REPORT NO. P-6

ACTION PLAN
FOR OPERATIONS SUPPORT OF THE PEHUR HIGH-LEVEL CANAL (PHLC) PROJECT

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Submitted to

IRRIGATION DEPARTMENT
NORTH WEST FRONTIER PROVINCE

Prepared by

Gaylord V. Skogerboe
Zaigham Habib

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PAKISTAN NATIONAL PROGRAM
INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE
LAHORE

TABLE OF CONTENTS

1. PHLC PROJECT BACKGROUND [1]

1.1 OBJECTIVE

The Pehur High-Level Canal (PHLC) Project (Figure 1) aims to realize the full agriculture potential of about 100,000 acres (40,300 ha) of agriculture land. The Project will also increase agricultural production in the adjacent Swabi SCARP Project (SSP) area by supplementing its water resources, allowing additional irrigation development in about 10,000 acres (4,000 ha) of mainly rainfed land. In providing the physical facilities and developing system management procedures to manage the increased irrigation supplies efficiently and control the groundwater table, the PHLC Project will preserve the resource base for agriculture in the Project area. Specific measures have been covenanted to prevent the Project from aggravating waterlogging in the adjacent command area of the existing Pehur Main Canal. In addition, the Project will prepare a detailed program for land resource conservation for the catchment area of the Naranji Hill Torrent. The program will provide a long-term solution to the current problems in maintaining surface drains in part of the Project area and SSP.

1.2 SCOPE

To achieve its objectives, the proposed Project provides for: (i) irrigation and drainage improvement and development; (ii) measures for accelerating agriculture development capitalizing on improved irrigation and drainage conditions; (iii) a land resource conservation study; and (iv) environmental and benefit monitoring and evaluation. The Project will provide the necessary support for implementing these components, including consulting services, as well as staff, vehicles and equipment for Project supervision and administration.

1.3 IRRIGATION AND DRAINAGE IMPROVEMENT AND DEVELOPMENT

This component incorporates: (i) construction, remodelling and improvement of irrigation and drainage infrastructure; and (ii) optimization of operations and maintenance (O&M).

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1. The material in this section has been extracted from the Asian Development Bank (ADB) Report RRP:PAK 19141 dated November 1993 for the Pehur High-Level Canal (PHLC) Project, pages 11-13.

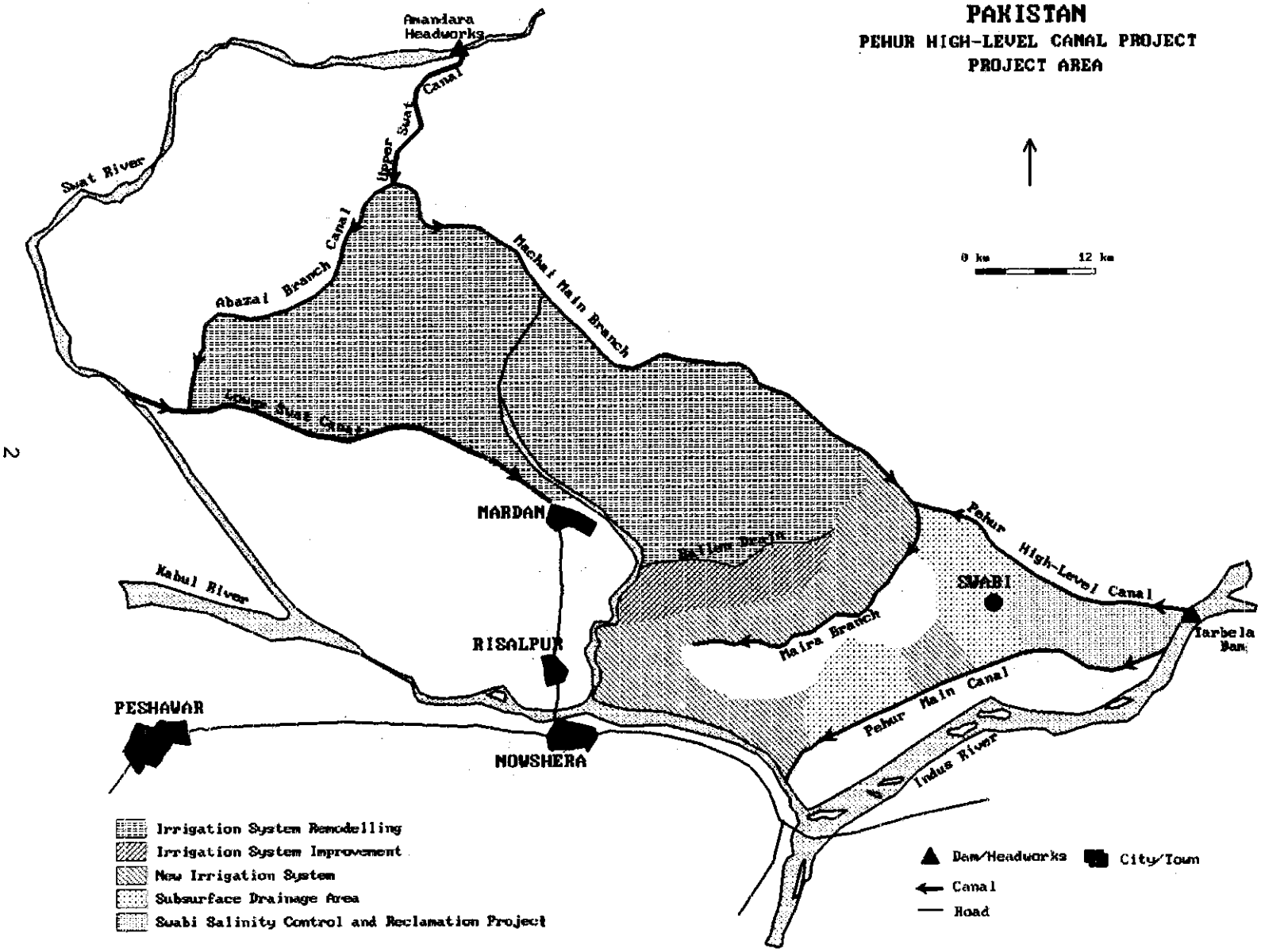

Figure 1. Pehur High-Level Canal Project Area.

1.3.1 Construction, Remodelling and Improvement

New irrigation facilities will be constructed, including: (i) the PHLC and the Gandaf and Baja Tunnels serving the entire Project area; and (ii) a distribution system for 4,500 ha in the Topi area. Most of the existing irrigation system below canal kilometer (km) 73.8 of the Upper Swat Canal's (USC's) Machai Main Branch Canal will be remodelled (i.e. its present canal capacity will be substantially increased). However, canals serving about 19,000 acres (7,600 ha) will not be remodelled but improved (i.e. their capacity will not be significantly enlarged) because present irrigation supplies are adequate and waterlogging in the adjacent command area of the Pehur Main Canal could be aggravated by further increasing present supplies.

The canals will be designed for a peak irrigation requirements of about 0.7 liters per second (l/sec) per ha (10 cusecs per 1,000 acres) and crop-based system management requiring the operation of the canal system at supply regimes ranging between 40 per cent and full design capacity. Existing watercourses with capacities above 4 cusecs (140 l/sec) will be converted into minors as discharges of this magnitude are difficult for WUAs to manage.

The existing Gandaf Tunnel will be extended through the right abutment of Tarbela Dam to supply water from the existing reservoir to the PHLC. The tunnel will be 3.9 km long with a 3.8-meter (m) internal diameter, and will have a conveyance capacity of 28.3 cubic meters per second (cumsec), which is 1,000 cubic feet per second (cusec). the Baja Tunnel will be 1.2 km long with a 3.5-m internal diameter. The PHLC, to be lined over its entire 26.2 km length, will be constructed for a capacity consistent with a capacity of 28.3 cumsec at the outlet of the Gandaf Tunnel. Four new distributaries will be constructed to irrigate the Topi area.

1.3.2 Optimization of Operation and Maintenance

The Project will provide for the development of operational procedures for crop-based operation of the linked USC and PHLC (USC-PHLC) main canal system and cost-effective maintenance procedures and methods for the Project's irrigation and drainage facilities. To optimize the use of the Indus and Swat Rivers water resources, and minimize the loss of hydro-power energy at Tarbela Dam, a comprehensive computer model of the USC-PHLC main canal system will be developed.

2. TERMS OF REFERENCE FOR OPERATIONS SUPPORT[2]

This proposal is concerned with the above subsection on "Optimization of Operation and Maintenance". Appendix 6 of the ADB report on PHLC describes the Terms of Reference (ToR) for Consulting Services. The third page (page 50) of this ToR contains Section F, "Project Commissioning and Operation and Maintenance-Irrigation and Drainage System", which contains seven items. Items 3, 4 and 7 are the subject of this proposal.

3. Develop a PC-based mathematical model of the PHLC and the Machai Main Branch of the Upper Swat Canal (USC) to:

   (i) optimize the use of the Indus and Swat River water resources while minimizing the loss of energy at Tarbela;

   (ii) anticipate the required canal operations for the USC-PHLC system under different discharge regimes; and

   (iii) prioritize canal maintenance for the USC-PHLC system.

   The model is to be prepared before the commissioning of the PHLC and will be refined, as required, during the course of the consultancy.

4. Develop operational procedures for crop-based operation of the PHLC system. The procedures are to be prepared before the commissioning of the PHLC and will be refined, as required, during the course of the consultancy.

7. Develop a PC-based program to monitor and evaluate the performance of the Project's irrigation and drainage system within and after the irrigation seasons and the maintenance conditions of the Project's irrigation and drainage facilities. Assist the system managers in the start-up of the monitoring program.

In addition, the International Irrigation Management Institute (IIMI) would provide support to the consulting firm responsible for designing and supervising construction of the irrigation facilities regarding Items 5 and 6.

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[2] The material in this section has been taken from the IIMI proposal dated January 1995 that is attached to the signed Agreement between the Irrigation Department, NWFP and IIMI, page 2-3.

5. Prepare an Operation Manual for the project's irrigation and drainage facilities specifying procedures and schedules for routine and emergency operation. The Manual will be prepared in draft from before the commissioning of the PHLC and will be amended, as required, during the last year of the consultancy.

6. Prepare a Maintenance Manual for the Project's irrigation and drainage facilities specifying benchmarks to be established, procedures and schedules for routine maintenance, maintenance equipment and materials requirements, and indicative costs.

3. MAJOR OPERATIONS SUPPORT ACTIVITIES

This action plan on "Operations Support for the Pehur High-Level Canal Project" has been developed using a strong collaborative mode with the Irrigation Department (ID), North West Frontier Province in implementing the operation of the USC-PHLC system. In addition, there would be considerable interaction with the consulting firm responsible for designing and supervising the construction of irrigation facilities.

3.1 WATER RESOURCES OPTIMIZATION AND ALLOCATION

3.1.1 Optimization of Water Resources

The water supply for the Upper Swat Canal (USC) comes from the Swat River, while the Pehur High-Level Canal (PHLC) diverts water from the reservoir created by the construction of Tarbela Dam in the 1970s on the Indus River. The Swat River is a tributary to the Indus River, with their confluence being downstream of Tarbela Dam.

Water diverted into PHLC is not available for producing hydropower just below Tarbela Dam. However, if water is passing over the spillways, then hydropower production would not be affected.

In general, the optimization becomes maximizing the water diversions from the Swat River, but taking into account the other water demands along this river. The crop-based water demands for the project area must also be established, along with the various losses, in order to ascertain the diversion requirements over time from the two water sources.

This optimization will be the responsibility of the IIMI Systems Analyst. A strong effort will be made to have a graduate student from NWFP, who works for ID, participate in this exercise. The small amount of funding shown in the budget for Years 2, 3 and 4 is for student support.

3.1.2 Water Diversion (Allocation) Model

The results of this optimization will be incorporated into a simple Water Diversion (Allocation) Model. This model software will be located at the Regulation Cell of the Northern Irrigation Circle, Mardan. Also, staff will be trained in using this model during Year 5 and again in Year 7.

3.2 CROP-BASED OPERATIONAL PROCEDURES

During Years 2, 3 and 4, it is proposed to fund a student from the University of Peshawar to develop allocations for crop-based operations. Again, a student would be sought who is on-leave from the Irrigation Department for an advanced degree. The purpose of these simulations would be to establish the flow velocity at numerous locations in the USC-PHLC System, which can then be related to sediment deposition. The IIMI Project Leader will work with the student's advisor in undertaking this model development.

The actual crop-based operation of the USC-PHLC system will involve determining the appropriate irrigation allocation over time at the head of each distributary and each direct outlet from a canal or branch canal. During peak crop water requirements, the irrigation channels will be operated at full supply discharge levels. When less irrigation water is needed, then rotational schedules between distributaries will have to be devised. Perhaps, in some cases, the discharge rates might be slightly reduced if this will not aggravate the problem of sediment deposition.

In this approach, the Head Regulators for each distributary becomes a water transfer point, where the appropriate quantities of water are delivered by the Irrigation Department to the farmers below. Thus, there is a need to have effective communications with the farmers. This can be facilitated by sharing actual information with them, such as calculated water allocations for the distributary, as well as how effectively these targets were achieved. Discussions will naturally follow regarding the appropriateness of the calculated allocations and inequities in actual water deliveries. This will place the Irrigation Department field staff in the role of providing technical assistance for the farmers under each distributary, which would include both irrigation and drainage practices. In addition, the field staff will become more sensitized to the problems being faced by groups of farmers.

During Year 5, the Irrigation Department and IIMI will complete the proposed procedures for crop-based operations. Then, during Years 6 and 7, these procedures will be refined based on actual operating experiences. The consultants from Delft Hydraulics, CEMAGREF and ISRIP will also advise on these procedures during their consultancies in Years 5 and 6, with the major emphasis being to minimize sediment deposition in the irrigation channels.

3.3 OPERATION OF USC-PHLC SYSTEM

This is the largest and most important component of the operations support activities. Also, the long-term success of this activity is absolutely dependent on highly effective field collaboration between ID and IIMI staff.

During Year 1, IIMI will interface with the design consultants. The design of the irrigation network will be placed in the computer model, "Simulation of Irrigation Canals (SIC)", that was developed by CEMAGREF, which is the French national research organization for water, agriculture and forests. This is the same model that has been used by IIMI for Stage I of the Chashma Right Bank Canal. The design of irrigation networks is commonly done using principles of steady-state hydraulics complemented with calculating backwater profiles. The advantage of SIC is that it simulates unsteady flow conditions, as well as steady-state flows. Surprisingly, many of the large canals in Pakistan are often operating under unsteady flow conditions. Thus, SIC is a valuable tool for simulating a variety of flow conditions that provides valuable insights for design modifications.

During Year 5, the SIC model for USC-PHLC will be updated according to "as constructed" drawings. The dimensions of the flow control structures will be field checked. For the USC system, discharge ratings will be undertaken for the flow control structures. For the larger flow control structures, the International Sedimentation Research Institute, Pakistan (ISRIP) of WAPDA will participate with the Provincial Irrigation Department (PID) and IIMI in developing discharge ratings.

During Year 6, the IIMI GIS unit will prepare maps of the PHLC project area using satellite imagery. This will provide a geo-referenced set of maps that are accurate at one point in time regarding cultivated area served by each distributary.

Before the start of the season, a seasonal plan needs to be formulated that gives the operational targets for distributaries and control structures. The plan can be developed, based on information about probable available water resources and agricultural production (cropping patterns and cropping intensities) the preceding year based on farmer interviews and the records of the Patwaris who collect abiana (land-water tax). These data need to be easily accessible for irrigation managers.

A PC-based Irrigation Management Information System (IMIS) will be developed for the USC-PHLC system to help irrigation managers to compare actual flows with targets (generated by the seasonal plan), enabling the manager to initiate actions to close the gap between the two. The information system has three components:

(a) data collection network
(b) communication system
(c) data processing unit

The data collection network (a) will target the following types of information: agricultural data (irrigated area/crops), (semi-) permanent hydraulic data (structure dimensions,/coefficients of discharge, etc.) and flow data (water levels converted into discharges) and data on available water resources (Swat River supplies, rainfall/snow melting in catchment areas, water level in Tarbela Reservoir). The intensity of data collection will be determined later by interacting with the irrigation managers and will depend largely on the information requirements.

Good communication lines (b) between the decision-making centre (manager) and the field (control structures) is a pre-requisite. In addition, the manager will need communication with Tarbela and with stations in the catchment area or upstream in the Swat River. Information needs to be relayed from the field to the manager, as well as instructions to be passed on to the field staff.

The processing unit (basically a database with computation modules) will store (semi-) permanent data, such as structure dimensions, while dynamic data (e.g., water levels) will be inputted routinely into the unit. Information regarding the actual flows in the system will be presented to the manager in a comprehensive and easily readable format, which can be used to better match actual flows with targets (operations). In addition to that, information will be available for ex-post evaluation. Managers will be able to evaluate the past season's/month's/ week's performance of their irrigation system through a set of appropriate indicators.

Finally, the information system will be linked with the SIC model. All the information stored in the database will be formatted to fit SIC's input requirement, thus facilitating the use of this simulation tool.

The PHLC is scheduled to begin operating during the kharif season of 1999 (Year 5)[3]. The primary focus during start up will be developing discharge ratings in a relatively short time period. Prior to obtaining these ratings, the SIC model will be operating using design discharge equations. Thus, PID and IIMI will be able to use SIC for operating USC-PHLC from Year 5 onwards, but the input data will be refined based on actual field measurements. However, the most important activity during Year 5 will be the actual operation of USC-PHLC by the Irrigation Department with backup support from IIMI. Year 5 becomes the year for refining the SIC model for PHLC and making field operational adjustments based on actual experience.

There will be two consultancies each year during Years 5 and 6. One consultant will be a person who is very much involved with the development of SIC at CEMAGREF in Montpelier, France. The other consultant will be a specialist in sediment transport from Delft Hydraulics, The Netherlands. Both consultants will work with IIMI and ISRIP on behalf of ID, with all organizations working side-by-side during these consultancies in order to share the expertise in order to arrive at better solutions.

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[3] At the time of revising this Action Plan during mid-1997, there are delays in beginning the construction of PHLC. Consequently, the commissioning of PHLC will be later than 1999, but when is not known. Thus, the original scheduling is being retained, but recognizing that modifications will have to be made at a future date.

3.4 COMPUTERIZED MONITORING AND EVALUATION OF SYSTEM PERFORMANCE

With all of the activities described above, the seasonal hydraulic performance of the USC-PHLC system can be easily accomplished as a computer printout. The maintenance conditions throughout the system will require some effort, but IIMI staff have been involved previously in computerized maintenance planning. Also, in order to prioritize canal maintenance, this type of effort is preferred.

For the long-term Monitoring and Evaluation (M&E), a Performance Assessment Program will be established. This will include, as stated above, the hydraulic performance of the irrigation channels, as well as distributary cropping patterns and cropping intensities. In addition, a sampling procedure will be devised for evaluating crop yields. Also, as a part of optimizing the use of water supplies in the Swat River, required watershed measurements for forecasting discharge rates will be investigated.. Because of the large water supplies available for this project, past experience has demonstrated that the surface drainage system tends to become overloaded during certain periods of the year. Thus, a few key locations will be identified among the surface drains for monitoring discharge rates, which will also be performance indicators for evaluating the effectiveness of the Crop-Based Operational Procedures.

The development of the M&E program will be the responsibility of the IIMI Irrigation Engineer/Associate Expert, who will work with a graduate student from NWFP. During Years 5, 6 and 7, when field operations are underway, quite a number of performance indicators will be evaluated. By Year 7, it will become important to have developed a manageable Performance Assessment Program that can be sustained on a long-term basis after project loan funds are no longer available.

3.5 PRIORITIZING CANAL MAINTENANCE

In the near future, the sediment load in the Upper Swat Canal (USC) will be reduced, while the sediment load will continually increase in the Pehur High-Level Canal (PHLC). A sediment excluder will be constructed at the headworks of the USC, thereby decreasing the sediment loads. However, at Tarbela Reservoir, sediment deposition is expected to reach the dam about the years 2005-2006. Thus, from the first year of operating PHLC in 1999, the sediment load will continually increase until 2006, when the sediment concentration will be essentially the same as run-of-the-river. Even then, the sediment load in the Indus River can be expected to slowly increase with time unless a major watershed management program is undertaken in order to reverse the present trend.

Once the SIC model has been calibrated for USC-PHLC,, then simple field measurements can be made to determine the depth of sediment deposition at various locations. This field data can be inputted to the SIC model. Then, simulations can be conducted wherein various sediment deposits are removed, or partially removed. After two seasons of operations, the Irrigation Department staff will develop a sensitivity about which locations are the most beneficial for removing sediment deposits in order to improve hydraulic performance.

3.6 OPERATION AND MAINTENANCE MANUALS

IIMI would assist the design and construction supervision consultants in their preparation of an Operation Manual and a Maintenance Manual. This would be accomplished by sharing with the consultants all of the IIMI outputs, but particularly from two activities: (1) crop-based operational procedures; and (2) prioritizing canal maintenance.

4. SCHEDULE OF ACTIVITIES

The work to be undertaken in implementing this Action Plan can be logically subdivided into three phases: Phase I, Unsteady Flow Simulations; Phase II, Operations Model Development; and Phase III, Field Operations. The schedule of activities for each phase is shown in Figure 2. Obviously, Field Operations is the major phase, with 85 percent of the budget allocated for this final phase (including equipment purchases for Phase III).

4.1 PHASE I, UNSTEADY FLOW SIMULATION

In September 1993, based on experiences at Chashma Right Bank Canal, the ADB Appraisal Mission decided that it would be advantageous to place the USC-PHLC system on the computer using the SIC model during the design stage rather than wait until PHLC was commissioned. Since this task had to be done anyway, there was an advantage in using an unsteady flow model to check the hydraulic design of PHLC and the remodelling of USC. Such a model is used to verify water surface elevations at design discharge rates for each reach to ensure adequate freeboard and for designing offtakes. Usually, a sensitivity analysis is done regarding hydraulic roughness, sediment deposition (however, SIC does not model sediment transport) and the stability of fairly rapid changes in discharge rates.

The work on Phase I got underway during February 1995. A few months later, the design consultants provided to IIMI the hydraulic data for the remodelling of Machai Branch Canal (see Figure 1). Later in the fall of 1995, this branch canal was being simulated on the SIC model.

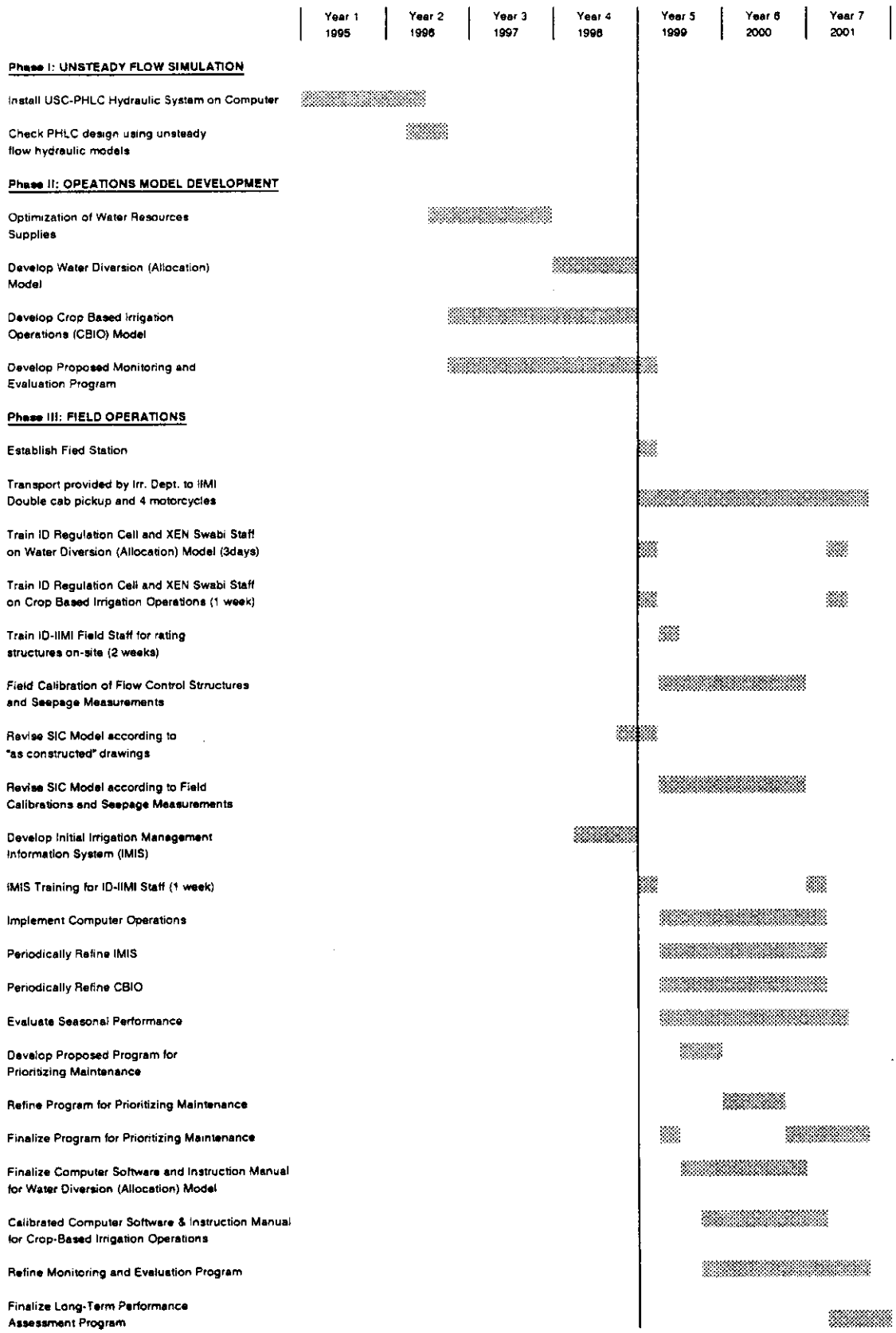

Figure 2. Schedule of Activities

The design consultants completed the basic hydraulic design for PHLC and the remodelling of Miara Branch Canal in December 1995. IIMI obtained this data in March 1996.

At a PHLC Design Workshop held in Peshawar during May 1995, the decision was made to incorporate automatic water level control gates. This necessitated that IIMI obtain appropriate computer software and a consultant experienced in using such a computer model. Arrangements were made in April 1996 and Dr. Kobkiat Pongput (Kasetsart University in Thailand) spent a few weeks in Pakistan during May 1996. In early June, he submitted a draft report, "Unsteady Flow Simulation of Pehur High-Level Canal Including Automatic Downstream Water Level Control Gates", which was shared with the design consultants.

During June 1996, the placement of Miara Branch Canal on the SIC model will be completed. The unsteady flow simulations will be completed during July 1996. A draft report for Miara Branch Canal will be submitted in late July to the design consultants for their review and comments, with a copy also to the Irrigation Department. This would complete the requirements for the design consultants regarding unsteady flow simulations.

A final report for Phase I (see Section 6, Outputs) will be completed by IIMI staff in late August and published in September 1996.

4.2 PHASE II, OPERATIONS MODEL DEVELOPMENT

For field operations during Phase III there are four models required. In addition, a Monitoring and Evaluation (M&E) program must be implemented in order to improve and refine the performance of the system. The relations between these models and their roles leading to the development of a Performance Assessment Program are shown in Figure 3.

The hydrodynamic model, "Simulation of Irrigation Canals (SIC)", is used for calibrating the irrigation channels (canal and branch canals). Under Phase I, this model has been calibrated according to the hydraulic design of PHLC and the remodelling of Machai and Miara branch canals. This model will be further refined during Phase III.

The Irrigation Management Information System (IMIS) is an operational model that will be jointly used by both ID and IIMI field staff during Phase III. This model has been developed through the collaboration between CEMAGREF (France) and IIMI. This model has been used for three years. During 1996, both CEMAGREF and IIMI staff are working together in upgrading this software package using other sources of funding. Under Phase-III, prior to implementing compute operations, an IMIS software package will be prepared that has been tailored to the USC-PHLC system (see Figure 2).

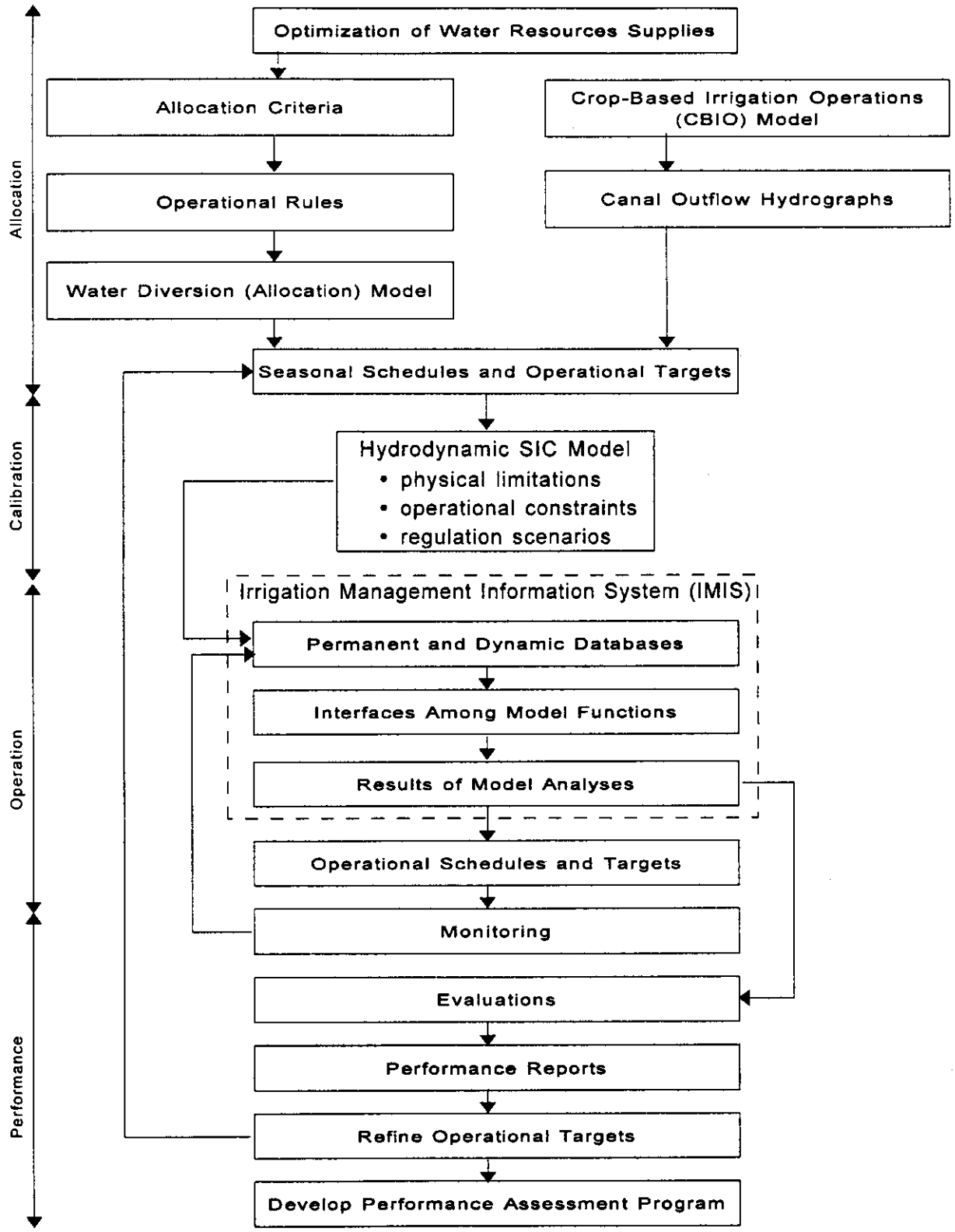

Figure 3. Schematic of Relations and Roles for Operations Models.

There are two allocation models to be developed during Phase II, one for defining inflow hydrographs into the USC-PHLC system, and the other for defining outflow hydrographs from the canal and branch canals. Work has already been done by the design consultants in optimizing the use of water supplies from the Swat River and Tarbela Reservoir on the Indus River. This work will be utilized, along with any other information required regarding the Lower Swat Canal (LSC), to develop a Water Diversion (Allocation) Model. The IIMI Systems Analyst will be responsible for developing this model. She may, or may not, use a graduate student to assist in this effort.

The second allocation model that must be developed under Phase II is a Crop Based Irrigation Operations (CBIO) Model for the USC-PHLC system. The principles for CBIO are known. Emphasis will be placed on operating distributaries and direct canal outlets at full supply discharge; however, there may be cases where it might be beneficial to reduce discharge rates, but only slightly (say 10-15 percent). The Project Leader will be responsible for developing this model. A student from NWFP, preferably an ID staff member, will assist in this effort.

As described in Section 3.4, a proposed Monitoring and Evaluation (M&E) program will be developed under Phase II, and then further refined into a Performance Assessment Program during Phase III. Performance Assessment is one of the four global research program of IIMI, which has strong support from the IIMI Board of Governors.

The results of IIMI's global research will be incorporated into the proposed M&E program. The IIMI Irrigation Engineer/Associate Expert will be responsible for developing this program. A graduate student from NWFP, preferably working with ID, if possible, will be used to assist in this endeavor.

4.3 PHASE III, FIELD OPERATIONS

Phases I and II are a prelude to Phase III. The vast majority of the effort under this Action Plan occurs during Years 5, 6 and 7 (1999-2001). This will be a strong collaborative field effort by both the ID and IIMI staff.

4.3.1 Establish Field Station

A field station will be established during the first three months of 1999 (January-March) somewhere in the vicinity of the project area. Most likely this station will be located in the town of Swabi. An Irrigation Engineer will be the Field Research Leader who will be in-charge of this field station. He will have four field staff to assist in the conduct of the field activities during Years 5, 6 and 7.

For this three-year period, the Irrigation Department will provide transport for this field station. One four-wheel drive double cab pickup and four motorcycles are specified in the signed Agreement, which is in accordance with ADB Report RRP:PAK 19141 dated November 1993.

4.3.2 Training for Allocation Models

A Regulation Cell is to be established in the Irrigation Department to assist in the operations of the USC-PHLC system. IIMI will interface with the staff in this cell regarding the use of the various models to be employed for improving operations. The initial training will be regarding the use of the Water Diversion (Allocation) Model and the Crop Based Irrigation Operations Model. Both models will be relatively simple, but will require some effort at first. However, for the training in Year 7, the use of these models is expected to be routine.

4.3.3 Field Calibration of Structures

At the beginning of the 1999 kharif season, IIMI will provide field training for the field staff of both ID and IIMI regarding the hydraulic calibration of flow control structures and measuring seepage rates. IIMI has previously provided this field training in Pakistan. Expectations are that the field discharge ratings will vary by 0-20 percent of the design discharge ratings. This does not imply that design procedures are faulty, but rather a recognition that there are many physical factors that influence the actual discharge rating which cannot be taken into account in the design.

All of the essential flow control structures will be calibrated jointly by ID and IIMI field staff. In addition, many reaches of the USC-PHLC system will be evaluated for seepage using the Inflow-Outflow Method. This is a big job that will be approached systematically and diligently. Some field staff from the International Sedimentation Research Institute, Pakistan (ISRIP) will participate by calibrating the larger flow control structures.

4.3.4 Revising SIC Model

Under Phase I, the SIC model had been calibrated based on the hydraulic design. During Phase III, this model will be modified according to "as constructed" details.

The most important calibration for SIC will be based on field measurements. The field calibration of flow control structures and field seepage evaluations, as described in the previous section, will be inputted into the SIC model. This will be supplemented by monitoring water levels over a period of time, most likely while evaluating seepage for a reach. Thus, the end product will be a hydrodynamic model that has been calibrated for actual field conditions.

4.3.5 Implementing the IMIS Program

Preceding the beginning of field operations under Phase III, an initial IMIS program will be formulated for the USC-PHLC system. This program will be periodically refined (like after each season) based on: (1) the development of actual field calibrations that are inputted into the SIC model; and (2) field operations experiences.

The initial IMIS training will be provided prior to the 1999 kharif season. Both ID and IIMI staff will be participants in this training, including staff of the Regulation Cell and the office of the XEN Swabi. This training will be repeated in Year 7, but will be given at other times if deemed appropriate.

The IMIS program is the "heart" of Phase III. Consequently, considerable effort will go into making the implementation of this program a successful venture.

4.3.6 Prioritizing Maintenance

A major maintenance requirement for irrigation channels in Pakistan is the removal of sediment deposits. Initially, the SIC model calibrated to constructed dimensions will be used to develop a proposed program for prioritizing maintenance activities related to sediment removal. This program will be refined using the SIC model calibrated for actual field conditions.

During canal closure early in Year 6 (2000), a sediment deposition survey will be conducted for the USC-PHLC system. This data will be inputted into the SIC model and the hydraulics of this sedimentation will be evaluated. Then, the removal of various sediment deposits will be assessed in the computer model in order to ascertain which sediment deposits, or portions thereof, have the most effect upon the hydraulics of the system. In this manner, the removal of various sediment deposits can be ranked, thereby resulting in a prioritized maintenance schedule for sediment removal.

Towards the end of Year 6, prior to canal closure, another survey of sediment deposition in the USC-PHLC system will be undertaken jointly by ID and IIMI. Again, this data will be inputted into the SIC model and the removal of various sediment deposits will be ranked in accordance with their effect upon the hydraulics of the system. Then, the Irrigation Department can decide how much of these deposits should be removed during canal closure.

Another sediment deposition survey will be jointly conducted by ID and IIMI field staff towards the end of Year 7, prior to canal closure. This data will be inputted into the final version of the SIC model, which will be retained by the ID Regulation Cell. Again, the removal of various sediment deposits will be ranked. Finally, the ID can establish the degree of sediments to be removed during canal closure.

4.3.7 Performance Assessment

The IMIS program is very good for evaluating the hydraulic performance of the USC-PHLC system. This information can be obtained as a printout from the IMIS model.

Under Phase II, a proposed Monitoring and Evaluation Program will be developed. During Phase III, considerable attention will be given to refining this M&E program. The proposed program will be reasonably comprehensive. During Phase III, relations will be sought among the many variables affecting performance so that the level of M&E can be minimized. In this manner, there will be a greater likelihood of sustaining a Performance Assessment Program after the termination of loan funds.

5. ORGANIZATION

5.1 IIMI OPERATIONS SUPPORT

For this project, the organizational arrangement for IIMI staff is shown in Figure 4. The Project Leader is assisted by an Irrigation Engineer/Associate Expert, who in turn is assisted by a Civil Engineer specializing in hydraulics, who is doing similar work with the Punjab Department of Irrigation and Power on the Fordwah and Eastern Sadiqia canals and their branch canals.

There are three organizations involved as consultants: (1) CEMAGREF, which is the French national research organization for agriculture, water and forests; (2) International Sedimentation Research Institute, Pakistan (ISRIP), which is a research unit of the federal Water and Power Development Authority (WAPDA); and Delft Hydraulics in The Netherlands. These consultants are all involved in Phase III, Field Operations. CEMAGREF is the developer of the SIC model and they are continually upgrading the capability of this model, so they will advise on any modifications to SIC based on the particular conditions being encountered in the USC-PHLC system. Delft Hydraulics will advise on matters related to the combination of hydraulics and sediment transport. ISRIP is involved with investigating sediment deposition and movement in Tarbela Reservoir, so they will advise on future trends in sediment concentrations, as well as participate in the deliberations regarding the combination of unsteady flow hydraulics and sediment transport.

The left column in Figure 4 under the heading, "Model Development", is involved with all three phases of this project, particularly the Systems Analyst, while the Computer Specialist is involved with Phases I and III. The Student Support will occur during Phase II, while the GIS-Remote Sensing occurs during Phase III (Year 6) in preparing maps using satellite imagery that provide the cultivated area for each distributary in the PHLC project area.

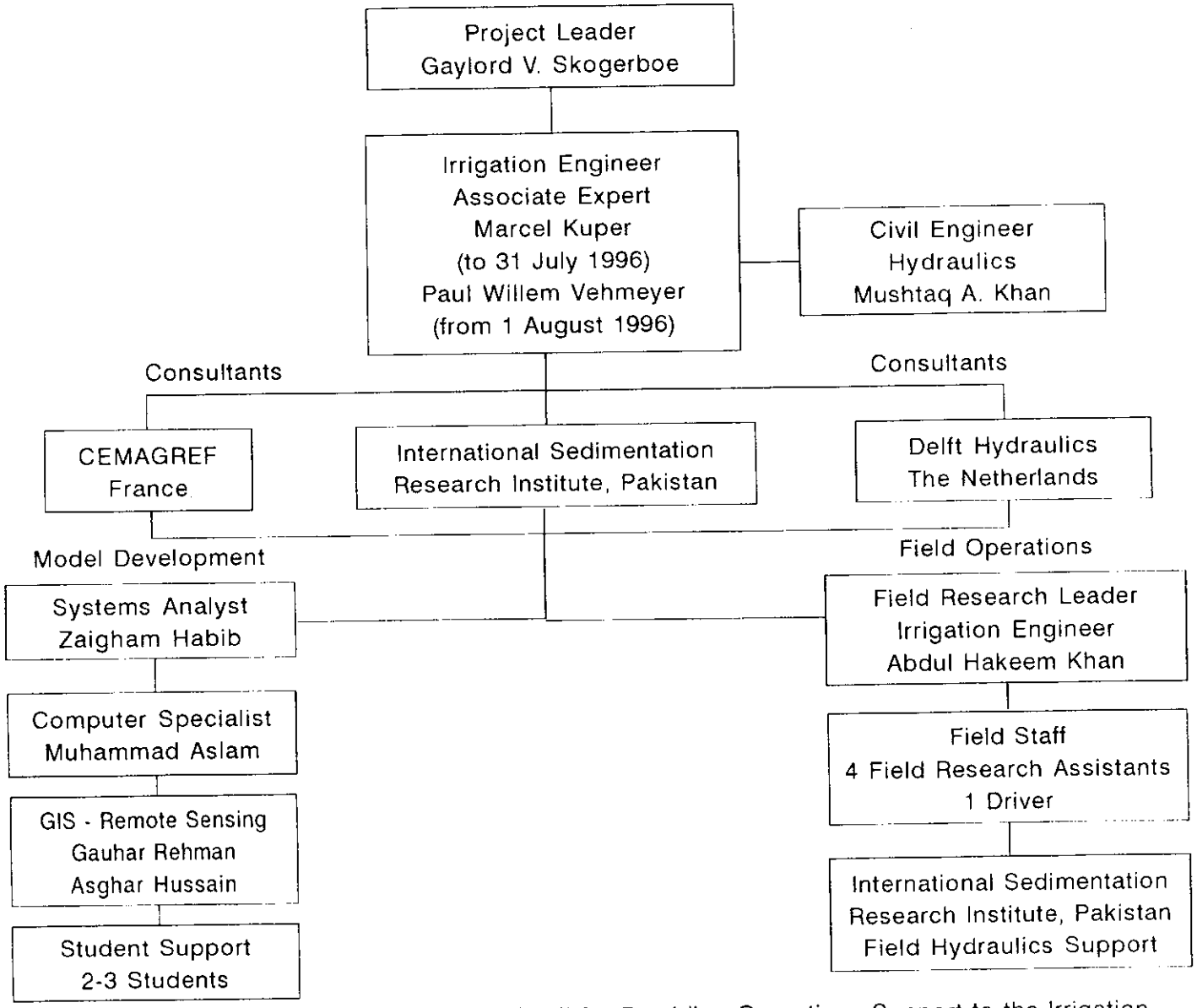

Figure 4. Organizational Arrangement of IIMI for Providing Operations Support to the Irrigation Department, NWFP

The right column in Figure 4 under the heading, " Field Operations", will be formed at the very beginning of Phase III. This staff will be located at a Field Station in the vicinity of the project area, and most likely at Swabi. The Field Research Leader was earlier involved with IIMI at D.I. Khan for the Chashma Right Bank Canal Stage I; presently, he is located at Hyderabad doing similar work with the Sindh Department of Irrigation and Power. The role of ISRIP is to assist the Field Research Leader in the hydraulic calibration of the larger flow contort structures in the USC-PHLC system.

5.2 NORTHERN IRRIGATION CIRCLE, MARDAN[4]

5.2.1 Present Organization

As shown in Figure 5, there are three Irrigation Divisions, plus the Canal Collector for Remodelling of Lower Swat Canal, in the Northern Irrigation Circle, Mardan. The Mardan Irrigation Division manages the hydraulic operations for the Lower Swat Canal (LSC). The Malakand Irrigation Division manges the Upper Swat Canal, plus the bifurcation structures for Machai Branch Canal and Abazai Branch Canal. This division manages all of the Abazai Branch Canal and roughly the upper one-third of Machai Branch Canal.

The Swabi Irrigation Division manages the hydraulic operations of the lower two-thirds of Machai Branch Canal. Also, they manage the system below the bifurcation of Machai Branch Canal into Maria Branch Canal, Pehur Branch Canal and Old Indus Branch Canal. In addition, this division manages the Pehur Main Canal, which lifts water from the Indus River below Tarbela Dam.

5.2.2 Proposed Reorganization

When PHLC becomes operational, there will be a need to establish a new subdivision called Pehur HLC Subdivision, with the present Pehur Sub-division redesignated as Pehur MC Sub-division. As shown in Figure 5, the Malakand Irrigation Division has two subdivisions, while Swabi Irrigation Division has four subdivisions. Adding the Pehur HLC Subdivision would result in a total of seven subdivisions for the USC-PHLC system.

The first inclination would be to establish an additional irrigation division. However, the establishment costs are somewhat high, particularly given the present situation in which the emphasis is to economize on O&M costs, while improving the performance of the system. This requires increased productivity from the field staff. There is a recognition that this can be achieved through better communications and adequate transport.

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[4] The material in this section has been extracted from a report, "Reorganization of Northern Irrigation Circle Mardan" issued by the Superintending Engineer for this Circle on 21 May 1997.

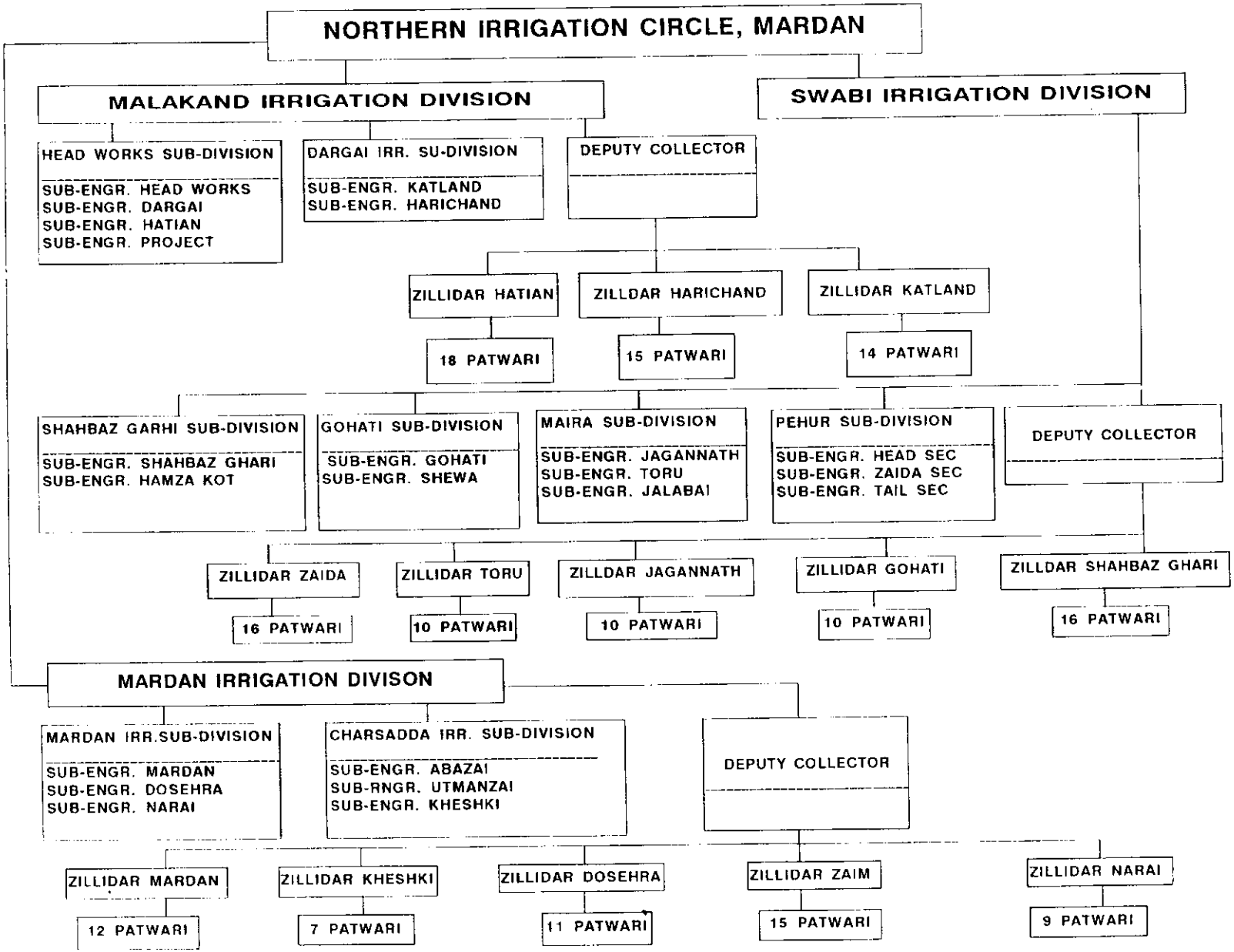

Figure 5.Present O&M Organization for Northern Irrigation Circle, Mardan.

If the present situation regarding communications and transport can be improved, then it becomes quite feasible to retain only the present two irrigation divisions.

For the Swabi Irrigation Division: (1) the Maira Irrigation Subdivision would remain as presently organized; (2) the Pehur Irrigation Subdivision would retain its present organization, but would be renamed Pehur MC Irrigation Subdivision; (3) Shahbaz Garhi Irrigation Subdivision would have the Sub-engineer Shewa added to their roster; and (4) the Gohati Irrigation Subdivision would be renamed the Pehur HLC Irrigation Subdivision, which would retain the Sub-engineers Gohati and add two sub-engineers, one located at the upper end of PHLC and the other located somewhere along the middle reach of PHLC. The proposed organization is depicted in Figure 6, including the Regualtion Cell. The Regulation Cell, proposed initially to be set up at Mardan is now being proposed at Gohati under the control of Swabi Irrigation Division.

The staffing requirements for the Regulation Cell to be located in the Operations Center, plus the staffing for two Sub-engineer Offices have been developed. The equipment requirements for improving O&M practices in the Northern Irrigation Circle, Mardan includes the renovation for an Operations Center for the Regulation Cell, two Sub-engineer offices, along with communications and transport equipment for these offices and other Sub-divisional Offices.

5.2.3 Regulation Cell

5.2.3.1 Purpose. The purpose of the proposed Regulation Cell is to facilitate improved operations for the USC-PHLC system that includes crop-based irrigation operations that enhance hydraulic performance in a manner that will reduce waterlogging and surface drain discharge, while increasing agricultural productivity.

5.2.3.2 Activities. The Regulation Cell would function as an Operations Center for the Northern Irrigation Circle, Mardan located at Gohati under the charge of XEN Swabi. However, the initial focus for about three years after PHLC becomes operational would be the USC-PHLC system.

The staff of the Regulation Cell will be trained in the use of the Water Allocation Model to be developed by IIMI. This training is scheduled in the IIMI contract. In addition, any techniques for forecasting river discharges based on watershed measurements, including present work by WAPDA on this subject, will be transferred by IIMI staff to the Regulation Cell staff.

The development of the crop-based irrigation operations (CBIO) procedures is the responsibility of IIMI. Their contract provides for training the staff of the Regulation Cell in these procedures. Then, when PHLC becomes operational, CBIO will be implemented by the Irrigation Divisions and their Sub-divisional Offices in the USC-PHLC system. Based on field operating experiences, the CBIO program will be modified,

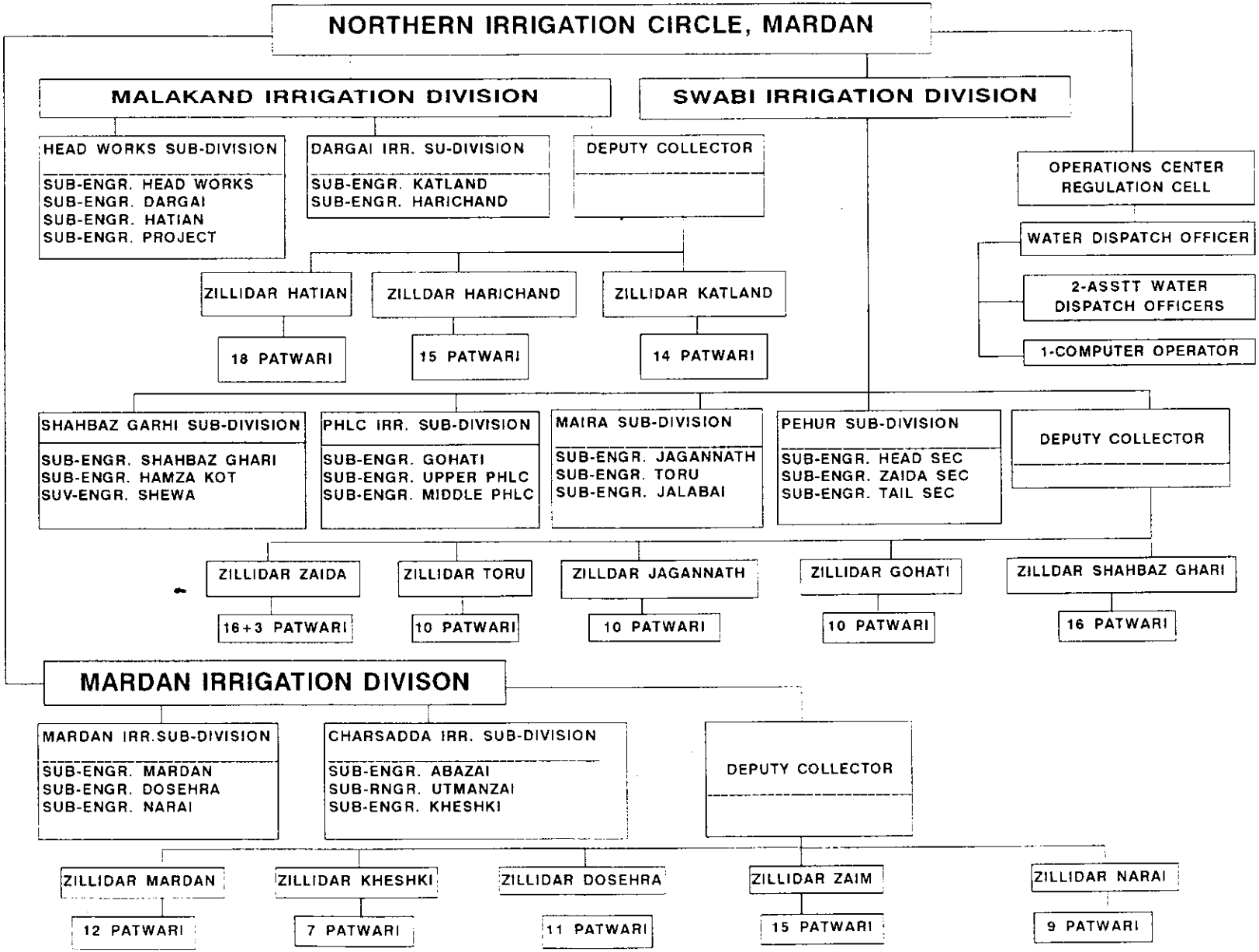

Figure 6. Proposed O&M Re-organization for Northern Irrigation Circle, Mardan.

which will be done jointly by staff of the Regulation Cell and IIMI, with advice from the Superintending Engineer (SE), Executive Engineers (XENs) and Sub-divisional Officers (SDOs).

The Irrigation Management Information System (IMIS) is the most important program for improved operations of the USC-PHLC system. This is the primary tool for the Regulation Cell in functioning as an Operations Center. The IMIS program will be linked from the Regulation Cell to the Irrigation Divisions and their Sub-divisional Officers.

An important input into IMIS is the use of a hydrodynamic model. The designed PHLC and proposed remodeling of USC has already been placed in such a model by IIMI during 1995-96. When the construction activities are completed, then this hydrodynamic model will be modified with any changes in the design that occurred during construction. Then, this revised hydrodynamic model will be used to develop the initial operational version of IMIS. Prior to operating PHLC, IIMI staff will provide training in the use of IMIS to ID staff, including XENs, SDOs and Sub-engineers.

During the first two years of operating PHLC, all of the flow control structures in the USC-PHLC system will be jointly calibrated by ID-IIMI field staff. The results will be inputted into the hydrodynamic model so that it can simulate actual hydraulic conditions in the field. These simulations will be used to further improve the IMIS program.

After another year of operating the USC-PHLC system, the field experience gained by ID staff should result in a highly reliable IMIS program that is very beneficial. Then, the staff of the Northern Irrigation Circle, Mardan may decide that they would like to expand the IMIS program to the Lower Swat Canal (LSC); certainly, ID staff would have sufficient field experience for such an endeavor.

Prior to PHLC becoming operational, IIMI staff will develop a proposed Monitoring and Evaluation (M&E) program. When the USC-PHLC system becomes operational, considerable effort will be made by staff of the Regulation Cell and IIMI to refine this M&E program. The IMIS program is very good for evaluating the hydraulic performance of the system, which can be obtained as a printout from the IMIS model. Relations will be sought among the many variables affecting performance so that the level of M&E can be minimized. In this manner, there will be a greater likelihood of sustaining a Performance Assessment Program after termination of loan funds.

During the first canal closure after the PHLC becomes operational, a sediment deposition survey will be conducted for the USC-PHLC system. This data will be inputted into the hydrodynamic model and the hydraulics of this sedimentation will be evaluated. Then, the removal of various sediment deposits will be assessed in the computer model in order to determine which sediment deposits, or portions thereof, have the most effect upon the hydraulics of the system. In this manner, the removal of

various sediment deposits can be ranked, thereby resulting in a prioritized maintenance schedule for sediment removal. The following year, the sediment desposition survey will be done prior to canal closure, so that sediment can be removed during the closure period.

5.2.3.3 Personnel and equipment. The individual in-charge of the Regulation Cell would have the title of Water Dispatch Officer, Grade 17. The academic requirements would be an M.Sc in Water Resources Engineering plus reasonable computer skills. There would be two Assistant Water Dispatch Officers, Grade 16 in this office. Their academic requirement would be a B.Sc in Computer Science. In addition, the Regulation Cell would have an Office Assistant, a Peon, and a Chokidar.

The most important equipment would be computers with sufficient capacity to accommodate the hydrodynamic model. The IIMI contract contains three such computers, two for the Regulation Cell and one for the IIMI Field Station that will be established just prior to PHLC becoming operational, with the most likely location being Swabi. At the completion of the IIMI contract with ID, this third computer would be given to the Regulation Cell. Also, the IIMI contract contains the funds for the hydrodynamic model software, with the IMIS, Water Allocation and CBIO software also being provided by IIMI. In addition, air-conditioned facilities will be required. A minimum of two air-conditioners should be supplied to the Regulation Cell for use in the Operations Center, but perhaps three will be required.

5.2.3.4 Training. The Water Dispatch Officer and two Assistant Water Dispatch Officers are expected to have reasonable computer skills. As mentioned previously, IIMI will be providing training to these ID staff on the Water Allocation Model, Crop-based Irrigation Operations Model and Irrigation Management Information System Model, along with training on the applications of the Hydrodynamic Model.

In addition to computer training, the professional staff would be expected to participate in the field training of SDOs and Sub-engineers on field calibration of irrigation flow control structures, as well as field measurements of seepage rates in canals, branch canals and distributaries. Besides developing a complete understanding about such field measurements, it becomes even more important that they have a high capability for analyzing this data.

6. OUTPUTS

The outputs, as well as their timing, are listed below in chronological order.

1. Recommendations Regarding the Design of the USC-PHLC Irrigation System Based on Unsteady Flow Hydraulic Simulation. (Year 2)

2. Optimization of Water Resources Supplies for the USC-PHLC Irrigation System. (Year 3)

3. Computer Software for Water Diversion (Allocation) from the Swat River and Tarbela Reservoir for the USC-PHLC Irrigation System. (Year 4)

4. Proposed Coop-Based Irrigation Operations Procedures for the USC-PHLC System. (Year 4)

5. Computer Software for Crop-Based Irrigation Operations in the USC-PHLC System. (Year 5)

6. Proposed Monitoring and Evaluation Program for the USC-PHLC Irrigation System. (Year 5)

7. Proposed Program for Prioritizing Canal Maintenance in the USC-PHLC Irrigation System. (Year 6)

8. Revised Computer Software and Instruction Manual for Water Diversion (Allocation) from the Swat River and Tarbela Reservoir for the USC-PHLC Irrigation System. (Year 7)

9. Calibrated Computer Software and Instruction Manual for Crop-Based Irrigation Operations, Including Prioritized Canal Maintenance, in the USC-PHLC System. (Year 7)

10. Long-Term Performance Assessment Program for the USC-PHLC Irrigation System. (Year 7)

This schedule of outputs is in accordance with the Schedule of Activities shown in Figure 2, which assumed that PHLC would become operational in April 1999. However, as of mid-1997, PHLC will not likely be commissioned until the end of 2000, or later. Although all of the listed outputs will be completed, their timing will be modified to conform with the commissioning of PHLC.

IIMI-PAKISTAN PUBLICATIONS

PLANNING REPORTS

Report Number	Title	Author	Year
P-1	Pilot Project for Farmer-Managed Irrigated Agriculture under the Left Bank Outfall Drain Stage I Project, Pakistan: Inception Report and Implementation Plan	IIMI-PAKISTAN (Project Leader D.J.Bandaragoda)	Oct 1995
P-2	Research Opportunities in Canal Irrigation Management in Malik Sub-division, Sadiqia Canal Division, Bahawalnagar: Inception Report	M. Shabbir Haider Mushtaq Khan	March 1996
P-3	Managing Irrigation for Environmentally Sustainable Agricultre in Pakistan: Plan of Operations	IIMI-PAKISTAN (Project Leader G. V. Skogerboe)	May 1996
P-4	Managing Irrigation for Environmentally Sustainable Agricultre in Pakistan -Decision Support Systems, Sindh: Inception Report	A. Hakeem Khan	Sept 1996
P-5	Social Organization for Improved System Management and Sustainable Irrigated Agriculture in Small Dams: Inception Report	IIMI-PAKISTAN (Project Leader D.J.Bandaragoda)	Sept 1996
P-6	Action Plan for Operations Support of the Pehur High-Level Canal (PHLC) Project	G.V. Skogerboe Zaigham Habib	Sept 1997