mr. Asim Khan: "A Two State Deterministic Dynamic Programming Model for Optimizing the Joint Operation of Mangla and Tarbela Reservoirs in Pakistan" August 1996 (BCHIL Report No.056).

Additional research related to evaporation from precipitation gauges was conducted to demonstrate that some observed decreases in precipitation-gauge levels were due to evaporation, not leakage. Finally, the entire project, being based in high-altitude regions was a research project in data-gathering and mountain hydrology (including the estimation of runoff using low-elevation data to estimate high-elevation precipitation, snow accumulation, and melt).

Three technical papers on the project were produced and several more, related to the broader benefits of the model for Pakistan, are planned. A complete list of papers and reports published in the project is given in Appendix F.

148 Recruit Personnel and Consultants:
External Consultants: The following external consultants were hired for the work program. For each consultant, specific terms of reference were prepared prior to initiating the work.

Hydrologic Model Consultant: Dr. M.C. Quick of UBC provided modelling advice on the UBC Watershed Model that had been selected for the project based on a review of models (see WBS 252). Because Dr. Quick was fully knowledgeable in the design and operation of the model (data required, theory and fundamental equations used, organization and flow chart of model, model outputs, expected ranges of parameters, and analysis of outputs), he was able to provide advice and guide students in the use of the model. In addition, he provided technical advice on an ongoing basis in Vancouver and direction and assistance with required model modifications.

Installation Consultant: Mr. D.J. Morgan and associates at VIA-SAT Data System Inc. were retained to provide the following services in Vancouver: design of the remote stations; site-selection criteria; review and comment on the draft Installation Manual prepared by WAPDA; guidance on requirements for the Operation and Maintenance Manual; assistance with preparation of specifications for snow pillows and precipitation gauges; assistance with procurement of miscellaneous installation hardware not available in Pakistan; and assistance with installation of a Meteor Burst transmitter at a remote site in British Columbia. (This last item was intended to test the Meteor Burst System; however, because of schedule problems it could not be carried out.)
Mr. Morgan and associates also provided training in Vancouver to 8 WAPDA staff on installation and calibration of hydrometeorological instruments, installation and

maintenance trip planning, operation of a maintenance facility, and trip documentation. This latter training was reinforced by Mr. Morgan during a mission to Pakistan.

Mr. Morgan also travelled to Pakistan to provide on-site training in the operations of an installation and maintenance office, testing and calibration of equipment, servicing of remote sites, documentation, and installation procedures.

Dr. K Hewitt provided liaison with SIHP Phase I and advice on remote-station locations, mountain hydrology, and research needs.

Alpine Guide: Although proposed in the original WBS, the alpine guide was not required because of changes in site-location requirements (see WBS 461).

Model Consultant: Mr. A. Pipes was hired to produce a report on the calibration of a hydrologic model for the Astore Basin to determine if inflow forecasts could be made accurately enough to justify remote data-gathering in, and hydrologic modelling of, the UIB. The normal variability of the Indus at Tarbela is relatively small. It was not immediately obvious that, given the unknown future weather component, it would be feasible to provide seasonal inflows to Tarbela with a sufficiently small range of probable flows to economically justify hydrologic modelling. A similar problem existed for Mangla but, in this case, the range of inflows to Mangla is much greater because of the much larger monsoon component. Mr. Pipes' work is documented in a report entitled "Pakistan Snow and Ice Hydrology Project, Examination of the Tarbela Basin Runoff Forecast Potential", 31 May 1991 and demonstrated that hydrologic modelling would be feasible. This information was used in the "Project Direction and Review Report" (see WBS 211).

Training Consultants: Further discussion of the training component is given in WBS 443 along with a discussion of some of the problems that arose.

(a) Nutec Training Limited: A request for proposals for a training consultant was prepared by BCHIL and reviewed by WAPDA and IDRC. Nutec Training Limited was the successful bidder. They met with staff of BCHIL, Via-Sat Data Systems Inc., and two WAPDA staff being trained in Vancouver. Together they developed lists of key learning points during group sessions and proposed how this training should be delivered and evaluated. In the opinion of IDRC's Training Consultant, the lists of key learning points were inconsistent in their level of detail and the proposed means of evaluating the success of training were not suitable. As a result of the foregoing, only a draft report was submitted and the work was terminated.

(b) Johnson Management Inc.: As a result of the problems with the Nutec work, a new training consultant was selected by the IDRC Training Consultant. Johnson Management Inc. met with BCHIL staff, and based on these meetings, information provided by Ms. Ferida Sher (see below), and the draft Nutec report, prepared a training plan. This plan consisted of a short report with a total of 200 pages of appendices with individual training plans for each of the WAPDA staff. This plan was presented by Mr. Lee Johnson of Johnson Management to WAPDA in Pakistan; however, it proved to be too complex and was not understood by WAPDA staff. Ultimately it was not used, except near the end of the project when the IDRC Training Consultant had WAPDA staff compare their training with that proposed in the Johnson Management Training Plan.

(c) Ms. Ferida Sher: Ms. Sher was engaged by the IDRC Training Consultant, on the basis of local recommendations, to assess the backgrounds of WAPDA staff relative to the training requirements to help Johnson Management determine the individual training needs of WAPDA staff. Unfortunately, her background proved to be unsuitable for her to carry out her mandate and her report did not greatly assist the training development program.

Training of Trainers:

(a) Lamoureux and Associates: This company was hired to ensure that WAPDA staff received the maximum benefit from training by BCHIL. They provided a 2-day seminar in Vancouver to staff of BCHIL, to help them identify ways to improve training. For the most part, this seminar reinforced the fact that BCHIL had been using appropriate techniques.

(b) Vancouver Community College (VCC): At the suggestion of the IDRC Training Consultant, Ms. Joan McArthur-Blair of VCC was engaged to provide a 1-week Training of Trainers course to WAPDA staff in Lahore. This training was very beneficial (see WBS 446).

Communications Consultant: Itelecon Research and Consulting Ltd. was engaged to examine the market worldwide for viable suppliers of Meteor Burst equipment. Their January 1992 report entitled "A Market Study on Meteor Burst Communications" identified several companies that had supplied, or attempted to supply, Meteor Burst equipment. The only viable supplier, with proven equipment, was identified as Meteor Communications Corporation (MCC) of Kent, Washington. This information was used to justify dealing with MCC on a sole-supplier basis.

Internal Consultants: Specialist advice in several areas was supplied to the main BCHIL team from several areas in B.C.Hydro. This advice included:

(a) Computer hardware and software advice: Provided advice on components, specifications, costs, potential or observed problems and solutions, and software (e.g., ease of use and compatibility with other hardware and software).

(b) Training Specialist: Supplied advice on the preparation of the request for proposals for a training consultant, suggested recipients, and evaluation of proposals.

(c) Structural Design: Carried out the design of the support structures for the equipment at the remote stations.

(d) Specifications and Tenders Specialist: Provided advice and reviewed wording of specifications and tenders, particularly for the Meteor Burst equipment, and also supplied advice on the procedures used to negotiate with MCC as a sole supplier.

(e) Purchasing and Shipping Services: Provided advice and services for issuing and receiving tenders, purchasing (procedures, rules, documentation required, and customs clearance procedures), and shipping (obtaining donation certificates, packing, and arrangements with air freight and other shippers).

149 Site Management: This activity commenced in April 1992 and was originally to be for a period of 2 years. As part of the work funded by the training supplement, the presence of a Site Manager was extended for 1 year.

The original Site Manager, Mr. W.C. Thompson, was engaged to assist WAPDA staff with installation, operation, and maintenance of the remote stations. In addition, he provided training in data decoding and quality control using the CLICOM system developed by the World Meteorological Organization. He also provided initial training in the use of the UBC Watershed Model and in the fundamentals of this model. Finally, he provided training in hydrology and meteorology fundamentals to enable WAPDA staff to better understand the physical processes involved and how they relate to hydrologic modelling and data gathering and quality control. As part of his efforts at team building, Mr. Thompson introduced team meetings so that the WAPDA team members would have a better understanding of each other's requirements. Although initially resisted, these meetings proved to be a valuable addition.

Additional responsibilities for Mr. Thompson included assisting with local purchasing, liaising with other groups and institutions, and assisting with, and preparing, progress reports. Mr. Thompson remained on site in Pakistan until June 1994. At this time, as a result of the additional funding provided by the training supplement, it was decided to focus training of WAPDA staff on hydrologic modelling and forecasting. Therefore, Mr. Thompson who was a generalist, well suited to the original mandate but not a modelling specialist, was replaced by Mr. Vladimir Plesa, whose experience lay in the fields of hydrologic modelling and forecasting. Mr. Plesa remained on site until June 1995. During this time he trained WAPDA staff in data handling and quality control, hydrologic modelling, and forecasting. Working with WAPDA staff, he developed a routine to calculate runoff from avalanched snow for the Kunhar Basin and developed an inflow-forecasting system that included:

- data input;
- running of the hydrologic model with the existing state (snow pack and groundwater storage) and with a series of historical weather sequences to provide an estimate of the magnitude and range of future inflows; and
- output of a forecast bulletin.

In addition, he provided support, where required, for:
- the operation and maintenance of the Meteor Burst remote data-gathering system;
- purchasing; and
- reporting.

Both Site Managers had a key responsibility to ensure that WAPDA staff assumed increasing responsibility for the management, planning, and operation of the project. Both managers were instructed that they were to work with WAPDA staff to complete tasks and not just do the work for WAPDA, which was the role with which WAPDA staff were accustomed.

During their stays in Lahore, the project paid for the rental of a house and the services of a cook. This house was used by visiting BCHIL staff in place of a hotel, resulting in significant cost savings overall to the project.

With the approval of IDRC, CIDA guidelines were used as the basis for determining allowances for housing, travel etc.

160 WAPDA Management

161 Project Approval: The project was approved by the Government of Pakistan, 1.5 years ahead of the IDRC project approval. This required the submission of a revised PC-1 proforma for an extension and budget increase for the project. The work was carried out under the direction of the WAPDA Project Director and completed in 1994.

162 Provide Personnel: WAPDA ensured that all project positions listed in the PC-1 proforma or revisions thereof were filled where possible. A government hiring freeze lead to a delay in filling some vacancies. Although this did not cause significant problems for the project, it reduced the number of core people that could be trained.

During negotiations for the project, the then General Manager of Planning, Mr. Khalid Mohtadullah, made an informal agreement with the BCHIL Project Manager, to keep WAPDA staff on the project for its duration if BCHIL would do the same. Both parties adhered to the spirit of this agreement to the benefit of the success of the project overall.

163 **Project Administration:**

Annual Work Plan: Draft Annual Work Plans were prepared for the annual Project Review meeting in September–October. These plans were prepared jointly with BCHIL. WAPDA provided input on the project status, proposed work items for the following year, schedule, and budget and ensured they could meet any resulting commitments.

Progress Reports: Starting in 1995, during the last few months of the Site Manager's tenure, WAPDA provided monthly progress reports to BCHIL and IDRC. These were prepared under the direction of the WAPDA Project Director and with input from the BCHIL Site Manager. Throughout the project, WAPDA provided input, review, and comments to the Semi-Annual and Annual Reports.

Management and Accounting Information: This ongoing activity included supervising the preparation of all necessary budget, accounting, and scheduling information to meet project, WAPDA, BCHIL, and IDRC requirements. The information for BCHIL was used to prepare monthly reports, quarterly financial reports by BCHIL, Annual Work Plans, and Semi-Annual Reports. The work was done in Pakistan under the direction of the WAPDA Project Director.

There were long delays in payment of expense accounts to WAPDA staff. This problem might have been reduced by bringing WAPDA accounting into the team (see comments in Section 7.1).

Management styles differed significantly between BCHIL and WAPDA. BCHIL management style was much more "bottom-up" with an expectation of self-motivation of staff. WAPDA management style is much more "top-down" with staff expecting direction from above. (Initiative by staff is not always looked upon favourably.) WAPDA staff also have many outside pressures that tend to divert them from their work. At times, this lead to the feeling by BCHIL and IDRC staff that WAPDA staff were not taking the initiative that they might have. While this was true in a Canadian context, WAPDA staff, although at times indicating that they wanted more direction, were considered by WAPDA standards to be very productive.

164 **Liaise with other Institutions:** The WAPDA Project Director met with staff of other agencies (such as the Surface Water Hydrology Department and Pakistan Meteorological Department) and institutions (such as the Federal Flood commission and German GTZ Project Manager) on a regular basis to ensure coordination of related projects. This led to information and equipment exchange with the GTZ project.

165 **Participate in Project Review Meetings:** The WAPDA Project Director carried out the following activities prior to the meeting: obtaining the names of nominees to the committee of BCHIL–IDRC–WAPDA; obtaining consensus on the date of the meeting; obtaining any necessary clearance for the field trip; and providing formal notification to nominees of the date, place, and agenda of the meeting at least 8 weeks in advance.

166 **Site Management:** This ongoing activity included ensuring that remote-sensor sites were operated, maintained, and protected and guarded to ensure that reliable data were received in Lahore. To this end, WAPDA arranged for chowkidars (guards) at all remote sites and the master station. Generally, this worked well. During the life of the project, vandalism was minimal. Adequate local funds and vehicles were provided for staff, chowkidars and travel. There were some delays in paying chowkidars and an indication that some of the observed vandalism could be traced to this delay.

167 **Identify Trainees:** This activity also included ensuring that staff were identified and cleared for overseas training as required. Generally, for short-term overseas assignments, although several months lead time was required, this was not a problem. Three problems arose with the university students. First there were significant delays in identifying students. Much of this delay related to government rules to ensure equality of opportunity for people from all provinces. After a student was selected they had to meet University of British Columbia language requirements. This required that the students obtain a score of 550 in the official TOEFL test. This test is different from the TOEFL test given by USAID and initially caused some problems. One potential student failed two attempts at the TOEFL test and a replacement had to be found, which resulted in further delays. The third problem was the fact that Canadian universities do not understand the system of marks from Pakistan universities and initially assumed that the marks for very capable Pakistani students did not meet Canadian requirements. This required explanation and clarification. In one case, when checking a student's marks, UBC found that they had been altered. There was some further delay as WAPDA had to find a replacement student. The result of all the problems and delays was that the final student did not complete his MASc degree until August 1996, which would have been 8 months after project completion under the original schedule.

168 **Provide Support to Canadian Specialists:** WAPDA assisted the BCHIL Site Manager with housing arrangements and customs clearance and provided assistance with clearance for travel to remote areas for the technical missions of BCHIL staff and consultants. WAPDA also provided any information or reports by WAPDA to Canadian Specialists as requested.

169 **Infrastructure and Facilities:** WAPDA ensured that all necessary office, storage, repair, and transmitter-housing space was provided as per the PC-1, Memorandum of Grant Conditions, and WAPDA procedures. In 1992, WAPDA provided additional office space for the electrical maintenance group to relieve overcrowding. With the approval of IDRC, project funds, originally proposed for an office at Gilgit, were used to provide the required office space in Lahore. In exchange, the Hydrology and Research Directorate paid for facilities in Gilgit, which were used to store equipment during the construction phase of the project.

A.2 200 Technical Assistance

210 Review and Planning

211 Project Direction and Review Report: This activity included a review of the potential benefits that could be obtained from this project. It was intended to demonstrate to WAPDA that positive economic benefits would be realized when compared to present procedures. Because of the lack of information available in both high-altitude hydrometeorological data and economic data, the benefits in the report were estimated. This report was not intended to be a definitive economic study but was intended to provide a sufficient basis to either confirm the project as proposed or recommend an alternative direction of study. (The original project assumption was that the report would confirm the present direction and all work prior to completion of the report was carried out on this basis.) The results of the study are presented in the Project Direction and Review Report (BCHIL Report No. 001) dated February 1993. The report confirmed that hydrologic modelling of the UIB could be carried out with sufficient accuracy to provide a conservative estimate of $20 million per year in net benefits (1992 dollars) to Pakistan through increased agricultural and energy production. Additional potential benefits could accrue for flood control, increased storage at Tarbela reservoir, and the addition of future projects. These additional benefits could be worth up to $10 million per year.

The draft report was issued in June of 1992 and was subject to outside review by Dr. Geoff Kite of the Canadian National Hydrology Research Institute who agreed with its findings.

The report was finalized and issued in February 1993. This was almost 15 months behind schedule. The major causes of the delay were the longer than expected time required for the technical studies to support the report's conclusions and the significant editing required to make the draft more easily readable for a larger audience.

212 Assess Satellite Imagery: Work on this activity was scheduled to be carried out in February–March 1992; however, because of the pressures of other work the report was not completed and issued until October 1992, about 7 months behind schedule. The study entitled "Application of Remote Sensing to Runoff Prediction", October 1992 (BCHIL Report No. 015) reviewed the benefits and costs of satellite imagery for long-term use to improve estimates of inflow to the UIB. This report recommended that satellite-imagery equipment not be purchased. This recommendation was based on the value and reliability of the data that would be produced, which did not justify the equipment costs, the effort in training staff, and an ongoing cost of satellite images. The work was carried out in Lahore by the Site Manager, and WAPDA staff provided review and comment.

213 **Determine Transmission Mode:** A preliminary memo on this subject was prepared in May 1991. This memo recommended that in the long-term, Meteor Burst should be used; however, because of the long lead time needed, and the desire to carry out field tests of installation procedures and equipment, it was recommended that three Argos transmitters be purchased for the 1991 installations. A draft report on this activity, containing recommendations on the transmission mode to be used, was completed by the end of 1991. The report "Transmission Mode Selection" (BCHIL Report No. 010) was reviewed by WAPDA and issued in 1992. This report initially examined four potential transmission modes: VHF, polar orbiting satellite, geostationary satellite, and Meteor Burst. Subsequently, after issuing the report and at the request of CIDA, the use of telecommunications satellites was also reviewed. The reviews concluded that only two options were technically feasible — polar orbiting satellite and Meteor Burst. The Meteor Burst option was selected on the basis of lower overall cost (capital and operating), local control of the system, regular reporting intervals, two-way communications capability, and proven operation under severe weather conditions. The major cost difference was the Argos service charge of $7.40 per day per station. Over the 10-year life of the project this would have amounted to a foreign exchange requirement of $0.5 million that would have been very difficult to obtain. Although this cost might have been decreased by a Joint Tariff agreement between Pakistan and CLS/Argos, the costs would still have been significant.

The overall cost analysis showed that the annual operating costs for a system with 20 remote stations including interest at 6% and amortization over 10 years would be $22,000 more for the Argos system. This did not include any allowance for Internal (to Pakistan) communications and processing costs from the down-link agency, the Space and Upper Atmosphere Research Organization (SUPARCO). Although, when purchased, the Meteor Burst System cost about double the initial estimate, the breakeven point for the number of units would have been moved to about 35. Given the likelihood of system expansion and the other benefits associated with the Meteor Burst system, it remained the best choice. The operational history of the system, and its selection by Pakistan for additional uses has further justified the selection.

Although all sensors were selected because they had been tested and proven in remote mountainous terrain subject to extreme weather conditions, it was felt necessary to make a test installation in Pakistan. There were three main reasons for this:

- the effects of extreme ultra-violet radiation and heating of sensors and components at altitudes almost twice those in North America were not known;
- the actual weather extremes from hot to cold were likely greater than in North America and these potential effects on sensors were unknown; and
- the difficulties (working and health) associated with installations at altitudes greater than the height of most mountains in Canada were not known.

To test the remote-station sensors, stations were installed in September 1991 at Babusar Pass and Deosai Plain using the Argos polar-orbiting satellite to transmit the signals because it was readily available and WAPDA had the necessary radio licences. This system proved awkward to work with because all data had to go through another Pakistani agency, SUPARCO. Although SUPARCO was cooperative, there was no direct link to their Karachi office and data had to be transferred by diskette, which resulted in delays and sometimes lost data. These problems also reinforced the use of the Meteor Burst system, which did not involve any outside agencies.

214 **Review Sensor Performance:** This ongoing activity consisted of the review and plotting of data transmitted from the remote sites to determine if there were any failures, inconsistencies, or unexpected variations in sensor readings. The reviews of sensor performance were carried out by BCHIL staff in Vancouver and WAPDA staff assisted by the Site Manager in Pakistan. These reviews showed that:

- there were no problems with temperature and relative humidity readings;
- there were no problems with wind speed and direction readings;
- precipitation gauge readings appeared normal except that they showed a great deal of "noise" (readings varying several millimetres during the day) and they showed a slow decline during periods of no rain. A review of B.C.Hydro's own data showed that the "noise" was not unusual and could be attributed to effects of wind both vibrating the precipitation bucket and causing air pressure changes. This can be smoothed during the data quality-control phase. The gradual decline was originally thought to be leakage from the bucket but was later traced to the extreme evaporation caused by the dryness of the air and heating of the precipitation bucket. This was combined with the fact that the circulation pump, which was installed to ensure that the antifreeze stayed mixed in winter, also broke up the oil film that was added to prevent evaporation. As a result, a decision was made to turn off the pumps during the summer months to preserve the oil film and reduce evaporation. (This demonstrated an advantage of the Meteor Burst system because the pump could be turned off and on remotely.)
- snow-pillow and solar-radiation sensors showed significant problems. These problems were traced to the interface between the sensors and the Meteor Burst transmitter. Modifications to the interface solved the problem with the solar-radiation sensors. Solving the problem with the snow pillow has proved to be more difficult. In late 1996, Meteor Communications supplied an "up-down counter" from Campbell Scientific Ltd. to replace the interface supplied by MCC. There was some question as to whether this worked, and in June 1997 a provisional decision was made to use a precision potentiometer attached to the shaft encoder to provide the water-level output. This solution had been tried by WAPDA at a remote site in 1995 and 1996 and proved effective. Data from this test are presently being reviewed in Vancouver before this solution is accepted (see discussion in Section 3.0).

During the maintenance trips to the remote sites, transmitted sensor measurements were recorded and compared with field measurements of climate parameters. These measurements were used for quality control of the data.

215 **Assess Computer System Needs:** The "Review of Computer System Requirements 1991" (BCHIL Report No. 004) recommend that the initial assessment of the needs presented in the report be reviewed on an ongoing basis and prior to any future purchases. Initially, two 386 personal computers and monitors were supplied from Canada as Pakistan prices were considerably higher. This caused problems because the monitors were not dual voltage and one was damaged early in the project.

Ongoing reviews were carried out and included:
- a review of project needs and WAPDA progress in using computers;
- a comparison of recent computer and related costs in Pakistan and Vancouver;
- an examination of any equipment problems to date and potential solutions; and
- the preparation of a memo recommending any changes to equipment or software purchases.

Over the life of the project, a total of 12 computers were purchased for the project in addition to two surplus computers donated by IDRC. This excludes three that were purchased for the Meteor Burst communications system. Prices for computers purchased in Pakistan declined significantly, but there were problems locating reliable suppliers and good quality equipment. Initial purchases in Pakistan were Everex computers. Both the company and the supplier went out of business. In 1996 two "unbranded" computers were purchased but they would not work on the LAN and had be returned to the supplier and replaced with a better brand of computer. By the end of the project, it appeared that more reliable suppliers and equipment could be found but it meant that the WAPDA staff had to be very careful when obtaining quotations and that the lowest priced machine might not be of suitable quality.

220 Remote Sensing

221 **Identify Site Locations:** Detailed studies to determine the locations of remote stations for the entire system were carried out in February and March 1992, and a draft report was issued 31 March 1992 to ensure that planning for reconnaissance, installation, and maintenance activities could be carried out to commence field work in June 1992. This work was an extension of the limited study carried out for the 1991 installation and included a review of SIHP Phase I work, a review of existing stations, an examination of the hydrologic regime and hydrologic model requirements, and an examination of WAPDA human-resource requirements related to installation logistics. A report entitled "Upper Indus Basin Climate Station Locations" (BCHIL Report No. 012) recommended that 24 remote stations be installed (two per proposed model sub-basin) and gave the priorities for installation.

The work was carried out under the direction of the BCHIL Senior Hydrologist assisted by WAPDA staff in Vancouver. Although the best available topographic maps were used, they were not always accurate, and reconnaissance showed some suggested sites were not feasible either due to access difficulties or lack of suitable terrain for a remote station. Future calibration of the hydrologic model using data from the project stations may demonstrate that it is desirable to move some of the stations.

222 **Reconnaissance:** Reconnaissance for the remote sites was carried out in several stages. The amount of reconnaissance carried out in any year was a function of the proposed installation program, and in 1992, limitations on access due to sectarian violence. The stages of reconnaissance that were carried out during the project were:

- October 1990: General reconnaissance of Khagan Valley, lower Hunza and Gilgit Valleys, and lower Shigar Valley. Burawai site (existing) was selected to be updated.
- September 1991: Reconnaissance and selection of sites at Babusar Pass and Deosai Plain. This reconnaissance was carried out by BCHIL and WAPDA teams.
- June–July 1992: Reconnaissance and selection of sites at Kalash Valley, Zani Pass, Khot Pass, Shandur Pass, Kalam, Shangla Pass, and Shogran. The proposed Lowari Pass site and a site north of Chilas on the Indus were deemed unsuitable. This reconnaissance was carried out by two teams, each with one WAPDA and one BCHIL engineer.
- June–July 1993: Reconnaissance and selection of sites at Ziarat, Kunjurab Pass, Yasin, Ashkore, Ishkoman, Rattu, Rama Meadows, and Naltar. This reconnaissance was carried out entirely by WAPDA staff.
- August–September 1993: Reconnaissance and selection of the Hushe site. The proposed site on the Biafo glacier was rejected due to its difficult access. WAPDA later chose an alternate site for the Hushe station. This reconnaissance was carried out by BCHIL engineers.
- May–June 1994: Reconnaissance of the Burzil Pass site by a WAPDA engineer and attempted reconnaissance of a site at Arundu.
- June 1996: Reconnaissance of sites at Gilgit (lower elevation stream gauge and weather gauge) and at Dassu (in place of Arundu).

Reconnaissance diaries were prepared and issued for all of the 1992 and 1993 reconnaissance trips.

Several proposed sites were eliminated as a result of the reconnaissance. Alternative sites could not be found for all cases.

- A proposed site at Lowari Pass was eliminated because of the steep terrain and replaced by a site in the Kalash Valley.
- Suitable road access could not be found for a proposed site at Zhandrai Pass on the western side of the Swat Valley and it was replaced by a site near Kalam.
- The terrain for a proposed site south of Kaphlu was too rugged, and access was too difficult, to be practical for installation and maintenance.

- The proposed site by the Biafo glacier was deemed to have too difficult access to be practical.
- A proposed site at Chogo Lungma (Arundu) could not be reached for 3 years in succession and was replaced by a site at Dassu. This site served to replace both the Biafo and Arundu sites.
- A proposed site at Hopar was eliminated because of travel difficulties and the potential for sectarian violence and the risk to WAPDA personnel.
- A proposed site at Thalpan Valley north of Chilas could not be located because of sectarian violence.

223 **Design Stations**: Studies of alternative designs for the remote stations were carried by BCHIL and WAPDA in 1991. The design examined the sensor requirements and the site location and installation criteria. As part of the design, fabric snow pillows were selected over metal pillows for reasons of portability and data accuracy. Shaft encoders were selected over pressure cells as the means of measuring the pressure in the snow pillow. The design was presented in the report "Remote Site Selection and Station Design", August 1991 (BCHIL Report No. 006). The design criteria had to consider porter load limits, ice and snow loads and snow depths, and ease of construction at high elevations. The ice and snow loads had to be estimated based on B.C.Hydro experience in Canada. The selected design was based on common construction scaffolding. Canadian scaffolding was manufactured from high-strength steel. Because this was not available in Pakistan, a larger diameter galvanized pipe had to be used. The design has worked well, and all scaffold components after the initial three sets were manufactured in Pakistan.

At three of the selected sites, the height of the towers had to be increased and the instruments raised because the depth of snow was greater than anticipated. In some cases the snow load bent the braces of the structures — possibly as a result of a subtle difference in design between Canadian- and Pakistani-built structures. In the Canadian built structures, the braces are joined in the middle where they cross; whereas, the braces in the Pakistani structures do not join where they cross. WAPDA added guy wires to strengthen these stations.

224 **Installation and Maintenance:**

Installation: The initial remote installations took place in September 1991. Two test sites using the Argos system for signal transmission were installed, one at Babusar Pass and one at Deosai Plain. The purpose of these installations was to test the scaffold tower and to check installation procedures and performance of the sensors during the following year. Because the purchase of the Meteor Burst equipment was delayed by difficulties in obtaining a radio licence, the installations in 1992 (5 sites) consisted of the scaffold towers only except for the station at Shangla Pass, which was completed using an Argos transmitter not installed in 1991. This was carried out by WAPDA staff. Installations in 1993 consisted of an additional 10 scaffold towers by WAPDA plus installation of the Meteor Burst equipment and sensors at all sites. With the exception of training during the installation of Meteor Burst equipment and sensors at 5 sites, all work was done by WAPDA staff on their own. At the end of 1993, a total of 16 sites were in service and civil works were installed for 17 sites. The remaining installations took place in 1994 (2 sites), 1995 (1 site), and 1996 (2 sites).

Generally, preparatory activities took place in May–June in Lahore, prior to the field work period of June–September. Wrap up activities in Lahore followed in October. The "heavy civil work" was installed first. This work included the preparation of equipment, its transport to Gilgit for temporary storage, and its transport to the sites. Two installation teams were fielded by WAPDA. The civil field work included:

- detailed site selection;
- construction of footings and erection of scaffold towers;
- installation of equipment shelters, snow pillows, precipitation gauges, and protective fencing;
- site documentation; and
- site clean-up.

The electronics field work included installation of transmitters and sensors at these sites. Porters were required for some sites (supplied from WAPDA funds). The following activities had to be carried out prior to the installations: Identify Site Locations, Reconnaissance, BCHIL Procurement (for scaffolds, shelters, precipitation gauges, and snow pillows), Design Stations, Local Procurement, and Training. Vehicles and WAPDA personnel had to be available. With more than one crew in the field at a time, the scheduling of work and resources had to be done carefully. Although the construction time at each site was 2–3 days for civil installation and 1 day for electronics installation, an additional 2–3 days per site, on average, had to be added for transportation to and from the site.

Maintenance: Maintenance trips were made by WAPDA staff each summer to the existing remote sites to repair or replace faulty transmitters or sensors, recalibrate the sensors where applicable, and drain and recharge the precipitation gauges. The activity was carried out under the supervision of the WAPDA Project Director assisted by a WAPDA Senior Engineer. Normally one visit per year was made to each site. A maintenance trip log was prepared for each site. Because new stations were being added while existing stations had to be maintained, considerable pressure was placed on WAPDA resources. Pressures on WAPDA's staff to carry out the installation and maintenance work required staff to be away from home for several weeks. This often made it difficult for the families and was source of concern to WAPDA staff.

Installation and Maintenance Manuals:

Installation Manual: The draft Installation Manual was completed by WAPDA and issued by 31 March 1992. The manual provided detailed installation procedures for remote sites including trip planning, logistics, equipment and food lists, site layout and construction procedures, clean-up documentation, and safety requirements. BCHIL and the installation consultant reviewed the draft. WAPDA revised the draft based on annual field experience.

Operation and Maintenance Manual: This manual included details on the operating characteristics and specifications of each remote sensor and transmitter and detailed the procedures to be followed for the calibration, checking, and preventative maintenance for each sensor and transmitter in the field and in the office. This activity was carried out under the supervision of the WAPDA Project Director in Pakistan and reviewed by the Senior Hydrologist assisted by the installation consultant in Canada.

225 **Testing Equipment:** All sensors and transmitters were tested in Canada or the United States before they were shipped to ensure that they were operating properly. A major problem was discovered with the pressure sensors for the precipitation gauges prior to shipping them in 1993. Over half of them, when tested, did not meet specifications. This meant that at three of the stations installed in 1993, there was no precipitation gauge readings. Discussions with the supplier traced the problem to the manufacturer calibrating the instrument before encasing the electronics. During the encasement process, the pressure sensors went out of calibration. The only other problem detected was that the regulators on the solar panels were not properly connected. The testing of the Meteor Burst equipment included bench testing of the Master Station and five remote terminals and a set of sensors to ensure that the system worked properly. The problem with the shaft encoder was not detected at that time.

In Pakistan, equipment was tested to ensure proper operation and that it had not been damaged in transport. Each year, prior to installation, the equipment to be installed or to be used to replace faulty equipment in the field was tested prior to taking it to the field.

The "remote" station set up at the electronic office was used to analyze equipment problems, particularly the snow-pillow problem — the readings from the snow pillow took sudden large, unexplainable "jumps." Although some of these "jumps" occurred at the Lahore station, their cause could not be determined. In 1994, all of the interface units were modified by the addition of additional resistors to limit currents that were causing key components of the interface to burn out. Initially these modifications appeared to be successful, but over time, most of the interface units failed again. In addition to tests at the Lahore station, a potentiometer-type shaft encoder was tested at the Murala and Kohala stream gauge sites. (These sites were actually part of the flood forecasting system. Two Meteor Burst transmitters were tested at these sites to determine if they would work properly given their "proximity" to the Master Station. This was to determine their suitability with the Meteor Burst units for the flood forecasting system.) The potentiometer-type shaft encoder was also tested at the Shogran station, while a Campbell Scientific data logger with "up and down" counters was tested at the Shangla station. Both were tested in place of the interface between the snow-pillow shaft encoder and the Meteor Burst remote units, which had been determined as the source of the problem with the shaft-encoder readings.

240 Data Acquisition

241 **Design Interface System:** The main activity consisted of the conceptual design of the software for decoding, archiving, checking, and controlling the quality of the data. It was built on software used at B.C.Hydro and software prepared in 1991 for decoding of Argos data. Initially it was intended to use a commercial software package for data quality control; however, most packages, besides being expensive, also required annual licensing fees. This latter cost would have been difficult for WAPDA to manage. As a result, a decision was made to use the CLICOM software developed by the WMO for use in developing countries. This software is free and is supported by the WMO; however, it is based on older software and is not as simple to use as some commercial software. The final design of the interface system consisted of the following:

XTERM: This communications software is required to exchange data via a VHF link between the Master Station and the Operations and Control Offices, and to control the operation of the remote stations. It was delivered in 1993. The last upgrade was issued in April 1994.

Decoding Software: This is required to decode data received from the remote stations. The software was first prepared in 1992 but required a couple of upgrades during the years to: accommodate a change in data-delivery format brought about by the introduction of the MCC 545 unit; prescreen data to remove errors caused by incorrectly operating sensors and/or remote units; and adapt the files to the CLICOM Database input requirements.

Quality Control and Archival: Final quality control and entry of the data into a permanent database was accomplished using the software package, CLICOM, developed by the WMO. This package was delivered in 1993 but required substantial modification and development to make it suitable for project use. A geographic dictionary (which provides information on station locations, observing programs, and sensor detail) and a data dictionary system (which provides information on data type and observing frequency) were created in 1994.

Further developments to the SIHP-II CLICOM implementation were done after the January 1995 CLICOM course. Data Query Language (DQL) routines were prepared to facilitate report generation and to export data in the special formats required by the UBC Watershed Model and other software packages.

242 **Develop and Document Software:** Decoding software was based on software in use at B.C.Hydro and was first supplied in 1992. It was updated during 1993–1995 by

BCHIL and WAPDA staff to make it more friendly and to prepare data already decoded in a format suitable for CLICOM and the UBC model. The software was informally documented using comment statements and attachments to the Data Management System Procedures Manual.

Documentation for XTERM was supplied by MCC and for the CLICOM program by WMO supplemented by comments after the 1995 CLICOM course as noted in WBS 241.

243 Develop Back-up System: A tape drive was purchased to back-up data. Data back-ups were performed weekly to tapes, which were stored at the electronics shop (Model Town) because it was a separate location from the data-management office and would not be subject to the same hazards.

244 Test and Implement Interface: The interface, as noted above, was installed and upgraded in stages. Testing was mainly completed in 1993–1994, but each subsequent addition was tested by WAPDA and the Site Manager working together.

The implementation commenced with the 1992 decoding software. Error checking, quality control of data, preparation of daily and monthly reports, and archiving of data were carried out by the Data Management section. Data quality-control standards are contained within CLICOM and are documented.

250 Hydrologic Model

251 Review Data: Maps, hypsometric curves, stream-flow records, and meteorological records were analyzed to identify both the data that were available for the hydrologic model and any deficiencies that had to be overcome. It was carried out by the BCHIL Intermediate Hydrologist assisted by the BCHIL Site Manager and WAPDA staff.

All available data sources in Pakistan had to be identified. Nearly all suitable data had been catalogued by the Hydroelectric Planning Organization in collaboration with GTZ and were identified in the report "Inventory of Hydroclimatological Stations in Northern Areas of Pakistan." The report provided an identification scheme for stations and classified them by element. What was not identified was the status of the quality control of the data. In some cases, data processing and quality control were over 10 years behind. This meant that the amount of work required to prepare basin data was not fully recognized until much later in the project (see WBS 253).

252 Review Models and Select: The analysis of model requirements, review of literature, examination of existing watershed calibrations, review of data requirements of various models, and analysis of documentation was completed in early 1992. The report "Evaluation of Hydrologic Models" (BCHIL Report No. 011) dated April 1992 was prepared by a WAPDA team member in Vancouver, who with the assistance of BCHIL staff, developed model-selection criteria and reviewed 14 models relative to these criteria. The report recommended that two models be tested in Pakistan: the UBC watershed model, which had been partially developed in Pakistan; and the US Army Corps of Engineer's SSARR model. Prior to testing the SSARR model, WAPDA learned that attempts to apply the SSARR model by other agencies in Pakistan had not been successful. As a result, only the UBC model was implemented. Because the model was in the process of being updated, the project worked with three versions of the model: V2.0, V3.0, and at the end of the project V4.0 was introduced as part of a more user-friendly integrated inflow-forecasting system. Documentation of the various versions of the UBC model were provided by the author at the University of British Columbia. The model has been demonstrated to be a robust model, capable of producing good results even with less than optimal data.

253 **Prepare Basin Data:** Preparation of basin data had already commenced in 1991 but significant activity did not occur until September 1992. It included: defining sub-basins for the model; checking and preparing hypsometric, hydrometric, and meteorological data; and entering these data into the computer files for use in calibration and operation of the hydrologic model. This task proved to be much more difficult than estimated because much of the data received from other agencies had not been quality controlled. This meant that WAPDA had to work with these agencies, sometimes supplying human resources, to control the quality of the data before entering then into the SIHP database. This diverted effort that could have gone into modelling and calibration.

254 **Applied Research and Stream Gauging:** The applied research that was carried out was discussed in WBS 147, Identify Research Needs. The proposed stream-gauging work to obtain runoff data from the Deosai Plain and the Barpu/Bualtar Glacier was not done because of the pressures of higher priority work. The failure to obtain these data did not adversely affect the modelling program.

Equipment originally proposed to be purchased for this work was not purchased. The funds were transferred to the purchase of equipment for the remote data-gathering network.

255 **Modify and Calibrate Model:** Two main modifications were made to the UBC Watershed Model to meet project needs:

- the addition of a flow-routing routine to aggregate flows from the sub-basins and route them to Mangla and Tarbela dams and to the mouth of the Kabul River; and
- a snow-avalanche melt routine to compute melt from the significant quantities of avalanched snow in the Kunhar Basin.

The flow-routing routine was developed by Mr. Danyal Hashmi of WAPDA as part of his MASc training at UBC. The detailed programming of this routine to make it a part of the UBC model was carried out by UBC.

The snow-avalanche melt routine was originally added to V3.0 of the UBC model by the BCHIL Site Manager with assistance from WAPDA. A refined procedure was developed by Mr. Inam Ullah Khan of WAPDA as part of his MASc thesis at UBC. His procedure did not require modification of the UBC model. Instead it used output from the model as a basis for revised input to the model in a two-step process.

Because there was not a sufficiently long database from the project-installed high-elevation stations, the calibration was carried out with low-elevation data. Generally, the results were good (in fact better than expected) and demonstrated the robustness of the UBC Watershed Model — particularly the temperature and precipitation gradient routines. The calibrations should improve further when the high-elevation database is sufficiently long to allow calibration.

One problem with the use of the low-elevation data was that the meteorological stations where data resulted in the best calibration sometimes were not available in real time. Attempts by the Hydrology and Research Directorate staff to obtain these data on a real-time basis were unsuccessful. As a result, the Hydrology and Research Directorate staff had to recalibrate the model for at least three sub-basins to data from stations that did not provide as good calibration results but were available in real time.

Calibrate Model: This activity commenced October 1992 and was ongoing thereafter. Flows estimated by the model were compared with observed flows. Model parameters were adjusted to obtain the best agreement using statistical techniques such as least-squares error. Calibration logs were produced as sub-basin calibrations were completed to outline calibration results, problems, and expected future model accuracy. This work was carried mostly in Lahore by WAPDA staff under the direction of the BCHIL Intermediate Hydrologist, assisted by the BCHIL Site Manager.

In 1994, two WAPDA staff members familiar with calibration status and problems travelled to Canada to work on the calibrations and discuss problems with BCHIL staff and Dr. M.C. Quick, the designer of the UBC watershed model. This proved very beneficial to both Dr. Quick and WAPDA staff.

Use of the model required on-the-job training as well as courses on the UBC hydrologic model.

256 **Test and Document Model:** Testing of the model in its predictive mode did not take place until the Spring of 1996. This test was not a complete system test because some stream-flow and weather data required in real time for model updating were not yet available [WAPDA had to install stream gauge "punch-in" devices (Section 3.0) and finalize arrangements to obtain some required meteorological data in real time]. In addition, because of a lack of data from the Indus upstream of Kachura, much of which is in Indian-held Kashmir, this basin was calibrated as one basin. Eventually, when

project data become available, this basin will be calibrated as three separate basins. Finally, because of the problems in obtaining quality-controlled meteorological data for 1995 and 1996, the test forecasts had to be made without adjusting the basin to true watershed conditions (i.e., the model could not be fully updated to the start of the forecast period). The test of the seasonal forecast predicted a mean seasonal inflow to Tarbela of 63.72 MAF with a high of 74.11 MAF and a low of 56.3 MAF. The 95% confidence limits were estimated to be ± 2.99 MAF. The observed flow was 58.3 MAF, which was just outside the 95% confidence limits. Considering the limitations of lack of real-time data, lack of data from Indian-held Kashmir, and lack of meteorological data, the accuracy of the model is surprising. Over time, as the system generates its own data and the calibration improves, the accuracy will improve.

Documentation of the UBC Watershed Model is a responsibility of UBC and has been carried out on an ongoing basis as the model has been developed. Copies of the updated manual have been annotated by WAPDA staff.

270 System Operation

Studies of system operation were made initially by BCHIL in 1991–1992 as part of the work for the Project Direction and Review Report. Rather than examine the optimal operation of Mangla and Tarbela reservoirs, these studies focussed on examining whether operation of the reservoirs could be improved by the use of inflow-volume information. As noted in WBS 211, the studies identified significant potential operational improvements. Aside from improvements due to improved data, the studies identified the fact that Mangla and Tarbela power plants were not being operated to produce as much energy as they could during periods of water surplus (when they could displace significantly more expensive thermal-energy sources). WAPDA revised its operating procedures for these plants before the final report was issued.

In 1996, as part of his MASc studies, Mr. Asim Khan of WAPDA examined the optimal operation of Mangla and Tarbela reservoirs under two main scenarios:

- maximizing energy demands while treating the irrigation demands as constraints; and
- maximizing combined benefits from energy and irrigation.

At present, with irrigation having, by law, first priority on water use, only the first scenario is applicable in Pakistan. The results of the studies showed that for the 5-year period 1985–1986 to 1989–1990 there would be further increases in benefits of the project over those given in the Project Direction and Review Report.

At the completion of the project, WAPDA staff were working toward the development of a real-time operational model for the multi-purpose, multi-reservoir system in Pakistan.

A.3 300 Procurement

Major equipment purchases totalling approximately $1.43 million were made during the project. Almost $1.2 million of this was for computer equipment, sensors, towers and transmitters, 33 remote stations (23 installed plus spares for future installations with a "punch in" device for data at some stream-gauge sites), and the Meteor Burst master station. The major portion of this amount ($0.8 million) was for the Meteor Burst equipment and related training and spare parts.
Some equipment such as wind sensors, shaft encoders, pressure cells, temperature and relative humidity sensors, flow meters, and water-level sensors was specified by brand name (no alternatives allowed) to ensure that only known, proven equipment would be supplied for installation in the UIB. For these cases, preparation of specifications and issuing of tenders was for the purpose of obtaining the lowest price from available suppliers. IDRC approved all sole-source purchases.

Every attempt was made to purchase equipment that had been tried and proven in extreme weather conditions. However, in spite of this, there was a problem related to the snow pillow. The snow pillow and shaft encoder that senses the pressure exerted on the pillow were tested and proven in Canada. The Meteor Burst equipment was tested and proven in the Northwestern United States. The interface between the shaft encoder and the Meteor Burst transmitter, a supposedly relatively simple device, was unproven. This was where a significant problem occurred. This problem will be solved by changing to an older type of shaft encoder, proven to work with the Meteor Burst system, and by eliminating the interface.

341 **Prepare Specifications:** Specifications for remote-sensing equipment were based on B.C.Hydro specifications whenever possible. The specifications for the original purchases of test equipment in 1991 were updated for later purchases using experience obtained during the installations and subsequent operation. The specifications included where applicable, environmental and reliability requirements; interface requirements between components; requirements for spare parts, training and field repair of equipment, performance testing requirements, and delivery dates. The specifications were reviewed by WAPDA to ensure the equipment purchased would meet Pakistani conditions.

Specifications were prepared by the Senior Hydrologist, assisted by staff of B.C.Hydro's contract department, for the following equipment:

- Master Station transceiver, interface, and remote terminals;
- Sensors (wind, temperature, pressure, water level, relative humidity, and solar radiation);
- Snow pillows; and
- Scaffolds, shelters, precipitation gauges, and antifreeze.

Mr. D.J. Morgan of VIA-SAT Data Systems Inc. assisted with some of these specifications. The Project Manager prepared specifications for clothing and expedition equipment and vehicles. The Intermediate Hydrologist prepared specifications for computer equipment. WAPDA provided specifications for vehicle canopies and racks.

342 **Issue Proposal Calls:** This activity was carried out as required to meet installation-schedule requirements for the equipment identified in the specifications. It included:

- identifying and qualifying suppliers;
- issuing requests for tenders and receiving bids;
- delivering the accepted bids to BCHIL staff; and
- assuring that all such procedures met established B.C.Hydro guidelines for this activity when carried out in Canada. (It was agreed with IDRC that B.C.Hydro standards were acceptable for Canadian-originated purchases.)

For the Meteor Burst equipment, which was sole sourced, a quotation was requested based on the specifications, which was then used for negotiation with MCC.

For small purchases where no specifications were required, quotations were obtained by telephone or fax and not by a formal tendering process.

343 **Evaluate Proposals:** Each tender was assessed for adherence to specifications, quantity, cost, and delivery dates and compared with the other tenders to determine which tender should be accepted. It was not necessary to consider nonconforming tenders as all equipment was essentially off-the-shelf components. Memoranda were prepared to document the reasons for selection.

344 **Purchasing:** This activity included issues of purchase orders, payments, obtaining and forwarding donation certificates and invoices to WAPDA to facilitate clearance of goods in Pakistan, and arranging for delivery in Vancouver for all purchases, whether tendered or purchased directly. B.C.Hydro purchasing rules were followed.

Negotiations of the sole-source purchase of the Meteor Burst equipment reduced the cost from the original tender offer of approximately $950,000 (US) to $650,000 (US). Cost reductions were achieved in almost all areas of the contract.

345 **Local Purchasing:** This activity was mainly a WAPDA responsibility and included providing assistance to BCHIL, or purchasing on behalf of BCHIL (with IDRC-supplied funds); purchasing using local funds; and all local procurement activities. These included issuing requests for tenders, accepting bids, and purchasing and receiving according to WAPDA's purchasing guidelines. Local fabrication capability had to be demonstrated before purchases were made.

In addition to the main local purchases of scaffold towers, equipment shelters, computers, and propylene glycol for the snow pillows, many local purchases of tools and equipment had to be made in the market prior to the field season. WAPDA obtained prior BCHIL approval for all IDRC-funded purchases. Funds were provided from a project account in Pakistan.

346 Shipping and Delivery:
Shipping: This activity was directed by B.C.Hydro Purchasing Department and used the services of B.C.Hydro Stores and a freight forwarder (Danzas Canada Limited). It included:

- packing;
- arranging transportation by air;
- preparing bills of lading and any required clearance documents; and,
- arranging insurance for the shipment.

Except for part of the initial shipment, which was lost in Karachi, there were no major problems or delays in shipping. All shipping was by air freight to minimize potential loss and meet schedule requirements. The lost shipment was insured and replaced.

Delivery: This activity included the clearance, checking, and delivery of all shipments to the Lahore office. It was mainly a WAPDA responsibility assisted by the BCHIL Site Manager. Donation certificates, bills of lading, and invoices were sent to Pakistan before the equipment was sent. Clearance in Pakistan normally required from a few days to 1–2 weeks.

A.4 400 Training

440 WAPDA Training
Detailed lists of training are provided in the Annual Reports for the project. The discussion below highlights only training and evaluation in key areas and where there were problems and successes.

441 Country Briefing: Both Site Managers participated in the country orientation courses given by CIDA both in Canada and Pakistan. One of the in-Canada sessions was presented in Vancouver and the other in Ottawa. Both Site Managers considered the sessions worthwhile. No other BCHIL team members had the orientation sessions and with one exception had no problems in working in Pakistan. This was likely because there was usually another BCHIL team member with them. In addition, many of the WAPDA team had worked with Canadians and in many cases been to Canada, thus probably helping to make the transition to working in Pakistan easier. The one problem occurred with a proposed Site Manager who worked alone in Pakistan for almost 2 months at a time when morale at the Hydrology and Research Directorate (H&RD) was at a low ebb (while the Project Director was away for training and was temporarily replaced by a manager from outside H&RD). The proposed Site Manager had not been given the CIDA country training because he had been to Pakistan a year earlier, had apparently had no cultural adaptation problems, and the WAPDA Project Director suggested that the training was not necessary given the individual's previous exposure to Pakistan. In retrospect, although only one BCHIL staff member had problems with culture shock, it would have been beneficial, but expensive, for all BCHIL team members who worked overseas to take the CIDA training.

442 **Assess Training Needs:** Review and assessment of training needs was carried out on an ongoing basis. The assessment of training needs was an evolving process. Initially, key input came from BCHIL staff who knew what was required to operate and maintain all elements of the system. As WAPDA staff progressed, they understood better what was required and where there were gaps in their knowledge and what they needed to fill out their skill set so that they could carry out their responsibilities. During the latter stages of the project, the IDRC Training Consultant held "Training Seminars" at which WAPDA staff could define the status of their training and outline their future needs. This was a very useful process.

443 **Prepare Training Plan:** As noted in WBS 148, three training plans were prepared; an interim training plan prepared by BCHIL staff; a plan that was prepared by Nutec consultants and deemed unsatisfactory by the IDRC Training Advisor; and a plan prepared by Johnson Management that used much of the information prepared by Nutec but was too cumbersome for most people to use. None of the training plans were in the original project proposal or budget. Each plan had some useful points. From WAPDA's perspective a great deal of effort and money was spent on selecting the appropriate training consultant. They felt that better results could have been achieved with more direct involvement of WAPDA and BCHIL. Because of this, IDRC's approach to training was simplified after the Johnson Management Plan.

The interim plan was necessary because the project was on a very tight time line and some preliminary planning of training was necessary to ensure that WAPDA staff would be capable of participating in the design and conduct of the required tasks of installation and operation of the remote data-gathering system. It did not include much detail on the training or evaluation, but did outline the major subject areas and provide a direction.

The Nutec plan provided the most detailed review of the subject matter that WAPDA staff would need to know if they were to be able to design, operate, and maintain the project upon completion. The major flaw in the listing the subject matter was the unevenness in the level of detail of the required knowledge. This was particularly evident in the more theoretical areas such as hydrologic model calibration and operation. Nonetheless, it was the most complete listing of the required knowledge produced during the project. This aspect of the report probably provided the most benefit to the project of any of the three training plans. Another difficulty with this plan was the disagreement between the IDRC Training Advisor and Nutec as to whether the training could be competency based, given that measurable performance standards are very difficult to define in the more theoretical areas of hydrologic modelling and inflow forecasting. Finally, there was the question as to whether the Nutec plan was learner-centred and considered the knowledge base of the WAPDA staff (two WAPDA staff members had attended the session where the required knowledge base had been developed).

The final training plan, developed by Johnson Management was intended to deal with the above difficulties. The question of level of detail in the subject matter was dealt with by providing broader categories of required knowledge and leaving the detail to be provided by the trainers who would develop "key learning points." The competency basis of evaluating training appeared to be maintained in the Johnson Management report. Finally, in an attempt to have the training more learner centred, individual training plans were prepared. However, WAPDA said that they found this approach too complex. This group learning – evaluation approach was far more practical than the proposed highly personalized plans.

The IDRC Training Advisor developed a workshop approach that involved BCHIL and WAPDA staff who jointly reviewed progress (an evaluation) and defined future training needs. This was a more practical learner-centred method of evaluation.

444 **On-the-Job Training:** This training was given in Canada (generally design related) and Pakistan (generally applied). On-the-job training methodology consisted of:

- presentation of information;
- having WAPDA carry out tasks with less and less supervision in a work context;
- obtaining feedback through questions or assigned work;
- modifying and revising the presentation and work assignments as required to fill in weak areas; and
- ultimately monitoring performance in the field.

Verification of this training was provided by WAPDA staff demonstrating that they could carry out tasks without BCHIL assistance and that any documentation (diaries, field trip reports, calibration logs, etc.) was complete and accurate.

On-the-job training was the main training methodology used. Initially some H&RD staff expected BCHIL staff to carry out all the work until it was pointed out (and followed up by BCHIL staff) that their mission was to assist WAPDA to do the work; not do it for WAPDA.

On-the-job training was given in civil and electronic installation, operation and maintenance of the master and remote stations, reconnaissance, design of the project, operation of a maintenance facility, data decoding and quality control, hydrologic model calibration, and inflow forecasting. Coordination meetings, attended by staff at all levels, were part of the on-the-job training and helped broaden staff exposure to each other's requirements.

On-the-job training in Canada, where it could be provided, was more efficient because there were less distractions for WAPDA staff. However, the number of staff who could be trained in this way was limited by cost, and it did disrupt home life for the WAPDA trainees. It also exposed them to a different working environment and culture and probably helped them understand how and why BCHIL staff worked the way they did (much less top-down leadership).

Verification of all the training was provided by WAPDA staff members, which demonstrated that they could carry out all project-related activities.

445 **Academic Training:** University training was provided for three WAPDA staff members. One WAPDA engineer commenced training in Hydrology at UBC in January 1992. A second WAPDA engineer commenced training in Hydrology in January 1994. The third engineer commenced university training in January 1995 in Systems Operations.

Hydrology training included:
- fundamentals of hydrology (snow melt, rain or snow precipitation, glacial melt, infiltration, runoff phases, flood routing);
- design, calibration, and operation of hydrologic models;
- hydraulic fundamentals relevant to hydrology (open-channel hydraulics and transients); and
- research on routing of flows in rivers and melt from snow avalanches.

Systems operating training included:
- statistical analyses;
- risk analysis and optimization;
- economics; and
- research on optimal operation of the Mangla and Tarbela reservoirs.

The university training was integrated into the overall program very well. Each student carried out research and produced a thesis on a relevant, practical, topic for the project. The academic training and experience with the UBC Watershed Model helped to remove the feeling that the model was a black box and gave the WAPDA staff more confidence in their ability to calibrate and use the model. Based on the results for this project, the MASc degree, which requires a thesis was clearly better than a non-thesis, M.Eng degree.

As noted in WBS 167, there was a problem with the academic qualifications required by UBC, in addition to the language requirements. UBC required that each of the students have a Masters' degree from Pakistan before accepting them into UBC

Master's degree program or else they would only be provisionally accepted and have to take some undergraduate courses while maintaining a 'B' average. This increased the time they had to spend at UBC.

446 **Courses:** More formal courses were given on a wide variety of topics. Most of the courses were given as a supplement to, or to provide direction for, on-the-job training (i.e., courses on the UBC model, meteorology, instrument calibration, writing and editing). Others were given as prerequisites for other training (i.e., computer training) or for safety purposes (i.e., wilderness first aid, high altitude sickness). Specialized courses were given for installation, operation, and repair of the Meteor Burst equipment by the equipment supplier.

One key course, discussed in WBS 148 was the Train-the-Trainer course. This was one of the few courses that could really help with team building and getting each member to realize the importance of their work to someone else and the reverse. Although BCHIL staff continually tried to increase cross communication, this course offered one of the best ways to accomplish it.

Initially the idea of this course was treated with a great deal of skepticism by WAPDA staff. However, the training proved very worthwhile from three points of view, two of which were unexpected outcomes of the course. The process of training WAPDA staff to be trainers involved staff members telling other staff about their work. This assisted greatly with team building and helping other staff members see what importance their work had to others. The second benefit of the training was to improve the presentation skills of the WAPDA team members. This proved very valuable when they had to make presentations to senior management, government officials, or other dignitaries. The final benefit, which was the original intention, was the improved ability of WAPDA team members to train new or replacement staff. Subsequently, WAPDA staff asked for further training in this area. During one of her project-evaluation missions to Pakistan, VCC's Joan McArthur-Blair gave an additional 1-day Train-the-Trainer session.

The evaluation of the success of these courses came in the on-the-job training and the demonstrated ability of WAPDA staff to apply their knowledge to work-related problems.

447 **Monitor Training:** All training undertaken by WAPDA staff was monitored on an ongoing basis. About half way through the project, the IDRC Training Advisor began holding semi-annual workshops with WAPDA and BCHIL staff to evaluate the progress of training and reassess training needs based, among other things, on results of the training that was conducted. These workshops were a worthwhile effort because they gave individual WAPDA staff the opportunity to define their progress and express their needs.

460 BCHIL Training

461 Safety Training: BCHIL staff who were expected to go into the field received wilderness first-aid training and high-altitude sickness training from the Wilderness First Aid Society of British Columbia. Along with WAPDA staff they participated in a self-taught course in the use of the Gammow Bag (a portable hyperbaric chamber). This latter training proved invaluable when one BCHIL team member fell ill with apparent high-altitude sickness (later it turned out it may have been a mild heart attack). After a session in the Gammow Bag, the BCHIL team member felt better and was able to continue working.

Proposed training in glacier travel by an alpine guide was not required.

462 Training of Trainers: All the BCHIL team members along with a VIA-SAT employee took part in a 2-day Train-the-Trainer course in Vancouver. The Modelling Expert (Site Manager) also participated in the course given to WAPDA staff. The training provided useful advice on how to train WAPDA staff and confirmed much of what BCHIL staff had learned on-the-job. Such a course would have been even more beneficial if given at the start of the project.

Appendix B: Interim Progress Report (1 January to 30 June 1997)

Summary

The project was extended for 6 months (originally with no budget increase) to:

- solve the problem of data corruption caused by the interface between the snow-pillow shaft encoder and the Meteor Burst remote transmitter; and
- practice inflow forecasting on a real-time basis.

After the completion of the Annual Work Plan and the Project Review meeting in Lahore, some funds remained in the budget and an addendum to the Annual Work Plan was issued in March. This addendum included a final mission by the Modelling Specialist to introduce a more user-friendly inflow-forecasting system, which was developed partly with project funds, and to train WAPDA staff in the use of this system. In addition, approximately $10,000 worth of additional equipment was purchased for the project.

By the end of June, the following progress had been made:

- A proposal was made by MCC to WAPDA to supply the parts that were needed to convert the shaft encoders to a potentiometer of the type that had been successfully tested by WAPDA. The proposal was discussed with the electronics staff during their training at MCC as part of the Flood Telemetry project, but to date the Project Director has not confirmed acceptance of the proposal (see WBS 225).
- The Modelling Specialist completed his mission to Pakistan and successfully introduced the new user-friendly inflow-forecasting system. Two WAPDA staff members received detailed training on the system and were trained to convert the UBC model calibrations to Version 4.0, which is used by the forecast system (see WBS 255 and 260).
- During his mission, the Modelling Specialist assisted with the purchases proposed in the addendum to the Annual Work Plan. Some purchasing was subsequently completed by WAPDA staff (see WBS 300).
- Although part of the intent of the 6-month project extension was to provide an opportunity for WAPDA staff to practice inflow forecasting on a real-time basis, to date this has not been possible. This was due to problems in obtaining recent data for model "wind-up" and real-time data for model updating (see WBS 253 and 260).
- WAPDA held a workshop on project capabilities and outputs in February that was attended by government officials, officials of other agencies, and representatives of other agencies within WAPDA (see WBS 164).
- A draft of the Final Report on the project was prepared and circulated to IDRC and WAPDA for comment.

Project Progress (1 January to 30 June 1997)

This section follows the Work Breakdown Structure and describes the work undertaken during the final 6 months of the project. Only those WBS items that are relevant to the work carried out are discussed.

B.1 100 Management

140 BCHIL Management

143 Reporting: The Annual Report on 1996 progress was prepared and issued in April. A draft of the Final Report on the project was prepared during May and June and sent to IDRC and WAPDA for comment in June.

This report presents the progress of the project and the outputs and lessons that were learned against the WBS given in the Project Inception Report and in the Logical Framework Analysis. Comments from IDRC have been received and the revisions included in the draft sent to WAPDA. Comments have not yet been received from WAPDA.

145 Liaise With Other Institutions: The BCHIL Project Manager traveled to Pakistan to participate in the seminar on project outputs and capabilities held by WAPDA for potential users. He gave a brief presentation on the estimated economic benefits of the project.

The BCHIL Project Manager prepared an outline for IDRC on the WBS for activities 3 and 4 of the proposed follow-up project and developed a preliminary cost estimate.

The BCHIL Project Manager prepared an outline for a paper on project implementation and continued work on a paper on the training carried out for the project. Three other papers are also proposed:

- the economics of the project based on the optimization procedures developed in the project;
- the forecasting system developed for the project (experiences and difficulties); and
- experiences with the remote data-gathering system.

Potential coauthors for these papers are being sought among WAPDA staff.

160 WAPDA Management

164 Liaise With Other Institutions: A seminar on the project was held in Lahore in February for expected and potential users of project outputs, relevant government agencies, and CIDA representatives. Approximately 50 guests attended the seminar.

WAPDA prepared a manual on all aspects of the project for the participants. The seminar was presented very well by WAPDA staff and well received by the participants. Details of the seminar are as follows:

Seminar on SIHP-II: A seminar was organized in a local hotel on 20 February 1997 to introduce the possible beneficiaries of SIHP-II to the activities and capabilities of SIHP-II. In this regard, the following materials were prepared:

- a brochure that briefly described the activities of SIHP-II and the program and venue of the seminar;
- letters for all invitees to the seminar;
- presentation materials for the seminar; and
- a report on the activities of SIHP-II, published in February 1997.

Purchases: Dr. Hamed Assaf, Consultant with BCHIL, visited Pakistan from 5 June 1997 to 21 June 1997. During the visit, Dr. Assaf installed a Windows-based version of the "River Flow Forecasting System" on two computers. He also made the following purchases:

- computers;
- slide projector;
- glycol propylene;
- camp supplies for field trip;
- books;
- fire extinguisher for the Master Station; and
- mountain gear for five staff members.

B.2 200 Technical Assistance

220 Remote Sensing

224 Installation and Maintenance:

225 Testing Equipment: The problem with the snow-pillow data was reviewed by BCHIL with both WAPDA and MCC. Based on these discussions, MCC proposed to WAPDA that they supply the parts that were necessary to convert the shaft encoders to a potentiometer (analog) type from the present digital type. This solution bypasses the interface that is required for the digital output and has been successfully tested by WAPDA with the flood-forecasting system at the Murala and Kohala stream-gauge stations. WAPDA staff discussed this solution and its implementation with MCC staff during their training for the flood-telemetry system. The solution was accepted pending approval of the Project Director. To date, the WAPDA Project Director has not yet responded to the proposal by MCC. However, in late August, the Project Director submitted data for the station at Shogran. This station had a potentiometer-type sensor fitted to the existing shaft encoder. The Project Director questioned whether the potentiometer modification was operating satisfactorily. A review of the data from the two sensors, along with precipitation and temperature data, showed that although the two sensors tracked each other in a general manner, the existing shaft encoder showed a downward drift away from the potentiometer readings. This was believed to be an example of the "drift" problem with the existing shaft encoders. The evaluation was further complicated by major jumps in the data. The first was a sudden increase that could likely be attributed to the collapse of a bridge over the snow pillow that is caused by ice formation during periods when temperatures are near freezing. The second, more perplexing jump, was a sudden decrease in the snow-pillow reading, which indicated that the snow pillow may have failed near the top of the filter tube. This can only be checked by field measurements of the zero-snow fluid level in the manometer. If these measurements are not available, a field check of the snow pillow will be required. WAPDA have been asked to check this possibility. Until this check has been made, the proper working of the potentiometer-type sensor cannot be confirmed.

An alternative approach, proposed by MCC in 1996, was also tested. This system used an interface developed by Campbell Scientific Instruments to count the "up" and "down" counts separately. Because the wind caused vibration of the water surface in the snow-pillow stand pipes, the "up" and "down" counts increased almost continuously. This created problems in tracking the counts after the counters reached their maximum and "wrapped around." This potential solution was therefore rejected.

250 Hydrologic Model

253 Prepare Basin Data: The following work has been done on updating the basin data.

Weather Data: The historic database has been updated to the dates that appear beside their names.

Kachura	31 Dec 1996	Karimabad	31 Jan 1997
Dainyour	31 Dec 1996	Gilgit	28 Feb 1997
Gupis	28 Feb 1997	Besham Qila	31 Jan 1997
Astore	28 Feb 1997	Oghi	31 Jan 1997
Bagh	31 Jan 1997	Garhi Dopatta	28 Feb 1997
Rawlakot	31 Jan 1997	Palandri	31 Jan 1997
Dir	28 Feb 1997	Balakot	31 Dec 1997
Saidu Sharif	28 Feb 1997		

Flow Data: Flow data for the years 1993, 1994, 1995, and up to August 1996 have been punched and prepared for the Surface Water Hydrology Directorate for approval:

Indus at Kachura	Gilgit at Gilgit
Hunza at Dainyour	Indus at Shityal
Indus at Besham	Astore at Doyian
Siran at Phulra	Kunhar at Garhi Habib Ullah
Neelum at Muzaffarbad	Jhelum at Domel
Poonch at Kotli	Swat at Chakdra
Chitral at Chitral	Kabul at Kabul

Real-time DCP Data: The following activities were undertaken:
- all the DCP data received during the progress period has been decoded;
- reports and graphs of the DCP data have been prepared on a monthly basis;
- sensor status has been reported on a daily basis;
- improvements have been made to the decoding software to accommodate a new snow–water equivalent (SWE) sensor at the DCP Station Shangla and Shogran;
- the database has been updated using the WMO package CLICOM;
- forms have been prepared in CLICOM to export weather data from different DCP stations into UBC Watershed Model format; and
- SWE and precipitation graphs were prepared at the beginning of melt season to inform the Ministry about the possible inflows to Mangla and Tarbela.

255 **Modify and Calibrate Model:** As part of his mission to introduce the more user-friendly forecast system, the Modelling Specialist trained two WAPDA staff in the use of Version 4.0 of the UBC Watershed Model and in the conversion of the existing calibrations to Version 4.0. The conversion to Version 4.0 will ultimately be necessary because Version 3.0 is no longer supported by UBC. As well, the new forecast system is Version 4.0. In addition to the two staff trained by the Modelling Specialist in Version 4.0, two other WAPDA staff have experience with this version of the model as a result of their training at UBC.

Calibration work on the various sub-basins continued through the first half of the year. On the Mangla Basin, additional work concentrated on the snow-avalanche routine for the Kunhar Basin and on a recalibration of some low-elevation stations with more readily available data. In the Kabul Basin, calibrations were completed for the Swat and Chitral Basins. Details for each of the basins are given in the following sections.

Indus: The following sub-basins were recalibrated on the UBC Watershed Model Version 4.0. Their calibration status ranged from fair to good. This exercise was done to incorporate newly supplied data from the River Flow Forecasting Model."
- Hunza;
- Gilgit;
- Area above Kachura;

- Area between Kachura and Besham Qila;
- Astore; and
- Tarbela Local.

Calibration of Jhelum Basin: Sub-basins of the Jhelum River were calibrated the UBC Watershed Model (Version 3.0). Their status was as follows:
Kunhar Basin: weather data from Balakot for the period 1979–1985 was used with a coefficient of efficiency of 88.2%.
Neelum Basin: weather data from Balakot for the period 1979–1989 was used with a coefficient of efficiency of 85%.
Upper Jhelum Basin: included the drainage area in India and used weather data from Palandri for the period 1987–1994 with a coefficient of efficiency of 55%.
Lower Jhelum Basin: weather data from Rehman Bridge and Palandri for the period 1981–1991 were used with a coefficient of efficiency of 45%.

Calibration of Kabul River Basin:
Chitral Basin (drainage area of Chitral up to stream-gauging station at City of Chitral): calibrated using meteorologic data from weather station at Dir (elevation 1425 m) for the period 1979–1995.
Swat River Basin (drainage area upstream of the stream-gauging station at Chakdara): calibrated using weather data from Besham and Saidu Sharif for the period 1981–1990.

Hypsometric curves for the area bounded by international boundary between Pakistan and Afghanistan, excluding Chitral River at Chitral and Swat River at Chakdara, were prepared up to Nawshehra for the calibration of local Nawshehra Basin.

Analysis of flows and meteorological data collected at Chitral and Mir Khawi is in progress to find the flow contributed by the area in Afghanistan.

Mean monthly flows for Nawshera, Warsak, and Chakdara have been entered into the computer for further analysis to ascertain the flow contribution of the catchment area in Afghanistan.

Flow measurements have been entered to plot rating curves for the year 1993, 1994 and 1995 for Mirkhawi and Chitral.

260 Forecast Operations

Development of a more user-friendly flow-forecasting system was carried out at B.C.Hydro and partly funded by the project. WAPDA had previously reviewed and commented on the flow chart for the system.

In June, the Modelling Specialist travelled to Lahore to install the new system and train WAPDA staff in its use. The system will not become fully operational until all the sub-basins calibrations have been converted to Version 4.0 of the UBC Watershed model. WAPDA staff have been requested to forward their comments and any problems they encounter with the system to B.C.Hydro, which will make any required improvements.

A description of the model and its implementations in Pakistan is given below.

River-Flow Forecasting Model: A newly supplied River-Flow Forecasting Model is now installed on the two computers at WAPDA. The software required for the model is Windows 95 and Visual Basic 5.0. To provide these facilities, two new Hewlett Packard computers with the required software were purchased. The model also requires that all the contributing sub-basins that lie in any main basin are separately calibrated in Version 4.0 of UBC Watershed Model and that the Flow Model be rewritten in Windows-based Visual Basic 5.0 (currently it is in Quick Basic, which is DOS based). The consultant advised WAPDA to maintain the current Forecasting System using Version 3 of the UBC Watershed Model and to make a parallel arrangement for the new Flow-Forecasting System.

As required by the new Flow-Forecasting System, all the sub-basins that lie in the Indus main stem have been recalibrated to a fair degree of accuracy in Version 4 of the UBC Watershed Model. Rewriting of the Flow Model is under progress.

As was noted in WBS 253, a great deal of effort was put into updating the database. In spite of this, there is still a 4–7 month lag in the data required for modelling. As a result, it is still not possible to carry out real-time forecasting.

270 System Operation

Work progressed on updating the estimate of potential benefits to Pakistan from SIHP-II by using the most recent inflows, plant capacities, and unit efficiencies for the Mangla and Tarbela reservoirs. At the end of June, the status of this work was as follows.

Determination of Optimal Operational Strategies for Mangla and Tarbela Reservoirs: The joint operation of the Mangla and the Tarbela reservoirs is planned using the dynamic-programming approach to determine the optimal strategies of operation for the two reservoirs during the Kharif and Rabi seasons. The operation would be on a 10-day time step. The objective is to maximize energy production while meeting the irrigation demands of the provinces. The irrigation demands (called indents) established by the Indus River System Authority (IRSA) will be used in the optimization model. Initially, historic data from April 1994 onward will be used to check and compare the performance of the model. The following factors have to be taken into account in connection with the water released from the two reservoirs for irrigation purposes:

- Irrigation demands upstream of Chashma Barrage for Punjab (discharge in Thal Canal);

- Irrigation demands upstream of Chashma Barrage for Punjab (discharge in C-J Link Canal);
- Irrigation Demands downstream of Chashma Barrage for Punjab, Sindh, and Balochistan;
- Irrigation releases from Mangla reservoir for Punjab; and
- Discharge requirements of Rasul Barrage (10 000 CFS) to be released from Mangla.

Present Work: The Dynamic Programming Model (PK-ROM) was modified to achieve more accurate results by increasing the number of state variables (reservoir elevation in increments of 2 ft between minimum and maximum conservation levels) for Mangla and Tarbela reservoirs. However, this greatly increased the computational and memory requirements and the model could not be run, even for a 1-year operation on a 10-day basis, on a 486DX4 computer. A new faster machine (Pentium 166 MHz) has now been acquired for this purpose. The 1-year run on this computer took about 48 hours to complete. This hopefully will serve the purpose for the time being. The increased energy-generating capacities of the two power plants have also been taken into account. Presently, the model is being run to optimize the operation of the Mangla reservoir because there are problems with the calculation of energy production for the Tarbela Power Plant.

Results: The operation of the Mangla reservoir using the single reservoir Dynamic Programming Model for the period 1994–1995 to 1996–1997 has been analyzed. The results indicate an increase in the overall energy production without violating the irrigation demands. For example, the increase in the energy production (over actual) for the year 1995–1996 (Kharif and Rabi) was 7.0%.

Benefits: In spite of the rigidity of the constraints on water releases for irrigation, the dynamic-programming optimization indicates that increased energy benefits can be obtained by modifying the operation strategy in the case of Mangla reservoir. By taking a conservative value of a 5% increase in energy production (instead of 7.0%) to account for power outages for maintenance and repairs for Mangla Power Plant for the year 1995–1996, the increase in economic benefits in respect of energy generation amounts to Rs. 10.1 million (at Rs.0.30 per kWh) for just 1 year of operation of Mangla reservoir.

The modified operation of Mangla reservoir reduced peak flows and thereby reduced the risk of floods. This aspect of operation, however, depends on the reliability of forecasts.

Irrigation constraints for joint Mangla–Tarbela operation: In the modified version of the Dynamic Programming Model for the joint operation of Mangla and Tarbela reservoirs the constraints on releases of irrigation water have been formulated in the light of the provincial irrigation demands (indents) as received by IRSA on a 5-day basis. The provincial demands, as received by IRSA, are:
(a) I_T = Indents for Thal Canal;

(b) I_{CJ} = Indents for C-J Link Canal;
(c) I_{CP}(d/s) = Indents for Punjab downstream of Chashma Barrage;
(d) I_{CSB}(d/s) = Indents for Sindh and Balochistan downstream of Chashma Barrage; and
(e) I_{MP} = Indents for Punjab releases to be made from Mangla Reservoir.

Note that (a), (b), and (c) can only be met by releases from Tarbela reservoir (plus flows from the Kabul River); whereas, (d) can be met by releases from both Mangla and Tarbela reservoirs, provided that Mangla can release water in excess of (e).

Problems:

- The equation used to calculate energy production, which assumes an overall turbine-generator efficiency of 85%, is not giving satisfactory results in the case of Tarbela reservoir. The Tarbela Power Plant consists of 10 units of 175 MW each and 4 units of 432 MW each. The energy equation, in the case of Mangla reservoir, gives excellent results. The daily energy production in mkWh as calculated by the energy equation was compared with the actual energy production for the years 1994–1995 and 1995–1996. In the case of Mangla reservoir there was a difference of ±1% (on average) between the calculated and actual values. However, the energy equation overestimated the energy produced by more than 12% in the months of March, April, May, and June and underestimated by 4–6% in the other months.
- To determine the unit efficiencies for the Tarbela Power Plant, relevant data were not available from the different divisions within WAPDA in Lahore. The National Power Control Centre WAPDA (NPCC) in Islamabad was also contacted 2 months ago to obtain the required data regarding energy generation at the Tarbela Power Plant, but no information has been provided to date.

B.3 300 Procurement

Table B1 lists the items procured for the project in 1997. All procurement was carried out in Pakistan according to WAPDA purchasing procedures.

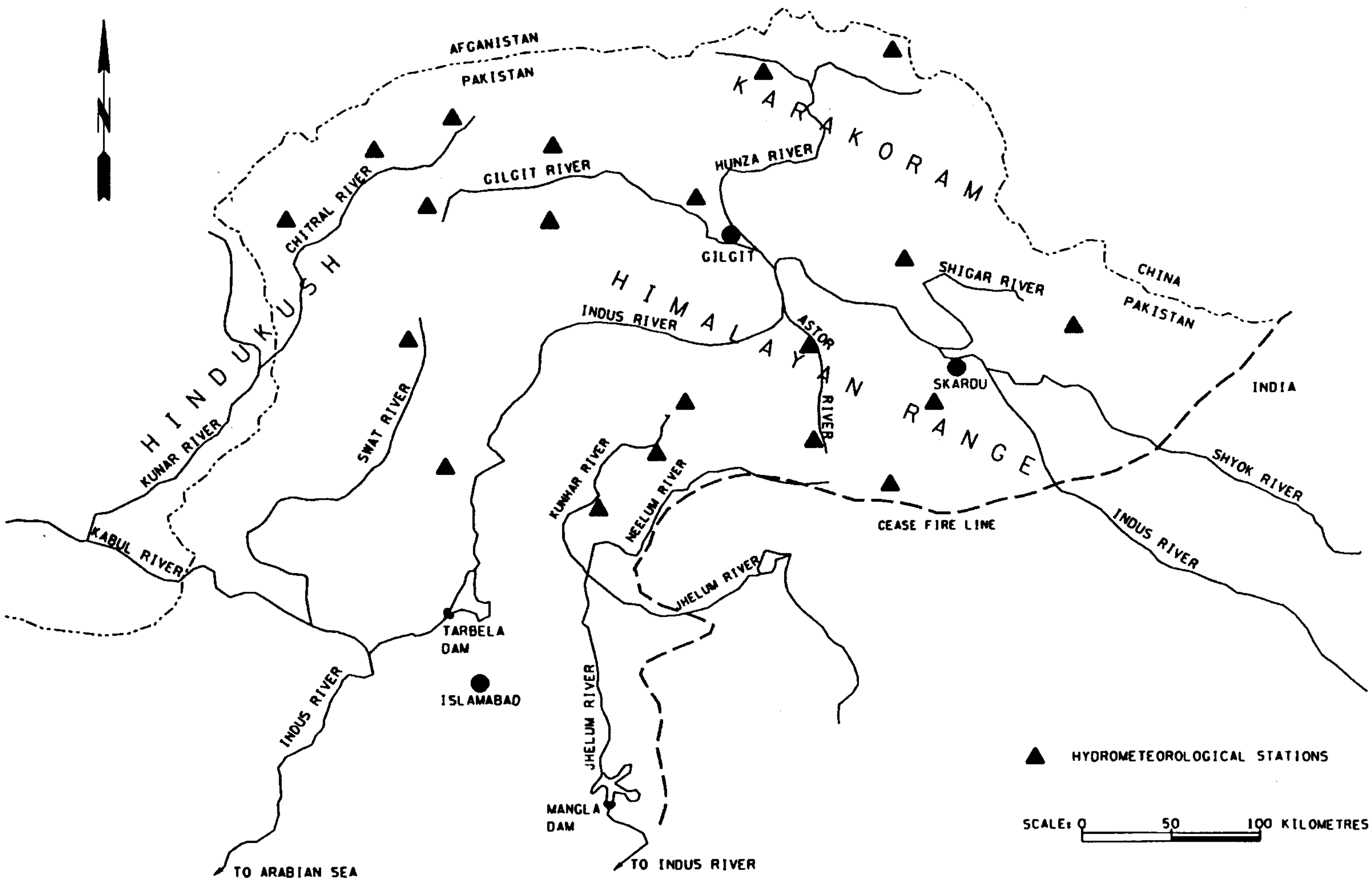
B.4 400 Training

As noted in WBS 255 and 260, WAPDA staff received training in the use of the new flow-forecasting system (5 staff members) and in the use of Version 4.0 of the UBC Watershed Model (2 staff members). This training was delivered by the Modelling Specialist during his mission to Lahore in June.

Table B1. WAPDA Equipment and Expense Requests (1997).

Quantity	Item		Cost (CAD)
	Equipment		
1	Computer - Pentium, 1.2 GB hard disk: 166 MHz, 32 MB RAM, keyboard, 3.5" DD, 14" SVGA monitor (Hewlett Packard)		3,980.00 (total for both computers)
1	CPU 486 DX4, 16 MB RAM, 1 GB hard disk, 3.5" DD, keyboard (Hewlett Packard)		
1	Bubble Jet Printer (Hewlett Packard)		500.00
1	Fire Extinguisher		130.00
1	Slide Projector		580.00
3	Solar Panels (30 Watt, 12–17 Volt, 250–1250 mA output) with regulator		1,460.00
7	Books (Operational Hydrology, Systems Analysis, Statistics)		165.00
Misc.	Mountain Gear for 5 people (boots, rain gear, fleece jackets)		840.00
3	Maintenance-free batteries with warranty		930.00
300 L	Propylene Glycol antifreeze		1,200.00
		Sub-Total	9,785.00
	Expenses		
Misc.	Assistance with field expenses (food)		500.00
		Total	10,285.00

Appendix C: Map of Upper Indus Basin



Appendix D: Logical Framework Analysis

NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE INDICATORS (OVR)	RESULTS	IMPORTANT ASSUMPTIONS
Project Goal (Program Purpose) To improve living conditions in Pakistan through increased energy production and farm output resulting from improved water management.	**Measures of Goal Achievements:** Increase energy production and/or agricultural production as a result of improved water management.	**Sources of Information and Methods Used:** This project has developed the capability in Pakistan to provide inflow forecasts that can be used to increase energy output and meet irrigation demands; however, to date, there is not a sufficient database to provide reliable forecasts. It is expected that about 2-3 more years of remotely gathered high altitude data will be required. It is estimated that annual net benefits from proper utilization of project outputs can exceed $20,000,000.	**Assumptions for achieving Goal Targets:**
Project Objective To improve the water resources management capability of WAPDA in the context of the Upper Indus River Basin.	**Conditions that will indicate purpose has been achieved:** **End of Project Status:** Monitoring stations and data transmission system being operated and maintained by WAPDA. Computer models forecasting seasonal and short-term flows of Indus, Kabul and Jhelum rivers used in planning.	**Monitoring and Evaluation Reports:** The monitoring stations and data transmission system have been maintained and operated by WAPDA since 1993. Data handling system, hydrologic and routing models, and a forecast system have been installed and calibrated. Trial forecasts have been made. Real-time forecasting (tests) have note yet been made due to difficulties in obtaining discharge and weather data required for model updating in real-time from other Pakistan agencies. This is being resolved by expanding the Meteor Burst systems to some stream gauge sites. Also, as noted above the required high altitude database required for inflow forecasting is not yet available.	**Assumptions for Achieving Purpose:** GOP continues to support program to improve water management in Upper Indus River Basin. GOP policies support the provision and access of inputs required by planners.
Outputs Improved hydrometeorological information-gathering system and developed a flow-forecasting model of the UIB from the improved database. Remote sensing equipment installed and operational. Data Acquisition interface established and operational.	**Magnitude of Outputs: Approx. Comp. Dates:** • Up to 30 remote stations in operation by Year 4. • Milestone report manuals on remote sensing (up to 5 reports by Year 3) • Computer programs and associated documents for data acquisition interface. (up to 3 by year 2) • Fully calibrated hydrologic model by Year 4, and up to 4 milestone reports by Year 3.	Nineteen remote stations were installed and operating by Year 4 and twenty-two by Year 6. The originally proposed 30 stations proved be an unrealistic number and even the final design number of 24 remote stations could not be installed due to the rugged terrain and lack of suitable sites in some proposed areas. Remote sensing (satellites imagery) was examined and deemed to be of too high a cost and insufficient value to justify installing remote sensing equipment.	**Assumptions for Achieving Outputs:** GOP commits financial and technical resources to implementing agency. Major political problems do not disrupt project due to proximity to disputed territories. WAPDA able to retain trained staff. No delays in approvals by IDRC/CIDA and WAPDA.

Logical Framework Analysis (continued)

NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE INDICATORS (OVR)	RESULTS	IMPORTANT ASSUMPTIONS
Fully operational hydrologic model for UIB. Preliminary development of an operational strategy. Trained personnel.	• Preliminary operational strategy developed and tested by Year 5. • 3 WAPDA Engineers/Scientists formally trained at Master's level. (By end of Year 4) • Up to 10 Research Officers and Engineers trained on the job. (By end of the Project)	The data acquisition interface was installed in stages. In year 1 an interface to decode data from the Argos satellite system (from remote test stations) was installed. In year 3 the data acquisition interface was upgraded for the Meteor Burst system with the addition of the X TERM and CLICOM software packages. Minor upgrading and improvements to documentation took place periodically thereafter. Initial calibrations of the hydrologic model began in year 2 and continued through to the end of year 6. Difficulties in obtaining data from other agencies in Pakistan (due to a backlog of unprocessed data) resulted in WAPDA staff having to assist these agencies to process the required data. The calibrations ranged from fair to excellent using low elevation data. It is expected that the future addition of high elevation data obtained by the project will improve these calibrations. A preliminary operational strategy was not developed until year 6 due to the delay in finding a suitable student for masters degree training. The delay was a result of difficulties in finding students who could meet the required University of B.C. entrance requirements. The three WAPDA engineers obtained Master of Applied Science Degrees by year 6. Eleven engineers/research officers and six technologists/sub-engineers were trained on the job by the end of the project.	
Inputs Technical assistance, training and equipment. Canadian funding ($5,624 million) through IDRC for equipment, technical assistance, training monitoring and evaluation; GOP funding ($0.7 million) through WAPDA for local personnel and logistical support. WAPDA personnel, equipment and support services.	**Implementation Target (Type, Quantity, Cost, Timing):** Project start: January 1991 Project complete: December 1997 BUDGET (uninflated) $1 x 1000 Equipment 1422 Services (BCHIL Fees & Disbursements) 3028 Training 206 IDRC Monitoring and Evaluation 968 Contingency 895 Total 6,519	The final project costs are[1]: Equipment $1,474,543 Services (BCHIL fees and & Disbursements) 2,896,649 Training 219,867 IDRC Monitoring and evaluation 979,646 Total $5,570,705 This is $53,295 less than the revised budget. The $895,000 Contingency Fund set-aside by CIDA remains untouched. [1]These were projected final costs at time final report was complete. As final costs are finalized (including production of this report), figures may change slightly (two or three thousand dollars).	**Assumptions for Providing Inputs:** CIDA and GOP funding are available on time. IDRC able to provide effective project management and technical assistance. WAPDA obtains extension to budget proposed in PC-1. CEA able to provide effective procurement services, technical assistance and training. WAPDA able to provide qualified staff and institutional support.

Appendix E: Work Breakdown Structure

PAKISTAN SNOW AND ICE HYDROLOGY PROJECT

100 MANAGEMENT

140 BCHIL MANAGEMENT
- 141 Administration
- 142 Supervision
- 143 Reporting
- 145 Liaise w/other Institutions
- 146 Participate in Project Review Meetings
- 147 Identify Research Needs
- 148 Recruit Personnel and Consultants
- 149 Site Management

160 WAPDA MANAGEMENT
- 161 Project Approval
- 162 Provide Personnel
- 163 Project Administration
- 164 Liaise w/other Institutions
- 165 Participate in Project Review Meetings
- 166 Site Management
- 167 Identify Trainees
- 168 Provide Support to Canadian Specialists
- 169 Infrastructure and Facilities

200 TECHNICAL ASSISTANCE

210 REVIEW & PLANNING
- 211 Project Direction & Review Rpt
- 212 Assess Satellite Imagery
- 213 Determine Transmission Mode
- 214 Review Sensor Performance
- 215 Assess Computer System Needs

220 REMOTE SENSING
- 221 Identify Site Locations
- 222 Reconnaissance
- 223 Design Stations
- 224 Installation & Maintenance
- 225 Testing Equipment

240 DATA ACQUISITION
- 241 Design Interface System
- 242 Develop & Document Software
- 243 Develop Back-up System
- 244 Test & Implement Interface

250 HYDROLOGIC MODEL
- 251 Review Data
- 252 Review Models & Select
- 253 Prepare Basin Data
- 254 Applied Research & Stream Gauging
- 255 Modify & Calibrate Model
- 256 Test & Document Model

300 PROCUREMENT

340 PROCUREMENT
- 341 Prepare Specifications
- 342 Issue Proposal Calls
- 343 Evaluate Proposals
- 344 Purchasing
- 345 Local Purchasing
- 346 Shipping & Delivery

400 TRAINING

440 WAPDA TRAINING
- 441 Country Briefing
- 442 Assess Training Needs
- 443 Prepare Training Plan
- 444 On-the-Job Training
- 445 Academic Training
- 446 Courses
- 447 Monitor Training

460 BCHIL TRAINING
- 461 Safety Training
- 462 Training of Trainers

Appendix F: Project Reports

BCHIL Project Documents

No.	Title	Date
BCHIL.001	Project Direction & Review Report	February 1993
BCHIL.002	Interim Review of Training	May 1991
BCHIL.003	Project Inception Report	July 1991
BCHIL.004	Review of Computer System	June 1991
BCHIL.005	System Evaluation and Design 23 March – 17 May, 1991	August 1991
BCHIL.006	Remote Sensor Site Selection	August 1991
BCHIL.007	Annual Report 1991	October 1991
BCHIL.008	Annual Work Plan 1992	March 1992
BCHIL.009	Installation of Climate Stations	March 1992
BCHIL.010	Transmission Mode Selection	March 1992
BCHIL.011	Evaluation of Hydrologic	April 1992
BCHIL.012	Upper Indus Basin Climate Network Station Locations	December 1992
BCHIL.013	Progress Report January to June 1992	August 1992
BCHIL.014	Annual Work Plan 1993	October 1992
BCHIL.015	Application of Remote Sensing to Runoff Prediction	October 1992
BCHIL.016	Interim Progress Report	December 1992

BCHIL.017	Hydrologic Model Selection Study and DCP Data Decoding Tour Report by G. Ali 21 January – 17 March 1992	December 1992
BCHIL.018	Site Selection and DCP Data Decoding Tour Report by M. Javaid 20 February – 31 March 1992	December 1992
BCHIL.019	1992 Annual Report	March 1993
BCHIL.020	Training Plan [Preliminary Work by NUTEC]	September 1992
BCHIL.021	Training Plan: Planning and conduct of individual training	July 1993
BCHIL.022	Interim Progress Report 1 January to 30 June 1993	July 1993
BCHIL.023	Annual Work Plan 1994	15 Nov. 1993
BCHIL.027	Annual Report 1993	1 Feb. 1994
BCHIL.028	Flow Routing Model for Upper Indus River (Thesis by D. Hashmi)	15 June 1994
BCHIL.033	Interim Progress Report 1 January to 30 June 1994	July 1994
BCHIL.034	Annual Work Plan 1995	October 1994
BCHIL.035	Annual Report 1994	February 14 1994
BCHIL.038	Interim Progress Report 1 January to 30 June 1995	July 1995
BCHIL.041	Annual Work Plan 1996	December 1995
BCHIL.053	Interim Progress Report 1 January to 30 June 1996	August 1996
BCHIL.055	Annual Work Plan	Nov. 1996

BCHIL. 055A	Addendum: Annual Work Plan	Mar. 1997
BCHIL. 056	A Two-State Deterministic Dynamic Programming Model for Optimising The Joint Operation of Mangla and Tarbela Reservoirs in Pakistan	Aug. 1996
BCHIL.059	1992 Renaissance Trip Diaries	Jan. 1997
BCHIL.061	1996 Annual Report	Mar. 1997
BCHIL.062	Final Report	October 1997
BCHIL.065	Interim Progress Report 1 January – 30 June 1997	October 1997

BCHIL Sub-Consultants and Other Reports

No.	Title	Date
1	Memorandum on Climate Station Location (1991)	May 1991
2	System Evaluation and Design Tour Report (by H. Afzal, A.A. Khan) (see BCHIL.005)	11 June 1991
3	Semi-Annual Progress – BCHIL	July 1991
4	Trip Report Pakistan (W. Bell, H. Walk, L.J. Parmley, D.J. Morgan)	5 November 1991
5	A Market Study on Meteor Burst Communications (by INTELECON)	January 1992
6	Monthly Highlights for Jan. 1992	12 February 1992
7	Monthly Highlights for Feb. 1992	5 March 1992
8	Monthly Highlights for March 1992	2 April 1992
9	Monthly Highlights for April 1992	14 May 1992
10	Monthly Highlights for May 1992	5 June 1992
11	Monthly Highlights for July 1992	17 August 1992
12	Monthly Highlights for Aug. 1992	8 September 1992
13	Training Plan Formulation and Evaluation (by Ferida Sher)	November 1992
14	Monthly Highlights for Oct/Nov 1992	December 1992
15	Periodic Progress Report January–August 1992 (by Danial Hashmi)	13 January 1993
16	Periodic Progress Report September–December 1992 (by Danial Hashmi)	29 January 1993

17	Monthly Highlights for Jan. 1993	26 February 1993
18	Trip Report – Renata Adamcik	17 March 1993
19	Monthly Highlights for Feb. 1993	22 March 1993
20	Terms of Reference: Confirmation of Learning attached to May's Highlights (by Via-Sat)	22 March 1993
21	Monthly Highlights for March 1993	7 April 1993
22	Monthly Highlights for April 1993	10 May 1993
23	Monthly Highlights for May 1993	7 June 1993
24	Monthly Highlights for June 1993	13 July 1993
25	Meteor Communications Corp. Factory Training February 22 – March 12, 1993 (by C.A. Roome)	June 1993
26	Train-The-Trainer Workshop	July 1993
27	Summary of Sensor/Maintenance Training in Lahore attached to July's Highlights (by Via-Sat)	8 July 1993
28	Trip Report Pakistan (L.J. Parmley) attached to September's Highlights	10 Aug. 1993
29	Monthly Highlights for July 1993	12 Aug. 1993
30	Periodic Progress Report January–June 1993 (by Danyal Hashmi)	August 1993
31	Monthly Highlights for Aug. 1993	7 Sept. 1993
32	Monthly Highlights for Sept. 1993	30 Sept. 1993
33	Monthly Highlights for Oct. 1993	17 Nov. 1993

34	Trip Report Pakistan October 1993 (R. Adamcik)	28 Oct. 1993
35	Trip Report Pakistan August 27 – October 18, 1993 (W. Bell)	4 Nov. 1993
36	Monthly Highlights for Nov. 1993	14 Dec. 1993
37	Monthly Highlights for Dec. 1993	11 Jan. 1994
38	Monthly Highlights for Jan. 1994	2 Feb. 1994
39	Reconnaissance: Hushe Valley August 26 – September 10, 1993 attached to January's Highlights (W. Bell and R.A. Adamcik)	14 Jan. 1994
40	Reconnaissance: Biafo Glacier Area September 12–21, 1993 attached to January's Highlights (W. Bell and R.A. Adamcik)	14 Jan. 1994
41	Rama Ridge Site Inspection 29 September 1993 attached to January's Highlights	21 Jan. 1994
42	Monthly Highlights for Feb. 1994	10 March 1994
43	Monthly Highlights for March 1994	14 April 1994
44	Monthly Highlights for April 1994	12 May 1994
45	Acceptance Testing and Training April 1–18, 1994 (Tom Donich)	May 1994
46	Monthly Highlights for May 1994	8 June 1994
47	Report of the Gilgit Valley Reconnaissance – May 1993 (by WAPDA)	15 June 1994

48	Reconnaissance Report 15 May – 30 June 1993 (M. Javaid)	15 June 1994
49	Monthly Highlights for June 1994	4 August 94
50	Monthly Highlights for July 94	15 August 95
51	Monthly Highlights for August 94	20 September 1994
52	Notes of debriefing for W.C. Thompson on 16 August 1994	29 September 1994
53	Monthly Highlights for Sept.–Oct. 1994	9 November 1994
54	Monthly Highlights for November 1994	5 December 1994
55	Monthly Highlights for December 1994	12 January 1995
56	Monthly Highlights for January 1995	13 February 1995
57	Report on CLICOM Training and Problem- Solving Mission Lahore, Pakistan, 9–19 Jan 1995 (by Tan Lee Seng)	February 1995
58	Tariq Masood's Management Course	March 1995
59	Monthly Highlights for February 1995	28 March 1995
60	Monthly Highlights for March 1995	6 April 1995
61	Monthly Highlights for April 1995	3 May 1995
62	Monthly Highlights for May 1995	6 June 1995
63	Economic Benefits of an Inflow Forecasting System in Pakistan (Publication: International Water Power and Dam Construction May 1993)	June 1995
64	Inflow Forecasting for Pakistan's Major Reservoirs (Publication: International Water Power and Dam Construction September 1994)	June 1995
65	Report on Delivery of VCC Train the Trainer for BCHIL and WAPDA by Joan McArthur-Blair	March 1995

66	Setting up of the Forecasting System - Memo	Nov. 1994
67	Monthly Highlights for June 1995	27 July 1995
68	Monthly Highlights for July 1995	8 Aug. 1995
69	In-Country Orientation Programme Newsletter	27 Aug. 1995
70	PC-I Proforma - revised (WAPDA) SIHP-II July 1989 to Dec. 1996 – March 1994	Oct. 1994
71	Monthly Highlights Aug. 1995	18 Sept. 1995
72	Monthly Highlights Sept. 1995	3 Oct. 1995
73	Participatory Self-Evaluation Design Facilitation Workshop (24–25 Oct. 1995) (J. McArthur-Blair and Marvin Lamoureux)	3 Nov. 1995
74	Monthly Highlights Oct. 1995	10 Nov. 1995

IDRC Monitoring and Other Reports

No.	Title	Date
IDRC.1	Report of a Trip to Pakistan October 25 – November 2, 1990	November 1990
IDRC.2	Monitoring Report (M. Morin) June 18 – July 4, 1991	4 July 1991
IDRC.3	Mission Report – August 14-31, 1991 (M. Morin)	9 September 1991
IDRC.4	Report of a Trip to Pakistan (S. Dufour) October 6–13, 1991	October 1991
IDRC.5	Report on the Annual Review Meeting and Field Excursion (M. Morin) October 8–9, 1991	28 October 1991
IDRC.6	Report Visit to Vancouver (M. Morin) November 25–30, 1991	3 December 1991
IDRC.7	IDRC First Annual Report Minutes of Meeting held 27 February 1992	February 1992
	Visit of Mr. Javed S. Qamar Report on Meetings at IDRC and CIDA (by M. Morin)	28 May 1992
IDRC.8	Mission Report (Pakistan) (M. Morin) July 1–18; 1992	July 1992
IDRC.9	Evaluation of Project Direction & Review Report (by G. Kite)	26 August 1992
IDRC.10	Mission Report (to Pakistan) (by G. Kite) June 22–26 and July 5–18, 1992	26 August 1992

	Minutes of the 1st Annual meeting of the PRC held at Lahore 8–9 October, 1991	18 November 1992
IDRC.11	Progress Report to CIDA 1 January – 30 June 1992	4 September 1992
IDRC.12	Trip Report (to Vancouver) (N. George) September 14–19, 1992	September 1992
IDRC.13	Minutes of Meeting held at the Headquarters of BCHydro September 17–18, 1992	3 October 1992
IDRC.14	Report of a Trip (to Pakistan) (S. Dufour) October 3–12, 1992	October 1992
IDRC.15	Trip Report (to Pakistan) (N. George) October 4–11, 1992	26 October 1992
IDRC.15a	Comments on NUTEC Draft Training Plan (by N. George)	26 October 1992
	Summary of Discussions of the 2nd Annual Meeting of PRC held at Lahore on October 6–7, 1992	6 January 1993
IDRC.16	Report of Visit to Vancouver (M. Morin) January 12–16, 1993	19 January 1993
IDRC.17	Trip Report (to Vancouver) (N. George)	21 January 1993
IDRC.18	Mission Report (to Pakistan) (M. Morin) February 5–17, 1993	10 March 1993
IDRC.19	Progress Report to CIDA 1 January – 31 December 1992	March 1993

IDRC.20	Report of a Trip (to Vancouver) (S. Dufour) April 25–28, 1993	3 May 1993
IDRC.21	Progress Report to CIDA by IDRC 1 January–30 June 1993	July 1993
IDRC.22	Monitoring of Training October 10–21, 1993 (N. George)	22 Dec. 1993
IDRC.23	Monitoring Report October 6–19, 1993 (S. Dufour)	23 Oct. 1993
	Summary of Discussions of the 3rd Annual Meeting of PRC held at Lahore on October 12–13, 1993	7 Jan. 1994
IDRC.24	Annotated Mid-Project Evaluation (S. Dufour, N. George)	7 March 1994
IDRC.25	Progress Report to CIDA by IDRC 1 January – 31 December 1993	January 1994
IDRC.26	Supplementary Support for Training – Proposal for CIDA (S. Dufour)	February 1994
IDRC.27	Mid-Project Evaluation November 1993 (L. Wynnyckyj)	Rec'd February 1994
IDRC.28 Restricted	Notes on Activities in Ottawa and Vancouver 28 May–9 June 1994 (N. George)	29 June 1994
IDRC.28	Memo abstract circulated to W.Bell/BCHIL, T. Masood/WAPDA, and N.George/IDRC	
IDRC.29a	Trip to Pakistan Senior Management Retreat at Bhurban (12–14 July 1994) (N. George)	3 August 1994

IDRC. 29b	Trip to Pakistan Training Review and Planning Workshop for Data Management/Modelling (18–19 July 1994) (N. George)	3 August 1994
IDRC.29c Restricted	Trip to Pakistan Summary of Activities (10–22 July 1994) (N. George)	3 August 1994
IDRC.30	Progress Report to CIDA 1 January–30 June 1994 (by IDRC)	16 August 1994
IDRC.31a	Monitoring Report 20 September – 6 October 1994 (S. Dufour and N.A. George)	24 October 1994
IDRC.31b	Monitoring Report Training Review and Planning Workshop for Electronics Group 5 October 1994 (N.A. George)	24 October 1994
IDRC.31c Restricted	Monitoring Report Summary of Activities 20 September – 6 October 1994 (S. Dufour and N.A. George)	24 October 1994
IDRC.32	First Review of Group "B" Projects Second Phase, February 28, 1994 (by S.Zia Al-Jalaly)	27 September 1994
IDRC.33	Group "B" Projects Review September 1994 (by S.Zia Al-Jalaly)	27 September 1994
	Summary of Discussions of the 4th Annual Meeting of PRC held at Lahore September 26–27, 1994	25 January 1995
IDRC.34	Progress Report to CIDA 1 January – 31 December 1994 (by IDRC)	28 February 1995

IDRC.35a	Monitoring Report to CIDA 8 6 March, 1995 (S. Dufour, N. Faruqui, and N.A. George)	23 May 1995
IDRC.35b	Monitoring Report to CIDA Senior Managers' Retreat 18–20 March 1995 (N.A. George)	25 May 1995
IDRC.36	Progress Report to CIDA 1 January – 30 June 1995 (S. Dufour)	August 1995
IDRC.37	Monitoring Visit to BCHIL, Vancouver 30 Aug. – 1 Sept. 1995 (S. Dufour)	5 Sept. 1995
IDRC.38	Writing and Editing Technical Documents (Michael Graham)	October 1995
IDRC.39	Monitoring Report – Training Review and Planning Workshop for Combined Project Team – 22 Oct. 1995 (N. George)	November 1995
IDRC.40	Report on the Participatory Self-Evaluation Design Workshop (24–25 Oct. 1995) (J. McArthur-Blair and Marvin Lamoureux)	November 1995
IDRC.41	Writing and Editing Technical Documents – Workshop Report (Michael Graham)	December 1995
IDRC.41b Restricted	Participant Evaluation – Writing and Editing Technical Documents (Michael Graham)	20 Dec. 1995
IDRC.42	Final Evaluation Design and Implementation Plan (J. McArthur-Blair and Marvin Lamoureux)	December 1995
	Summary of Discussions of the 5th Annual Meeting of PRC held at Lahore October 26, 1995	8 March 1996
IDRC.43	Progress Report to CIDA 1 January – 31 December 1995 (N. Faruqui)	March 1996

IDRC.44	Monitoring Visit to BCHIL, Vancouver March 15–19, 1996 (N. Faruqui)	28 March 1996
IDRC.45	Final Evaluation and Implementation Plan (J. McArthur-Blair and Marvin Lamoureux) Final Report (revised)	19 March 1996
IDRC.46	Trip Report - Pakistan 12–22 April 1996 (N. George)	July 1996
IDRC.47	Monitoring Report 14–28 April 1996 (N. Faruqui)	July 1996
IDRC.48	Advanced Train the Trainer April 1996 (N. George and J. McArthur-Blair)	July 1996
IDRC.49	Evaluation Implementation Report Stage One and Two 21 May 1996 (M. Lamoureux and J. McArthur-Blair)	July 1996
IDRC.50	Monitoring Visit to Vancouver August 8–18, 1996 (N. Faruqui)	Aug 1996
IDRC.51	Progress Report 1 January – 30 June 1996 (N. Faruqui)	Dec 1996
	Summary of Discussions of the 6th Annual Meeting of PRC held at Lahore September 23, 1996	Dec. 1996
IDRC.52	Progress Report 1 January – 31 December 1996 (N. Faruqui)	Apr. 1997
IDRC.53	Final Evaluation Report (J. McArthur-Blair and M. Lamoureux)	May 1997
IDRC.54	Final Report to CIDA	Dec. 1997