RESTRICTED

For official use only
Not for publication

REPORT TO THE PRESIDENT OF THE INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT AS ADMINISTRATOR OF THE INDUS BASIN DEVELOPMENT FUND

STUDY OF THE WATER AND POWER RESOURCES OF WEST PAKISTAN

VOLUME I

General Report

Prepared by a Group of the World Bank Staff

Headed by

Dr. P. Lieftinck

July 28, 1967

CURRENCY EQUIVALENTS

4.76 rupees	=	U.S. $1.00
1 rupee	=	U.S. $0.21
1 million rupees	=	U.S. $210,000

INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT

Washington, D.C.
July 28, 1967

Mr. George D. Woods
President
International Bank for
Reconstruction and Development
as Administrator of the Indus Basin
Development Fund

Dear Mr. Woods:

On November 14, 1963 you reached an understanding with Field Marshal Mohammad Ayub Khan, President of Pakistan, to the effect (among others) that the Bank would organize a Study of the water and power resources of West Pakistan which would serve as a basis for development planning in the water and power sectors of the economy. It was agreed that the first objective of the Study would be the completion of a report covering the technical feasibility, construction cost, and economic return of a dam on the Indus at Tarbela. On February 15, 1965 I presented that report to you, as Part I of the Study. It reached the conclusion -- now confirmed in the second, comprehensive phase of the Study -- that the Tarbela Project is technically and economically feasible, and that in order to meet Pakistan's urgent needs for greater agricultural production and to derive the greatest advantage from the Project when completed, a major effort must be made in the interim to modernize agriculture by improvement of farm practices and wider use of technical inputs such as fertilizer.

The second part of the Study, now presented, deals comprehensively, as was intended, with West Pakistan's water and power resources as a whole. It considers the need for increased supplies of irrigation water, relative to other means of increasing agricultural production, and finds them essential complements to one another. It analyzes in detail the several alternative means of providing more water for irrigation purposes -- enlargement of canals to enable increased diversions from the rivers, storage of flood flows in surface reservoirs for release in winter when river flows are low, and development of West Pakistan's extensive groundwater resources by means of tubewells. Implications of each alternative mode of water development for electric power -- both hydroelectric potential at dam sites and requirements of energy for tubewell pumping -- have been studied in the context of the long-term development of the entire electric power system of the Province. The potential of each mode of development has been assessed in the light of the contributions it can make, both on the irrigation side and on the power side, to further economic development in West Pakistan.

The report that follows consists of four volumes, with their various annexes. The first volume of the report is concerned with integrating the results of all the studies and relating these combined results to the context of development and development planning in West Pakistan. The second volume deals with the agricultural potential of the Province and the steps needed to realize that potential -- not only surface and ground water development projects but also policies and institutional measures to secure improvements in farming standards and wider usage of farm inputs. The third volume treats in detail the several alternative sites for surface water storage which have been identified -- in particular Tarbela, Kalabagh and High Mangla -- and sets forth a tentative schedule for their development. The fourth volume projects the long-term growth of power loads in West Pakistan and proposes a program for meeting those loads.

Specific water development projects have been selected for execution in the years before 1975 and their relative priority has been assessed, on the basis of detailed studies of the long-term potential for integrated water resource development, assessment of what part of this potential it may be physically, administratively and financially feasible to realize before 1975, and preliminary studies establishing the technical feasibility of the specific projects, their anticipated investment and operating costs, and the benefits they could yield to the economy of West Pakistan.

Beyond an Action Program proposed for development of agriculture, irrigation and power in the years before 1975, the report also deals with prospects through the remainder of this century but especially with suggested steps for further development of the irrigation and power systems of the Province in the decade 1975-85. These steps can only be formulated more tentatively than those needed in the early years, but it is intended that they should be a useful guide to future development possibilities. All the proposed programs, whether for the early period or for later years will need continuous revision and updating in the light of new information as it becomes available.

I have been impressed by the priority which the Pakistani authorities are attaching to the development of agriculture and by the measures that they are taking in expression of this priority. I believe that greatest success will be achieved if increased emphasis is laid on the role and the capabilities of the individual farmers and of those who advise them; technical and financial assistance to enable them to meet their needs, as they see them, must be made available in greater quantity, and incentives must be structured in a manner which is conducive to the modernization of agriculture. With such a framework of incentives the heavy burden which the programs proposed will lay on the public sector could be reduced by greater reliance on the private sector whose enterprise and activity are such a heartening feature of development in West Pakistan.

Execution of the Study has taken longer than originally envisaged. The main phase of the work started in the spring of 1964 when the consultants who had been retained first gathered in Pakistan. Delays were inevitably encountered. Moreover it was found that the scope of the Study -- combining general planning to identify directions of development in the sectors of agriculture, irrigation, surface storage and power, with preparation of feasibility reports for selected projects -- was such as to require more time than originally envisaged for investigations, analyses and final integration of results into phased multi-sectoral programs for systematic exploitation of West Pakistan's water resources.

The Study has been made possible only by intensive international cooperation -- as regards its financing and as regards the sources from which ideas and expertise have been drawn as well. Close contact was maintained throughout the course of the Study between the Bank Group, which formed my immediate team, and our consultants and between them and the Pakistani authorities and their consultants. We have had many rounds of discussions, both formal and informal, in Pakistan and the United States and at the European headquarters of the consultant firms involved. These frequent contacts and the fruitfulness of them were practical expression of the spirit of international cooperation which was at the heart of the Study. I would like here to express my deep appreciation for the assistance afforded us by the Pakistani authorities and by our and their consultants. Our consultants accomplished a major task in preparation of their comprehensive reports, totaling more than thirty volumes, and their knowledge and technical judgment were invaluable to the Bank Group.

In coordinating and directing execution of the Study and in preparing this final report -- following the one on Tarbela -- I have been assisted by selected staff members of the Bank. Jointly we formed the Bank Group for whose findings, opinions and recommendations, as expressed in these reports, I assume full responsibility. Each of the staff members associated with the Study has given a great deal of his thought and effort, some of them over a period of several years, to this challenging experiment in comprehensive sectoral planning. I feel deeply indebted and most grateful to them for their individual contributions, their spirit of cooperation and their unfailing loyalty.

I want to thank you sincerely, Mr. Woods, for the opportunity you offered me to make this Study and for your confidence. I hope that, despite its shortcomings, which I fully recognize, the voluminous report I herewith submit will go some length in serving the purposes you had in mind when arranging for the Study with President Ayub and including it in your supplemental agreement with the members of the Indus Club. It was not an easy but certainly a most rewarding assignment you gave me.

Sincerely,

Pieter Lieftinck

Pieter Lieftinck

TARBELA DAM PROJECT

MAY 1967

SOURCE: TIPPETTS - ABBETT - McCARTHY - STRATTON INTERNATIONAL COMPANY, CONSULTING ENGINEERS FOR THE WATER AND POWER DEVELOPMENT AUTHORITY OF WEST PAKISTAN.

IBRD - 1953R

TABLE OF CONTENTS

Page No.

PREFACE

PROPOSED PROGRAMS AND PRINCIPAL RECOMMENDATIONS i

I. INTRODUCTION 1

II. THE DEVELOPMENT OF THE IRRIGATION SYSTEM 7

III. THE INADEQUACY OF THE PRESENT SYSTEM 18

The Lag in Agriculture 18
The Shortage of Electric Power 20
Crop Yields and Agricultural Inputs 21
The Need for More Irrigation Water 24
The Choice Between Water and Other Inputs 24
The Effect of the Indus Basin Works 28

IV. FOUR TECHNIQUES OF WATER DEVELOPMENT 32

Canal Remodeling and Enlargement 33
Surface Storage 39
Private Tubewells 48
Public Tubewells 50

V. PROJECT IDENTIFICATION AND SELECTION 55

Identification of Irrigation Projects 57
Selection of Irrigation Projects 63
Sequential Analysis 66
Project And Program Review 67
Agricultural Development 68
The Formulation of the Power Development Program 68
Joint Planning for Power and Irrigation 69

VI. AGRICULTURAL IMPROVEMENTS AND IRRIGATION PROJECTS 72

Crops 73
Livestock 74
Farms And Farmers 74
Fertilizer 75
Improved Seeds 78
Plant Protection 81
Agricultural Implements and Mechanization 82
Livestock Development 83
Improved Farming, Physical Inputs and Water 86
Irrigation Development -- Third Plan Period 87
Irrigation Development -- Fourth Plan Period 97
Irrigation Development -- Fifth Plan Period 108
Irrigation Development -- Sixth Plan Period 111
Irrigation Development After 1985 112
The Growth of Irrigation Supplies 113
Expected Results of Development 114

TABLE OF CONTENTS
(Cont'd)

		Page No.
VII.	SURFACE WATER STORAGE	120
	Introduction	120
	Current Storage Development	120
	Future Storage Developments	121
	Flows Available for Storage	122
	Surface Storage Requirements	125
	Recommended Program of Surface Storage Development	126
	First Stage Storage on the Indus	127
	Tarbela and Kalabagh	128
	The Benefits of Tarbela	133
	The Silt Problem on the Indus	138
	Financial Requirements for Tarbela	141
	Second Stage Storage on the Indus	141
	Sehwan-Manchar Project	142
	Four Major Alternatives	143
	Side Valley Storage	143
	Upper Indus Sites	145
	Thal Storage Scheme	146
	Second-Stage Storage -- Assessment	147
	Further Storage Projects on Tributaries	149
	The Project for Raising Mangla	150
	The Swat-Ambahar Project	151
	Chiniot Project on the Chenab	151
	Financial Requirements of the Proposed Program	152
VIII.	ELECTRIC POWER	155
	Introduction	155
	The Structure of the West Pakistan Power System	155
	Recent Growth of Electricity Consumption	156
	Load Forecast	157
	Agricultural Pumping	159
	Residential and Commercial Load Forecast	159
	Industrial Load Forecast	160
	Contingency Load Forecasting	161
	The Existing Power Situation and Current Programs	163
	Stone & Webster Bulk Power Supply Program	165
	Bank Group's Adjustments to Stone & Webster's Program	167
	The Evaluation of Tarbela	168
	The Scarcity Value of Thermal Fuel	169
	EHV Interconnection Between the Major Power Markets	170
	The Timing of Interconnection	172
	Operation of Mangla and Tarbela Reservoirs	172
	Annual Operating Decisions and Hydrological Uncertainty	175
	Peaking at Mangla and Tarbela	176

TABLE OF CONTENTS
(Cont'd)

Page No.

The Peaking Role of Thermal Plant 176
Thermal Fuel Supply 177
Additions to the Power System during the Fourth Plan Period (1970-75) 178
Utilization of Tarbela Potential and the EHV System 180
Kunhar and Raising Mangla for Power 180
Nuclear Generation 181
Use of Indigenous Coal for Electricity Generation 181
System Development After 1980 182
The Bank Group's Proposed Power Program 182
Distribution 183
Financial Requirements 183
Tariffs and Accounts 186

IX. ORGANIZATION AND IMPLEMENTATION 188

Institutional Framework of Water and Power Development 188
"Implementation Capacity" 192
Project Planning and Construction 193
Management and Operation of System and Projects 195
Promotion of Farm Inputs 199

X. PROPOSED PROGRAMS AND PAKISTAN'S PLANS....................... 204

Agriculture and The Development Plans 205
Sectoral Growth Rates 209
Investment Requirements of Proposed Programs 210
Public Sector Financial Requirements 213
Private Investment 218
The Growth of Agricultural Employment 221

GLOSSARY 223

MAPS — Following Page No.

1. Indus Basin - Location of Canals and Links 16
2. Development Plan for the Indus River System 30
3. Program 1965 to 1975 Project Areas 118
4. Tarbela and Kalabagh 154
5. Main Power Stations and Principal Transmission Lines ... 186

TABLE OF CONTENTS
(Cont'd)

FIGURES	Following Page No.
1. Historical Usage of Available Surface Water in the Indus River Basin of West Pakistan	10
2. Mean Monthly Discharge: Indus, Jhelum and Chenab Rivers	40
3. Derived Average Yields for Reference Years	62
4. Cotton Yield Projections	68
5. Projected Usage of Available Surface Water in the Indus River Basin of West Pakistan	114
6. Revised IACA Program for Irrigation Development	110
7. Average Annual Yield and Efficiency of Storage Capacity on the Indus and Jhelum Rivers	124
8. IACA's Estimate of the Total Mean-Year Demand for Stored Water on the Jhelum and Indus Rivers	128
9. Tarbela Project - Water Course Requirements and Supplies by Sources	134
10. Comparison of Tarbela With or Without Systemwide Interconnection with Cheapest Alternative Programs	168
11. Projection of the Economic Value of Natural Gas at Well Head	170
12. The Absorption of Hydro-Energy	172
13. West Pakistan: Alternative Development Patterns with 4 1/2% Per Annum Growth in Agriculture	208

The following is a brief table of contents of the other volumes of the Study. A detailed table of contents precedes the text of each of the respective volumes.

TABLE OF CONTENTS
(Cont'd)

Page No.

VOLUME II: Program for the Development of Irrigation and Agriculture in West Pakistan

Chapters:

	Introduction	1
I.	Past and Present Performance of Agricultural Sector	3
II.	Agricultural Development Potential	25
III.	Development of Water Resources	73
IV.	Priority Development Projects	121
V.	Program for Irrigation Development	167
VI.	Agricultural Inputs and Supporting Services	208
VII.	Financial Requirements of the Development Program	249
VIII.	Comparison of Supply and Demand	262
IX.	Conclusions and Recommendations	291

Annexes:

2.1 Watercourse Studies
2.2 IACA Agricultural Zones and Estimated Production
2.3 Factors Affecting Cropping Intensities
3.1 IACA Estimates of Cost of Groundwater Mining
3.2 Sequential Analysis
3.3 Priorities for Groundwater Development
4.1 Report on Project Content of Water Development Program
6.1 IACA Estimates of Area Covered by Fertilizer Applications
6.2 Prospects for Supply, Distribution and Use of Fertilizer in West Pakistan
6.3 The Program for Artificial Insemination in West Pakistan as Proposed by IACA
7.1 Indicative Estimate of Public Investment Expenditures for Water Development during Third and Fourth Plan Periods
8.1 Definition of Developmental Activities Employed in GPV Projections
8.2 IACA Projections of Growth of Agricultural Production
8.3 Bank Group's Projections of Growth of Agricultural Production
8.4 Assumptions Used in Estimating Gross Value Added
8.5 IACA's Derivation of Elasticity-Coefficients of Demand for Agricultural Products
9.1 Terms of Reference, Memoranda to Consultants and Guidelines for the Study

TABLE OF CONTENTS
(Cont'd)

Page No.

VOLUME III: Program for Development of Surface Water Storage

Chapters:

I.	Introduction	1
II.	Surface Water Hydrology	3
III.	Historical Use of Surface Water	12
IV.	The IACA Approach	17
V.	Identification of Dam Sites and Comparison of Projects	29
VI.	Factors in the Operation of Surface Water Storage Reservoirs	63
VII.	The Sequence of Projects for Developing Surface Water Storage	81
VIII.	Program for Investigations	95
IX.	Financial Requirements and Cost Comparisons	105
X.	Findings and Conclusions	112

Appendix: Terms of Reference and Guidelines for Dam Site Consultant

Annexes:

1. Tarbela Project
2. Kalabagh Project
3. Gariala Project
4. Skardu Project
5. Ambahar Project
6. Kunhar Project
7. Mangla/Raised Mangla Project
8. Chasma Project
9. Sehwan/Manchar and Chotiari Projects

VOLUME IV: Program for the Development of Power

Chapters:

I.	Introduction	1
II.	The Existing Situation	11
III.	Past Growth	18
IV.	Forecasts of Energy Requirements and Power Demands	29
V.	The Power Supply Program 1966-1985	62
VI.	Evaluation of Stone & Webster Program	82
VII.	The Bank Group's Adjusted Power Program	106
VIII.	The Distribution Problem	131
IX.	Tariffs and Organization	137
X.	The Financial Requirements of the Power Development Program	145
XI.	Conclusions	152

TABLE OF CONTENTS
(Cont'd)

Annexes:

1. Load Forecasting
2. The Industrial Load Forecast
3. The Residential Load Forecast
4. The Overall Energy Situation -- Supply and Demand
5. The Price of Thermal Fuel
6. Hydroelectric Projects and Reservoir Operation
7. The Power Aspects of the Tarbela Project
8. The Development of Mangla's Power Potential
9. Energy Transmission: EHV Interconnection and Gas Pipelines
10. The Power System Simulation Model
11. Guidelines and Terms of Reference

ECONOMIC ANNEX

Part I. Programming Methods Used in The Study

Part II. A Linear Programming Analysis of Irrigation Development Potentialities in The Indus Basin

Part III. Proposed Programs and Economic Growth

PREFACE

In November 1963 the World Bank was assigned the task of organizing a comprehensive investigation of the water resources of West Pakistan. The chief purpose of the investigation, which became known as the Indus Special Study, was to develop a program for the optimum exploitation, for agricultural and power purposes, of the water resources that would be available to Pakistan after implementation of the Indus Waters Treaty of 1960. This report, in four volumes and their annexes, summarizes the conclusions that were reached in the course of the Study and outlines recommended development programs in the fields of agriculture, irrigation, surface water storage and electric power for the next ten to twenty years.

Dr. Pieter Lieftinck -- an Executive Director of the World Bank and former Finance Minister of The Netherlands -- accepted an invitation from the President of the Bank in January 1964, to head the Study. Several senior members of the Bank's technical staff were also assigned to assist Dr. Lieftinck in the organization and execution of the Study. This nucleus is referred to collectively in this report as the Bank Group.

To provide the various skills required for the complex and detailed field work involved in the Study, the Bank Group obtained the services of a number of consulting firms. For the irrigation and agriculture aspects of the Study, three firms of international repute agreed, at the request of the Bank, to assume joint responsibility and to form, for this purpose, an Irrigation and Agriculture Consultants Association (IACA); the member firms were Sir Alexander Gibb & Partners and Hunting Technical Services Limited, both of the U.K., and International Land Development Consultants (ILACO) of The Netherlands. To handle questions concerning dam sites, Chas. T. Main International, Inc., a U.S. firm, was retained. For power aspects of the Study, the Bank retained the services of Stone & Webster Overseas Consultants Inc., also from the United States. In addition to their role in IACA, Sir Alexander Gibb & Partners were responsible for overall coordination among the consultants.

The Agreement between the President of the World Bank and the President of Pakistan which instituted the Study divided it into two distinct phases. In the first phase attention was concentrated on a proposal to build a large multi-purpose dam and reservoir on the Indus at Tarbela. This project was widely considered to be of high priority but it was also a center of controversy, and so the Bank Group had agreed to provide an interim report on the Tarbela Project separately. Draft reports on this project were prepared by the consultants by mid-November 1964; in early December a Pakistan delegation visited Washington to discuss the consultants' findings; and in February 1965, Dr. Lieftinck submitted the Bank Group's report on the Tarbela Project to the President of the Bank who transmitted it to the Pakistan Government.

Immediately after completing their initial Tarbela studies the consultants moved into the second phase of the Study which was to result in comprehensive reports on the development of the water and power resources of West Pakistan. It was originally intended that discussion drafts of these comprehensive reports would be completed by early 1966, i.e. within two years of the Study's commencement. However, unavoidable delays were encountered and drafts of the reports were submitted at various times through 1966.

It was recognized from the beginning of the Study that the time element and the scope of the problems made imperative the closest possible cooperation between the Bank Group, the Pakistan authorities and the consultants. All phases of the work, including such matters as the consultants' terms of reference, were therefore discussed in detail with the Pakistan authorities. To ensure a regular exchange of views and to guide the investigations along the most fruitful lines, certain tripartite committees were established: a Coordinating Committee in the sphere of irrigation and agriculture, which met on eight occasions; a Dam Sites Committee which also met on eight occasions; and an informal Power Consultative Committee which met twice. Although these committees had only an advisory role, they served to ensure that Pakistan and the Bank Group remained in agreement with the consultants on the scope of the work and the detailed methodology. The consultants' terms of reference were supplemented from time to time through the provision of additional written guidelines and other instructions from the Bank Group.

The final reports of the consultants were submitted simultaneously to the Bank and to Pakistan between May and November, 1966. One report, in 23 volumes, prepared by IACA, covers the irrigation and agriculture aspects of the Study. Another report, in six volumes, prepared by Chas. T. Main, covers surface water storage. And the third report, in two volumes, prepared by Stone & Webster, covers the power aspects of the Study. In addition Sir Alexander Gibb & Partners, as coordinators among the consultants submitted two reports, one, entitled "Summaries of Reports by Consultants on Irrigation and Agriculture, Electric Power and Surface Water Storage", and a second, updating the information presented earlier on Tarbela. At the request of the Pakistan authorities and the Bank Group, Sir Alexander Gibb & Partners also undertook, with the assistance of Harza Engineering Company International, of Chicago, a sequential analysis of the power and irrigation programs recommended by the consultants. This analysis resulted in a special report entitled, "Sequential Analysis of a Programme for Irrigation and Power Development in West Pakistan".

These reports, together with their supporting annexes, provided a basis for discussion between the Bank Group and the Pakistan authorities in November 1966. Discussions were held with the Government of Pakistan in Rawalpindi and with the Government of West Pakistan and affiliated agencies in Lahore. Senior members of all the consultant firms which had shared in the Study participated in these meetings.

Following the discussions in Pakistan in November 1966, the Bank Group prepared drafts of this four-volume document, which represents the conclusion of the Study. The report is based on the work and findings of the consultants, on suggestions made by the Pakistan authorities and on studies carried out by the Bank Group itself. Preparation of the report had to be compressed into a short space of time. Drafts of the three main volumes -- on irrigation and agriculture, surface water storage, and power -- were sent to Pakistan in March 1967. A final round of discussions between the Bank Group and the Pakistan authorities was held in Lahore and Islamabad in mid-April on the basis of these drafts. Thus throughout the Study the Bank Group has had the benefit of frequent contact with the Pakistan authorities, who made many helpful suggestions and comments.

At the last round of meetings in Islamabad in April 1967, Dr. Lieftinck stated that the main purpose of the Bank Group's report was to assist the Pakistan authorities in achieving the maximum feasible rate of economic development. The Study had been concerned with collecting as much basic data as possible and analyzing it with a view to clarifying the potential for growth and identifying priorites, particularly for the Third and Fourth Plan periods. Dr. Lieftinck said he hoped that the report would serve as a useful background document to the Pakistan Government in taking decisions about future development and to the World Bank in assessing Pakistan's progress and plans. The report was in no sense intended to be binding, either for Pakistan or for the World Bank, which would, he felt sure, continue to reassess Pakistan's need for assistance on a year-to-year basis.

The report now presented consists of four volumes, of which this general volume is the first. Volume II presents in detail the recommended program for the development of irrigation and agriculture in West Pakistan. Volume III covers dam sites and puts forward a tentative schedule for their development. Volume IV discusses the prospective growth of demand for electric power and proposes a plan for the development of resources to meet that demand. Each of these three volumes has a number of supporting annexes, discussing individual projects or topics in greater detail. An Economic Annex to the Report presents some of the economic work undertaken in the course of the Study.

The Bank Group's work was carried out under the personal responsibility of Dr. Lieftinck. Under him the Bank Group consisted of A. Robert Sadove as Deputy Head of the Study; Thomas C. Creyke in charge of Irrigation and Agriculture; General Herbert D. Vogel in charge of Dam Site Engineering; and A. D. Spottswood in charge of Electric Power. From the beginning Willi A. Wapenhans was principal assistant to Mr. Creyke in supervising the work and preparing the reports on Irrigation and Agriculture. Christopher Willoughby assisted Mr. Sadove in the preparation of Volume I of the report and was primarily responsible for the background work on electric power; he drew heavily on the assistance of Dr. Henry D. Jacoby of the Harvard Water Program who prepared a simulation model of the West Pakistan power system. Heinz Vergin assisted Mr. Sadove in the economic aspects of the Study and carried out the linear programming analysis of investment in irrigation and agriculture with direction from Professor Robert Dorfman of Harvard University. E. P. Delaney and K. B. Norris, on assignment in Washington from Sir Alexander Gibb & Partners, assisted considerably with engineering aspects of the Study. To assist in the preparation of Volume II an agricultural group was established, consisting of James B. Hendry, Harold Manning and Kyaw Myint, all of the Bank's staff. Added to this group for a period of several months at Bank headquarters were key members of the Irrigation and Agriculture consultant groups, including W. R. Rangeley, James Turtle and Roger White, of Sir Alexander Gibb & Partners, Thomas Jewitt of Hunting Technical Services, and Pieter Mulder of International Land Development Consultants. Other Bank staff members who made substantial contributions to the work of the Bank Group are: Firouz Afrouz, Stanley P. Johnson, Gary G. Luhman and Miss Huda S. Qubein. Thomas B. Winston assisted with editing at the later stages of the Study. Each of these staff members contributed many months to the Study, but the report could never have been completed without the valuable cooperation of many other people in the Bank, particularly those responsible for the task of accurately reproducing large volumes of written material.

PROPOSED PROGRAMS AND PRINCIPAL RECOMMENDATIONS

i. This report deals with the development prospects of agriculture and electric power in West Pakistan. Agriculture is the most important single sector in the economy. It is responsible for nearly 45 percent of the output and 75 percent of the foreign exchange earnings of the Province, and about 70 percent of the population are directly dependent on it for their livelihood. Much of the industrial activity in the Province is concerned with processing the products of agriculture and, to an increasing extent, with manufacturing farm inputs. The power sector is, in comparison, small in its contribution to total provincial output, but electric energy is a critical element in much of the economic activity of the Province; farming is beginning to become dependent on electricity for provision of additional supplies of irrigation water pumped from underground by means of tubewells.

ii. Growth of the agricultural sector has in the past lagged seriously behind the growth of other sectors of the economy. Increasing amounts of food have had to be imported and agricultural exports have grown slowly. Total agricultural output grew between 1950 and 1960 at a rate of only about 1.5 percent per annum; population was probably growing during this period at about 2.5 percent per year. During the Second Plan period (1960-65) the performance of agriculture improved sharply, reaching an annual average growth rate of 3.8 percent, and agricultural exports grew from about PRs 500 million at the beginning of the period to about PRs 800 million in each of the last two years. Nevertheless, by the end of the Plan period, agricultural production per head of provincial population was still below what it had been 15 years earlier, in 1950. Output of electricity has grown extremely rapidly -- at an average rate in excess of 20 percent per annum between 1950 and 1965. However electricity has been almost continuously in short supply, so that load shedding and heavy voltage fluctuations have been commonplace. The shortage of electric power grew to particularly serious proportions during the past year when upwards of 20 percent of the load on the largest power system in the Province had at times to be shed. These shortages of electricity have constrained the growth of industrial and agricultural output.

iii. West Pakistan is aiming for an annual growth rate of about six percent in total provincial output. It is the view of the Bank Group that this implies a need for at least 4.5 percent annual growth in gross value added by agriculture -- and more if agriculture is to make any contribution to easing the acute foreign exchange stringency from which the economy suffers. As regards power, the Bank Group believes that a six percent annual growth in total output implies a need for about 13 percent annual growth in generation of electricity by public utilities over the next decade -- though, of course the need may be higher in some parts of the Province and lower in others. Over the decade 1965-75 the population of West Pakistan is expected to increase by about one-third. The target rates of growth just mentioned imply that over the same decade total provincial output must nearly double, total agricultural output must increase by a minimum of about two-thirds and total utility production of electricity must more than triple. Over a 20-year span West Pakistan is aiming to have total provincial output triple, almost doubling current per capita income levels; agricultural output would have to nearly triple and electricity production increase eight times over. Sustained performance in agriculture of this magnitude and on the scale required for the Province is almost without precedent. Its achievement, however, is a necessity if major crises in food supplies are to be avoided.

iv. The Bank Group is in no doubt that a much higher level of agricultural production than is presently achieved or has been projected in this report is technically feasible. The basic resources, soils, climate, water availability and the farmers are all capable of supporting a program even more ambitious than the one presented here. The means by which it could be accomplished are also generally known. The real imponderable is the time it would take. This is primarily dependent upon policy to provide incentives, confidence and stimulation; availability of funds for both public and private investment; and above all administrative, managerial and implementation capacity. Policy attitudes generally appear to be well attuned to the needs of the situation. Availability of funds will always be a problem but does not appear to be the most stubborn constraint. The key consideration is implementation capacity as it relates to policy implementation, construction and operation of projects and the development of institutional support to provide goods and services to back up the program and to mobilize all the available resources and ensure their integrated application.

v. The program proposed is heavily dependent upon the public sector, but events may prove that greater reliance can be placed on the private sector. The Bank Group attaches great importance to the careful monitoring of progress and in the light of experience ensuring that preoccupation with the public sector is not allowed to damp down the vital contribution which can and must be made by the conspicuously active private sector. The fundamental point that must never be lost from sight is that in the last resort it is the farmers who will decide whether agricultural production grows at three percent or five percent and hence whether per capita provincial income will stagnate or will double in the next 20 years. Only if the farmers have the incentives, the supplies and the knowledge together with confidence and conviction will they produce the results desired. Incentives and confidence are of outstanding importance and policy determinations, prices and marketing opportunity must be kept under constant review to ensure that farmers have the required incentives.

vi. The growth of agricultural production is severely constrained both by shortage of irrigation water and by the standards of husbandry employed including the slight use that is made of other yield-increasing inputs such as fertilizer, good seeds and insecticides. Past water resource development has already harnessed about one-half of West Pakistan's renewable water resources for irrigated agriculture on about 26 million acres of land. Up to now this extensive irrigation system has supported a traditional form of agriculture in which little use was made of modern technology and production aids. However the farmers have shown themselves ready to adopt means to increase production when they appear profitable. The most profitable results can be achieved when the various inputs are applied at the right time and in the right balance. To achieve such results the farmer needs increased knowledge -- which must be provided largely by the extension service at the present time -- and greatly improved availability of the various inputs as well as incentives to use them. It is not possible, on a general basis, to identify water or any other single input as being most critical. Most of the inputs are in short supply in most parts of the Province, including the irrigated areas which account for about 80 percent of agricultural production. Rapid progress in one, be it water or any of the modern production aids, would only show up more acutely the lack of the others. There are also technical, administrative and social limits to the rate of progress that can be achieved on any single front. A concerted effort is needed on all, and the Bank Group has endeavored to prepare a program which maintains a proper balance between progress on the agricultural front (i.e. better farming, more agricultural inputs, etc.) and further water development.

The Tarbela Dam

vii. The centerpiece of the programs put forward by the Bank Group is the Tarbela Dam on the Indus. Completion of this dam by 1975/76 is a crucial element in the strategy outlined in this report for meeting West Pakistan's need for additional supplies of irrigation water and electric power. The detailed programs proposed have been built on the assumption that the dam would be completed on schedule, and the importance of the project is so great that this expectation has influenced and conditioned almost all the other proposals made regarding future development. The Tarbela Dam is estimated to cost the equivalent of about $775 million, excluding duties, taxes and interest during construction and all the costs of power plant and its housing. The main purpose of the dam would be to store water from the summer flood season, when Indus discharges are greatly in excess of the amount that could be used for irrigation purposes even with an expanded canal system, to the rabi (winter) season when the main food crops are grown but natural river flows are low and variable and irrigation deliveries consequently unreliable. At its initial capacity, the Tarbela Reservoir will store sufficient water to increase rabi river flows on the Indus in a mean year by about one-third and those in a dry year by about one-half.

viii. The Tarbela Dam is such a strategic element in the integrated programs proposed that it is extremely difficult to quantify the contribution which it makes itself to increased production. Nevertheless the Bank Group tried to measure this contribution and it believes that, to the extent it is measurable, a reasonable conservative range for the rate of return would be about 9-13 percent. The Bank Group also attempted to weigh the costs that would be involved in a 10-year delay of Tarbela by comparing the costs of the recommended program with the costs of a hypothetical alternative making up for the 10-year lack of Tarbela water by the use of groundwater mining techniques that have potential in Pakistan but have not yet been tested there; the alternative program worked out $50 million more expensive in terms of the present worth of economic costs and it could not provide a degree of security comparable with that provided by a program including Tarbela in 1975. However this alternative program was the cheapest of several alternatives considered; it involved interim developments in power and irrigation significantly different from those that would be best in a program built around Tarbela. Thus unforeseen delay in the execution of Tarbela, even of shorter duration than 10 years, would likely result in greater losses than those stated above in financial terms and in terms of increased risk, because it would mean that no integrated program could be firmly chosen and that other parts of the recommended program, which are undertaken, would be out of step.

ix. The Bank Group's estimates suggest that about three-quarters of the benefits of Tarbela would accrue to agriculture. System analyses indicate that deliveries direct from Tarbela storage would account for more than 10 percent of total rabi supplies of irrigation water in 1985 and 25 percent of the water delivered to farmers additional to that which they now receive in rabi season. The availability of additional surface water in rabi season is particularly important to further development in those areas which are not underlain by fresh groundwater -- about 40 percent of the Punjab and 80 percent of the Sind. Additional rabi canal supplies are a sine qua non of further irrigation development in areas with the most saline groundwater (about 11 million acres or 35 percent of the canal irrigated area) and, in the 15 percent of canal irrigated area underlain by groundwater of intermediate salinity, additional rabi canal supplies can be mixed with pumped groundwater and can thus have a multiplied effect on total rabi water supplies in such areas. Nevertheless the total addition to rabi canal deliveries that would come from Tarbela Reservoir is only one part of the benefit that the project would confer on agriculture. Existence of a large reservoir on the Indus will make it possible to regulate to a significant extent the time pattern of river discharges and hence to match canal deliveries, in combination with supplies pumped from the groundwater aquifer, to the rather inflexible time pattern of crop-water requirements in a way that has not been possible in the past.

x. About one-quarter of the total benefits of Tarbela relate to the hydroelectric potential of the dam according to the Bank Group's studies. The Bank Group proposes installation of 12 turbine generators, each of nominal rating 175 mw, over the years 1975-80. With this development of its hydroelectric potential Tarbela will contribute more than one-quarter of the total amount of electric energy required by West Pakistan over the decade 1975-85. By 1985, according to the Bank Group's projections, Tarbela will be contributing some 10 billion kwh or more than one-third of the Province's total annual requirements of electric energy at that time. Under mean year flow conditions 12 turbines would be capable of generating 12 billion kwh, and the additional 2 billion kwh, which would be produced almost entirely in the summer flood months, would be absorbed gradually after 1985 as loads on the power system grow. In the course of its analysis of the effects of a 10-year postponement of Tarbela the Bank Group found that completion of Tarbela in 1975 would save some 700 trillion Btu of natural gas -- or about 10 percent of West Pakistan's known usable reserves of gas -- that would otherwise have to be devoted to generation of electric power over the decade 1975-85; such a saving is important because known gas reserves are limited and gas is required as feedstock for the production of badly needed fertilizer.

xi. These figures make it clear that Tarbela will have a very large impact on the irrigation and power systems of West Pakistan and they thus underline the importance of careful planning in advance to make sure that the systems in existence by 1975 are well prepared to absorb the irrigation and power supplies from the dam as quickly and as effectively as possible. It is not only the scale of the project which emphasizes the need for a very active development effort in the meantime to prepare the way for Tarbela. The project is also very expensive; irrigation supplies from Tarbela have advantages of flexibility as mentioned, but they will cost Pakistan about three times as much per acre-foot as water pumped from the groundwater aquifer within the limit of annual recharge by seepage from the surface; theoretically substantial additions to rabi water supplies could be made at lower cost for a number of years by pumping beyond this level or 'mining' the groundwater aquifer in some areas, but this technique would not serve to increase water supplies so rapidly as surface storage, it would be less flexible, it might be hazardous, it would be inconsistent with the optimum integrated pattern of water-resource development and in the long run it would be more expensive. Thus any substantial addition to rabi irrigation supplies would inevitably be costly. This emphasizes the need to make sure that water is used to the greatest possible advantage. The time required for construction of Tarbela -- it could not be completed before 1975 -- also underlines the need for other immediate efforts to improve agricultural productivity. Increased production of food and fiber are required immediately, and Tarbela will be of no help for another eight years.

Action Program for Agriculture, Irrigation and Power

xii. Examination of West Pakistan's needs and resources in a long-term perspective and in the light of the anticipated completion of the Tarbela Dam by 1975/76 has led to the preparation by the Bank Group of a Ten-Year Development Program for Agriculture, Irrigation and Power. This program spans the Third and Fourth Plan periods (i.e. July 1, 1965 to June 30, 1975). In compiling the public-sector costs of the program in Table 1 below the Bank Group has tried to follow cost concepts used in Pakistan's Five Year Plans so that the figures will be directly comparable. (The breakdown of the costs presented in Table I by five-year plan periods is presented in Chapter X). Table I shows that the costs that would be incurred within the two plan periods for construction of the main reservoir structures at Tarbela, excluding interest during construction, would represent about 17 percent of the total public-sector costs of the recommended program.

Table I

Public Development Expenditures for Proposed Program, 1965-75 a/
(Million PRs)

Tarbela Dam b/	3,862
Other Surface Storage Projects -- Raised Chasma	116
Sehwan Manchar c/	22
Surface Storage Investigations	115
	4,115
Irrigation and Drainage Projects d/ - -	
Ongoing Public Tubewell Schemes	991
Proposed New Public Tubewell Schemes	1,563
Canal Remodeling and Other Irrigation	1,002
Surface Drainage	900
Tile Drainage	223
Investigations	431
Flood Protection	149
Miscellaneous	25
	5,284
Agriculture --	
Fertilizer Subsidies	1,200
Plant Protection Subsidies	800
Extension and Research	440
Mechanization, Forestry, Others, etc.	4,051
Capital Liability for Agricultural Credit	528
	7,019
Electric Power e/--	
Generation	2,070
Transmission	1,115
Distribution	3,070
General	62
	6,317
Total	22,735

a/ Including duties, taxes and interest during construction at six percent per annum, where appropriate. Interest during construction is not included in the figure for Tarbela.
b/ Costs through 1974/75 only, and excluding civil engineering and all mechanical and electrical items for power plant.
c/ Expenditures commence at the end of decade, but project not scheduled for completion until 1982.
d/ See details in Table II.
e/ See details in Table III.

The figures shown under Agriculture in Table I represent in effect the allocations to Agriculture, mainly the Department of Agriculture, that the Bank Group believes would be necessary to implement the proposed program. The other groups of expenditures cover water and power development works that would be undertaken largely by the West Pakistan Water and Power Development Authority (WAPDA) and by the Irrigation Department, except for a small portion of the allocation under Electric Power which represents the cost of the nuclear power plant being built by the Pakistan Atomic Energy Commission outside Karachi.

Agricultural Development

xiii. Proposed public sector expenditures on agricultural development represent the largest single block -- more than 30 percent -- of the total program costs shown in Table I (an annual average of nearly $150 million equivalent) and this is consistent with the very great emphasis that, in the opinion of the Bank Group, should be placed on this aspect of the development effort. It would serve two purposes. First, it could lead to immediate and rapid growth of agricultural production. Second, it represents the most vital part of the job of preparing the way for Tarbela. Only if farming standards are greatly improved over the next decade will the large agricultural benefits anticipated from Tarbela in fact be realized. Increase of water supplies alone, upon which so much emphasis has been placed in the past, will do no more than extend and prolong the traditional agriculture of low productivity; technological improvement in farming, on the other hand, could, with a large enough effort to spread it widely, raise agriculture in West Pakistan to an entirely new plane of productivity.

xiv. Existing water supplies could be used to much greater advantage than they are now if they were combined with better irrigation farming practices and more physical inputs such as fertilizer, improved seed and plant protection. Application of improved methods depends on the farmers themselves; public policies and investments can only provide the environment within which the farmer must employ the means put at his disposal to the best of his ability. It is thus vital for the future of West Pakistan that its farming community be equipped as a matter of urgency with knowledge of modern agricultural technology. This puts all those concerned with training, education, and dissemination of information on better husbandry practices and the use of non-water inputs in a position of the utmost importance. The Bank Group believes that the status of the men serving the farming community in these ways must be raised to a level commensurate with the responsibility they carry and that they must be provided with more material support if the requisite improvement in general farming standards is to be achieved.

xv. Among the physical inputs required for increased production fertilizer has the greatest immediate potential. The Bank Group is convinced that substantially larger amounts of fertilizer could be beneficially applied in conjunction with the existing water supplies. Every effort should be made to make available to farmers at reasonable costs and in timely supply all the fertilizer that they will absorb, and the use of fertilizer should be energetically promoted through all means available to the Government. Fertilizer consumption in each of the years 1964/65 and 1965/66 was estimated at about 90,000 nutrient tons. The Bank Group considers that off-take targets of 350,000 nutrient tons (equivalent to 1.6 million tons of ammonium sulphate) in 1969/70 and 700,000 nutrient tons in 1974/75 are feasible provided that appropriate arrangements are made for supplies and distribution, and the costs to the farmers are kept at levels which generate incentive to continuing use. The 1975 target includes about 470,000 nutrient tons of nitrogen and 230,000 nutrient tons of phosphate. These targets for 1970 and 1975 are about double those adopted by the Bank Group's consultants and represent rates of increase in the use of fertilizer of about 30 percent per annum through the Third Plan period and 15 percent per annum through the Fourth Plan period. The large allowance shown in Table I for fertilizer subsidies is calculated on the basis that the price of fertilizer to the farmer will not be allowed to increase significantly from its present subsidized level but the amount of subsidy required per ton of fertilizer will fall as a result of reduced procurement costs.

xvi. Improved seed material, particularly of superior varieties of wheat, cotton and rice, constitute a second major agricultural input which could have significant impact within the next decade with adequate research and promotional effort. High-yielding varieties of wheat and rice have reached an advanced stage of development, but further research is still required on these crops and on others. Achievement of productivity increases from this source will depend mainly on the establishment of effective multiplication and distribution networks capable of maintaining the quality of the seed and on the extent to which farmers adopt the cultivation practices and complementary inputs which lead to best results. To the fullest possible extent private entrepreneurs should be encouraged to participate in the multiplication of improved varieties, under Government supervision to ensure maintenance of quality. The Bank Group has assumed that about 50 percent of the wheat acreage (about six million acres) and one million acres of rice will be covered by improved varieties by 1975. Seed experts in Pakistan have predicted faster rates of growth which would be highly desirable if they could be achieved without any sacrifice in terms of seed quality. The Bank Group feels that achievement of its projections would already represent a very important advance in terms of organization.

xvii. Effective plant protection could increase current yields significantly and, as potential yields grow as a result of increased use of other inputs, it will become increasingly important. It is believed that at present about 15 percent of potential production is lost due to lack of plant protection. Timeliness of application is critical to obtaining good results from insecticides, and therefore much depends on the farmers' awareness of the problems, their cooperation and the ready availability of effective service. The existing system of plant protection services rendered free through the Governmental extension service is inadequate, lacks efficiency and diverts scarce extension personnel from their important functions of disseminating agricultural knowledge. Plant protection is an area where private sector participation could play an increasing role because there would be a merging of the interests of the suppliers and the needs of the farmers for improved protection. As the importance of plant protection is not yet widely accepted, subsidies will probably need to be continued for some years. Other important Government contributions would be research to develop simple, practical procedures which can be readily employed by the farmers and continuation of aerial spraying against epidemic attacks such as from locusts. Since protective measures will probably not improve much before the use of fertilizer and better husbandry become more general, the Bank Group has not projected large increases in the acreage sprayed until the years after 1975.

xviii. Mechanization of farm operations will be important in the progress towards more intensive and highly commercialized agriculture, permitting tighter cropping schedules, freeing fodder acreage and enabling better and more timely land preparation. Use of mechanical equipment is confined to very few farms at present and it will spread slowly on small farms, but even before farmers reach the stage of mechanizing their operations they could be assisted by improved hand tools and animal-drawn equipment. A larger research and promotion effort is needed for these. The Bank Group believes that every encouragement should be given to the spread of mechanization in the form of credit, advice on suitability of machinery for particular conditions and purposes, instruction in operation, ensured supplies of machinery and parts, and adequate service facilities. Mechanization will continue to be adopted mainly by the larger farms, but in view of the preponderance of small farms careful consideration should be given to the stimulation and support of contract mechanization service and the cooperative use of farm machinery.

xix. Animals will continue to be the main source of power on the farm for a long time to come and livestock products which now account for some 35 percent of total agricultural output will be increasingly important because demand for milk and meat is likely to grow more rapidly than demand for other agricultural products. Despite the very great importance of the livestock sector very little is known about it and it has not been possible to assess its development potential with any degree of reliability. The Bank Group's consultants have drawn an outline of a massive program of artificial insemination designed to build up an improved Zebu milk herd to replace the existing buffaloes as the main source of milk, but even with an early start on this program large-scale results are not expected to occur until well after 1975. The livestock sector is so little understood that the Bank Group suggests it be made the subject of a special comprehensive study to establish the sector's present status more accurately and to provide a basis for deciding the requirements for future development.

Irrigation and Drainage Works

xx. Expenditures on irrigation and drainage projects represent about 23 percent of the total public-sector costs of the Action Program outlined in Table I or an annual average of about $110 million equivalent. A breakdown of these expenditures by project areas is given in Table II. In the

Table II

Irrigation and Drainage Program 1965-75

Completion Date		Canal Commanded Area ('000 acres)	Cost (PRs. mlns.) a/
	Ongoing Public Tubewell Projects		
1971	SCARP II (Chaj Doab) (2510) b/	1,600	281
1970	SCARP III (Thal Doab) (1470)	900	165
1973	SCARP IV (Rechna Doab) (3270)	1,700	366
1969	Khairpur (568)	300	179
		4,500	991
	New Tubewell Projects Proposed in Program		
1969	Wagah	50	13
1970	Shorkot Kamalia (426)	294	53
1974	Rohri North (1580)	598	156
1973	Panjnad Abbasia (1623)	878	190
1973	Dipalpur above B-S Link (630)	372	75
1973	Shujaabad (725)	379	84
1974	Ravi Syphon-Dipalpur Link (780)	595	109
1976	Bahawal Qaim (924)	522	107
1975	Fordwah Sadiqia (665)	359	79
1977	Rohri South (1,500)	528	136
1977	Sukkur Right Bank (820)	273	82
1977	Dipalpur below B-S Link (850)	611	103
1976	Begari Sind (880)	349	92
	Other small tubewell projects		36
	Project investment after 1975 c/		-67
	Initial work on further projects		315
		5,808	1,563
	Canal Remodeling and Other Irrigation		
	Khairpur East and West	454	54
	Panjnad Abbasia	100	63
	Ravi Syphon -- Dipalpur Link	330	48
	Lower Bari Doab	70	8
	Shorkot Kamalia (Haveli)	60	8
	Other irrigation works in canal commands		482
	Other irrigation works outside canal commands		337
		1,014	1,000
	Surface Drainage		
	Sukh Beas Scheme		191
	Lower Indus Left Bank Outfall (start)		374
	Other smaller schemes		335
			900
	Tile Drainage		
	Shorkot Kamalia (Haveli)	40	16
	Lower Bari Doab	70	46
	Tando Bago	90	96
	Khairpur East	30	45
	Kalri Baghar (Ochito and pumps) (start)	120	20
		350	223
	Investigations		431
	Flood Protection		149
	Miscellaneous		25
	Total		5,284

a/ Costs including taxes, duties and interest during construction @ 6 percent per annum.
b/ Figures in parentheses represent number of wells to be completed from July 1, 1966.
c/ Investment required after 1975 to complete the listed tubewell projects.

view of the Bank Group the main emphasis in irrigation development in the years up to 1975 should be on getting more water onto the land. The drainage effect of public tubewells will be important, especially in some areas where the groundwater table needs to be lowered before additional surface supplies from Tarbela can prudently be absorbed, but the past preoccupation of public tubewell development with reclamation of saline and waterlogged lands should be reduced in favor of efforts to exploit groundwater resources as rapidly as possible for irrigation purposes in areas where the wells can yield the highest returns. At the same time public tubewell development should on no account be undertaken in any large areas where private wells are spreading rapidly. Thus the recommended public tubewell program tries to steer a middle course, including projects in areas which are predominantly underlain by fresh groundwater and where the reclamation problems are not the most severe but excluding areas where the technical, social and hydrological conditions are most favorable to continued rapid growth of private tubewells. Extensive surface drainage schemes are included in the program which will help to lower the water table and thus provide valuable support to tubewells, whether private or public, and enable additional surface supplies from Tarbela to be absorbed subsequently. The recommended public tubewell projects generally cover substantially smaller areas than those that have been initiated in the past to enable more discrimination with respect to water quality and drainage needs and to leave for private development all possible areas where private wells can make a substantial contribution.

xxi. Nearly 50 percent of the public-sector expenditures on irrigation and drainage works in the recommended program are allocated to public tubewells. The program foresees the installation and energizing of some 6,700 public tubewells between July 1, 1966 and June 30, 1970. 5,900 of these wells would be in the four projects that WAPDA has under way, while the remainder would be in four high priority projects -- Wagah, Shorkot-Kamalia, Rohri North and Panjnad Abbasia -- that the Bank Group recommends for early initiation. Wagah is a small project, identified but not studied in detail by IACA, in an area which will cease receiving surface supplies once the Indus Treaty is fully implemented and where tubewells would therefore be fulfilling a replacement function. The other three projects belong to a group of 12 for which the Bank Group's consultants prepared detailed project feasibility reports and the Bank Group made project reviews. These projects which were identified on the basis of a survey of all canal commands and with a view to the prospective completion of Tarbela by 1975, cover some 5.8 million acres. Most of the work on them would be undertaken during the Fourth Plan period, in the course of which a total of about 11,000 public tubewells would be installed under the recommended program. This program excludes SCARP V, a major tubewell project proposed by WAPDA, because there are good prospects of strong private tubewell development continuing over most of the area that would be covered by the project, and the small portion where hydrological conditions are more difficult is included in one of the recommended smaller public projects.

xxii. The Bank Group found that all the 12 projects proposed would yield high rates of return and it has included each of them in the recommended program -- although some would not be completed until after the end of the Fourth Plan period. The Bank Group attaches particular priority to eight of the projects. The remaining four, all in the Bari Doab, have only marginal advantages over the alternative of continued private development. The indications are that the substantial private development which has already taken place in the Bari Doab will continue in the absence of public tubewell projects -- and that it is likely to be sufficiently dense to provide some drainage effects. Therefore this may well be an area where economies can be made in the public development program, so that effort may be concentrated on other areas where there are good opportunities for groundwater development but the private sector is less enterprising. Since designation of an area for public tubewell development naturally tends to discourage installation of private wells -- even though the first water from the public wells may not materialize for some years -- the Bank Group feels strongly that these areas in Bari Doab should not be announced as public tubewell areas until there is complete assurance that WAPDA will be able to carry through all or at least most of the recommended tubewell program.

xxiii. No provision is included in Table II for private tubewell development because expenditures shown are only those for which the public sector would be responsible. Nevertheless the Bank Group attributes very great importance to a continuation of private tubewell installation. The public part of the water development program recommended is believed to be at the limit of administrative feasibility and it alone will not suffice to support the increases in agricultural production that are needed. The Bank Group recommends that the Pakistan authorities implement policies conducive to rapid private development as an insurance against shortfalls in public sector performance. Projections underlying the proposed development program assume that the number of private wells in operation would rise from about 34,000 in 1965 to some 55,500 by 1970 and then decline slightly to 52,500 by 1975 if the public tubewell program maintains the schedule called for. However it is likely that, given appropriate incentives, the private sector could sustain a higher installation rate than this and would do so in certain areas if public projects were not going forward. Most recent information suggests that the rate of installation of private wells has continued to accelerate during the time the Study has been under way so that there may be about 50,000 currently in existence in West Pakistan, and the Bank Group believes that this number might well grow to about 66,500 by 1970. It is important that, until the successful implementation of consecutive public-well fields appears assured, private development be given proper encouragement, even in areas that may later be scheduled for public development.

xxiv. Following the public and private tubewells the Bank Group attributes most importance to some of the drainage works proposed, especially the Sukh Beas Nallah Drainage Scheme. This project, originally formulated by the Government of Pakistan and substantially revised by the Bank Group's consultants, comprises a 327-mile drain using mainly the old Beas River bed and having a catchment area of 3.3 million acres in the Bari Doab. It would reduce flood damage in one of the most productive agricultural areas in the Province and also reduce the recharge to the aquifer, thereby contributing to control of the water table in a large part of the Bari Doab. The Bank Group also believes that work should be started at an early date on the Lower Indus Left Bank Outfall Drain. The drain, which would be 267 miles long and have a maximum discharge of 15,000 cusecs, is expected to take 16 years to build; its purpose would be partly to drain away surface run-off but mainly to remove to the sea saline sub-soil water from most of the irrigated area on the left bank of the Indus below Khairpur. Studies and site investigations must be carried through without delay to enable commencement of construction by the recommended date of 1968. The Action Program includes a number of other smaller drainage schemes, besides Sukh Beas and the Left Bank Outfall Drain, primarily in the Rechna Doab and in the Sind.

xxv. Under canal remodeling and other irrigation works the recommended program includes a number of schemes both inside and outside the canal-irrigated area which WAPDA and the Irrigation Department already have under way. But about PRs 200 million of the proposed allocation under this head would be devoted to enlargement of canals serving altogether about one million acres. Most of the areas proposed for canal remodeling are parts of the areas covered by ongoing and recommended tubewell projects where the underlying groundwater is brackish, so that additional surface water is needed to increase irrigation supplies and to enable the cropping intensity to be raised there. Generally it is the distributaries and minors which require remodeling rather than the main canals.

xxvi. The program also includes five small tile drainage projects, chiefly in the Sind. These projects, which cover about 350,000 acres in all, are mainly intended as pilot projects which would provide experience with this form of development under the specific conditions encountered in various parts of the Indus Basin. Tile drainage may subsequently become an important mode of development in the saline groundwater zones.

Surface Water Storage

xxvii. Apart from Tarbela, there are two small but important components to the Bank Group's program for surface water storage development up to 1975: raising of Chasma Barrage to provide storage of 0.5 MAF and a major program of investigations in connection with the siltation problem at Tarbela and identification of the best site for second-stage storage development on the Indus. Expenditures would also commence within the Fourth Plan period on the Sehwan-Manchar Project, which would provide a small amount of interseasonal storage in the Sind.

xxviii. Chasma Barrage is being built on the Indus nearly 200 miles downstream of Tarbela as part of the Indus Basin Works to divert water into the Chasma-Jhelum Link Canal. The project included in the recommended program covers only the costs of building the barrage structure some six feet higher than would have been necessary simply to serve the Link and extending bunds on either side. This will serve to provide some 0.5 MAF of storage at relatively low cost. The project should be completed in 1971.

xxix. The Bank Group is of the opinion that there is an urgent need to start major investigation of the problem presented by the silt load of the Indus. Calculations on the basis of data from a few years of record indicate that all but one MAF of the live storage capacity of Tarbela will be lost within about 50 years; siltation could be more rapid if completion of the dam happened to be followed by some high flood years or if bed load is larger than expected. Additional points should be established on the Indus for measurement of silt, and attention needs to be given to identifying the sources of both suspended sediment load and bed load and to discovering means of checking the movement of silt or reducing the rate at which it will deplete Tarbela storage capacity. In conjunction with the study of silt in the Upper Indus geological and hydrological data should be collected on potential dam sites in the area, which might be developed for small scale local purposes or for large-scale regulation of the Indus or its tributaries supplementary to Tarbela.

xxx. The Bank Group found that there are four projects which, on the basis of present knowledge, can be considered contenders for second stage storage development of the Indus -- Kalabagh, Gariala, Skardu and the Thal Scheme. Though the Bank Group believes that the best of these may be Kalabagh, with a conventional structure and a firm power capability of about 350 mw, insufficient is known about any of the four alternatives to permit a firm judgment at this stage. The need for major second-stage storage on the Indus may be expected to arise during the late 1980's or early 1990's. Since it may take seven years or more to construct the necessary structures and because, if one site proves to have significantly less favorable conditions than now believed, there must be time to investigate other sites before construction of second-stage storage has to be commenced, the Bank Group recommends early efforts to carry investigations further. Skardu should be studied in connection with the Upper Indus investigations mentioned in the previous paragraph. The Thal scheme is little more than a concept at present and the Bank Group thinks it would be worth giving some early attention to general aspects such as foundation conditions, seepage rates, siltation rates, actual feasible reservoir capacity, evaporation problems, and suitability of local materials for embankment construction in order to provide a firmer idea of the feasibility of the concept. More detailed investigations should be undertaken at Kalabagh, at latest early in the Fourth Plan period, and they should include subsurface exploratory works and seismic studies, detailed survey of the site, access routes and reservoir area, sediment sampling and material analysis.

xxxi. Maintenance and expansion of the network of stations for gathering basic hydrological and meteorological data is of utmost importance, for the storage sites which now seem to be the most attractive for further development may not prove to be so as techniques of dam design develop and as more is learned about geological conditions along the rivers.

xxxii The Sehwan-Manchar Project is not scheduled in the recommended program for completion until 1982, but intensive investigations and initial works would have to be started about 1974 in order to meet this schedule. The project is in fact the most important single irrigation work proposed by the consultants who have been investigating water resource development in the Lower Indus area. It is designed to increase water supplies to some of the best agricultural land in the Sind at the lower ends of Rohri and Nara canals on the left bank of the Indus. It would comprise a new barrage across the Indus at Sehwan, which would provide about 0.8 MAF storage, bunds around the existing Lake Manchar some four miles away on the right bank of the river creating storage capacity there of about 1.0 MAF, expanded channels linking Lake Manchar to the river and a large 36,000 cusec feeder canal to carry water from Sehwan to the Rohri and Nara canals.

Electric Power Development

xxxiii. Proposals in the field of electric power account for about 28 percent of the cost of the Action Program outlined in Table I or an annual average of about $130 million equivalent. Proposed allocations for power development appear to represent a significantly higher proportion of total plan investment than has been devoted to this sector in the past. This is accounted for by several facts. First, the power system has been expanding so fast in recent years that a serious backlog has arisen in maintenance, renovation and expansion of the distribution system and the proposed program includes provision for making up this backlog. Second, in view of the planned completion of Tarbela in 1975, the Bank Group recommends an early start on the installation of a 380-kv transmission system to interconnect all the main power markets of the Province. Third, the Bank Group's program includes sufficient generating plant to make up the backlog in system capability that has developed in recent years and to raise the margin between generating capacity and anticipated loads to a more adequate level than it has been possible to attain in the past. The Bank Group's plans are generally based on provision of about 10 percent reserve generating capacity in the 10-day period when the hydroelectric plants reach their lowest capability. The nature of the main power system in West Pakistan is in a transitional phase which began with the recent completion of the first units at Mangla. These units will have greatly fluctuating capability over the course of the year, depending mainly on the height of water in the reservoir. As a result, if reserves are reasonably adequate at the time when the reservoir level is at its lowest, then they will be ample at other times in the year. Taking account of this aspect of hydroelectric development, of the need for improvement in reliability of power supply and of the uncertainty inevitably attaching to load forecasts the Bank Group believes that the level of reserves built into its program is appropriate. Nevertheless it recommends further consideration of the reserve problem in light of these factors and the increasing importance that will attach to the tubewell pumping load with its dependence on variable climatic and meteorological conditions.

xxxiv. The Bank Group expects that the peak power loads on the public utilities in the main power markets of the Province will rise from a combined total of about 560 mw in 1965 (650 mw, had there been no load shedding) to about 2,300 mw in 1975. The Bank Group's power consultant thought that load growth would be more rapid in the south of the Province than in the north. Despite the rapid development of tubewells anticipated in the north, the effect of this on total loads would be outweighed by faster growth of industrial loads in Karachi and the Sind. The Bank Group concurred with the power consultant and adopted a main load forecast rising from a nonsuppressed peak of 473 mw in 1965 to about 1,400 mw in 1975 in the Northern Grid and from 136 mw in 1965 to 640 mw in 1975 in Karachi; load growth in the Sind would be even more rapid than in Karachi but loads are presently very small there and they would remain less important in the overall picture. These peak loads are all calculated on the assumption that most of the public tubewells would be shut off in the evening hours of peak load, which would serve to reduce peaks in 1975 by about 100 mw from what they would otherwise be.

xxxv. There is a possibility that the figures mentioned above and used in most of the Bank Group's planning may somewhat exaggerate the extent to which loads in the North will grow slower than those in the South. For a number of reasons the situation in the North is rather uncertain: load shedding has grown to such significant proportions in recent years that the actual current level of demand is not clear and there is also doubt about the extent to which the transfer of Government from Karachi to Islamabad and the Government's emphasis on industrial development outside Karachi may result in greater growth of large-scale commercial and industrial load in the Northern Sind and the Punjab. Some of these uncertainties will be reduced by 1968 when installed capability should be adequate, for the first time in several years, to meet demand during the critical period on the system. The Bank Group recommends that in 1968/69 a careful reappraisal of prospective loads in the early 1970's be undertaken, but in the meantime it has adopted an alternative contingency load forecast for the Northern Grid which leads to a peak of about 1,600 mw in 1975, some 200 mw higher than the figure used in the main load forecast.

xxxvi. The Bank Group believes that, provided existing construction schedules are adhered to, then loads in all areas can be adequately covered between 1968 and 1970 inclusive, whether loads in the Northern Grid are at the higher or the lower of the two levels projected. The top portions of Table III list the main generating units which are under construction or which are recommended in the proposed program. The third unit at Mangla is expected to be ready for service late in 1968, and the fourth unit late in 1969. Negotiations for supply of two 100-mw steam units from Czechoslovakia for installation in the Upper Sind about 1970 or 1971 are being finalized by WAPDA. A double circuit 132-kv link between the Northern Grid and Upper Sind is also being completed so that the Northern Grid would be able to draw about 120 mw from the Upper Sind. The World Bank has recently approved a loan to Karachi Electricity Supply Corporation (KESC) for addition of a 125-mw steam unit at Karachi, which

Table III

Power Program, 1965-75

Completion Date		Installed Capacity (mw)	Cost a/ (PRs mlns.)
	Electrical Generation: Units Completed or Under Construction		
1966	Lahore Gas Turbines	26	15
1967	Sukkur Steam Units	25	17
1967	Lyallpur Steam Units	124	44
1967/69	Mangla Units 1, 2 and 3	300	115
1967	Kotri Gas Turbine	13	10
1968	Lahore Gas Turbines	52	37
1968	Kotri Gas Turbines	26	19
1969	Korangi Unit 3 ("C" station)	125	99
1971/72	Karachi Nuclear Station	125	286
			642
	Electrical Generation: Units Proposed		
1970	Mangla Units 4, 5 and 6	300	100
1970	Mari Steam Unit I	100	98
1970	Hyderabad Gas Turbines	26	19
1971	Mari Steam Unit II	100	98
1973	Mangla Units 7 and 8	200	86
1974	Mari Gas Turbines	200	146
1975	Tarbela Units 1 and 2	350	278
1975	Korangi Unit 4	125	99
1974	Quetta Units	19	31
	Initial Work on further units		473
			1,428
	Electrical Transmission (lines only)		
1969	220 kv Mangla-Wah		33
1968/72	220 kv Mangla-Midway		68
1968/72	220 kv Midway-Lyallpur		31
1969	220 kv Midway-Kotlakhpat		11
1969	220 kv S. Lyallpur-Montgomery		11
1975	220 kv Montgomery-Multan		23
1969/73	220 kv Wah-Tarbela		12
1971	380 kv Lyallpur-Mari		99
1971	380 kv Mari-Hyderabad-Karachi		101
1974	380 kv Mari-Karachi		65
1975	380 kv Tarbela-Lyallpur		61
	Other (line Terminals, Transformers, 33, 66 and 132-kv lines)		600
			1,115
	Distribution (400 v/11 kv lines, customer connections, etc.)		
	Third Plan Period		1,180
	Fourth Plan Period		1,890
			3,070
	General b/		62
	Total		6,317

a/ Including taxes, duties and interest during construction at six percent per annum.
b/ Including buildings, offices, miscellaneous equipment, etc.

should be completed by mid-1969. The main point is that by the critical period on the northern system, at the time of lowest reservoir level at Mangla, in March of 1970 the minimum requirement is that either Mangla units 5 and 6 or both the 132-kv line between the Northern Grid and Upper Sind and the first 100-mw Czech unit should be fully completed. Either of these sets of installations would provide sufficient capacity to meet loads projected on the main load forecast with adequate reserves and enough to cover those projected on the contingency load forecast, though with inadequate reserves. The Bank Group's recommended program includes more than this bare minimum -- Mangla units 5 and 6 as well as the 132-kv link and the first Czech unit -- which would provide sufficient capacity to meet the highest anticipated loads with adequate reserve. If Mangla units 5 and 6 cannot be completed by the Spring of 1970 then the Bank Group feels that completion of the second Czech unit in the Upper Sind would be warranted by that time. In the South the situation would be somewhat similar: provided that the 132-kv line between Karachi and Hyderabad is completed on schedule in 1968 and generating plant is installed as noted in Table III, then projected 1970 loads could be covered, but the Bank Group's program includes an additional 26 mw of gas turbines in order to raise reserves to a more adequate level, close to the size of the largest single unit on the system at the time (125 mw).

xxxvii. The most critical concept in the Bank Group's program for the Fourth Plan is 380-kv transmission interconnection between all main power markets; and the earlier this can be completed after 1970 the better, in the Bank Group's view -- which means that work on these lines should be initiated at the earliest opportunity. Province-wide EHV interconnection will be especially valuable after the completion of Tarbela in enabling more rapid absorption of the dam's hydroelectric potential. It will also serve to reduce the amount of reserve generating capacity required in the Province and the amount of gas-pipeline capacity which must be installed to provide fuel for thermal generation. However, if EHV interconnection is warranted after Tarbela, then it should be installed as soon as possible in order to develop the power system in the interim into a pattern appropriate to the expeditious absorption of Tarbela power. The Bank Group considers that there would be advantages in having a complete EHV line between Lyallpur in the Northern Grid and Karachi in the South by 1971 or 1972. However highest priority for early completion attaches to the northern section of the line between Lyallpur and the Upper Sind because it would enable the development of a better geographical pattern of thermal generation (concentration of capacity at the gas fields in Upper Sind) and it would reduce problems that would otherwise arise in supplying large quantities of fuel -- gas or fuel oil -- to plants in the Northern Grid for short periods during the year. Nevertheless the Bank Group recommends that the southern half of the proposed EHV line, between the Upper Sind and Karachi, should also be installed at latest by 1975, and preferably earlier, because without it West Pakistan will lose some of the main potential benefits of the proposed system -- such as consolidation of Province-wide generating reserves, reduction of reliance on gas (with its significant opportunity cost) and fuel oil (with its heavy foreign exchange component) and rapid realization of the power benefits of Tarbela.

xxxviii. The Bank Group's proposals regarding installation of generating equipment during the Fourth Plan period are built around the concept of the EHV transmission lines linking Karachi, the Sind and the Northern Grid. The main additions to generating capacity during the Fourth Plan would be at Mangla and at the Mari/Sui gas fields in the Upper Sind. Mangla units 5-8 are scheduled for early completion because they would provide much base-load power for the Northern Grid and, once the EHV interconnection was in place, much of the base-load energy which they would produce in some six to nine months of the year in excess of Northern Grid requirements could be exported to the South. Thermal units at the gas fields would provide supplementary power for the Northern Grid in the months when hydroelectric capability was low and they would also be used to help meet loads in the South; their role in the South would be largely semi-peaking, base load being met by the Atomic Energy Commission's nuclear plant and by hydroelectric energy from the North and peak load being met by local thermal units in Karachi and Hyderabad. Concentration of thermal development in this period on the gas fields would eliminate the need for expansion of the gas pipelines to meet the needs of the power plants after 1970, it would facilitate the operation of the EHV transmission interconnection, and it would usefully complement the proposed hydroelectric developments. The generating units proposed in Table III are scheduled to meet the main load forecast adopted by the Bank Group, but if loads should at the end of the Third Plan period appear likely to be closer to the contingency load forecast during the Fourth Plan, then the extra 200 mw of capacity required should also be installed at Mari/Sui. Taking account of the relative prices of gas turbines and conventional steam turbines, the value that can be attributed to the natural gas reserves and the largely semi-peak role that would be played by the plants at Mari/Sui, the Bank Group concluded that a relatively large proportion of the generating capacity installed there during the Fourth Plan -- possibly as much as one-half -- should be gas turbines. At the very end of the Fourth Plan the first 380-kv line between Lyallpur and Tarbela would be completed and the first two Tarbela units would come into operation.

xxxix. Nearly half the cost of the proposed Action Program for electric power relates to the last stage of power supply -- distribution lines, customer connections, meters, etc. The Bank Group considers that the allocations proposed for this part of the program are vital; without sufficient effort on this side of development, which has been somewhat neglected in the past, the distribution system will deteriorate and become more dangerous, there will continue to be wasteful delays between the time when tubewells are installed and the time they become operational, and the projected loads will simply not materialize. According to the Bank Group's projections, WAPDA needs to connect about 516,000 new customers during the Third Plan period (including 16,000 public and private tubewells) and about 725,000 new customers during the Fourth Plan period (including 25,000 public and private wells). The Bank Group estimates that this will involve construction of about 23,000 miles of 11-kv and 400-volt distribution line during the Third Plan and 35,000 miles during the Fourth Plan, compared with an actual achievement of about 15,000 miles during the Third Plan. In the Bank Group's opinion there are three main steps required to improve performance in the construction of distribution lines. First, adequate funds must be provided and allocations for distribution work should not be made to bear the brunt of budget cuts, as has sometimes happened in the past. Second, an improved system of inventory control must be established to make sure that components are ordered sufficiently early and distributed in such a way that they are available at the time and place required. Third, more emphasis needs to be given to training of labor in distribution-line work, and the training provided should be given a much more practical bent than it now has.

Organization and Implementation

xl. The capacity of the public authorities to implement projects to increase the supply of electric power, irrigation water and agricultural inputs and the capacity of the farmer to absorb new agricultural techniques and inputs were assessed by the Bank Group and its consultants and accepted as factors limiting the size and composition of the recommended development program. Nevertheless, as the size of the resultant program makes clear, the targets adopted are ambitious and some of them are very ambitious. They will not be realized without substantial improvements in organization and management in the near future, especially in some fields. In the view of the Bank Group these necessary improvements will be achieved most quickly and effectively by adjusting the existing organizational structure and improving coordination among its parts rather than by establishing wholly new organizations or other radical structural change.

xli. It has been suggested, for instance, that some of the responsibilities of WAPDA's Power Wing might be transferred to a new organization, but the Bank Group is not convinced that this would be a prudent move at the present time. The Power Wing has done a reasonably good job under rather difficult circumstances and through trial and error has gained much valuable experience. Establishment of a new organization would not ease the basic problem of shortage of qualified and experienced people; indeed it would more likely only exacerbate this problem since the new organization would have to have its own separate management hierarchy, and more people in both the new and the old organizations would have to devote time to ensuring proper coordination between them. New organizations, such as municipal power distribution agencies, would also likely encounter even more difficulties than WAPDA does in securing adequate financing for distribution work because they would lack the financial strength of WAPDA. The Bank Group believes that reassignment of responsibilities in different organizations at this time would tend rather to delay than to expedite work on the expansion of the distribution and transmission systems that will be necessary if the large amounts of hydroelectric and thermal energy that will soon become available are to be marketed. It would be more prudent to concentrate on strengthening the Power Wing. The General Manager should have sufficient authority to make all the decisions that would normally be made by the management of a commercial power company.

xlii. The Bank Group believes that much more effective coordination among Government departments and between the departments and other entities working in related fields is required in all phases of the development effort. Planning needs to be better coordinated to reduce the present duplication of effort and to enable all departments and agencies to review plans at an early stage and give their best advice. This applies especially to the public tubewell projects which must necessarily be a cooperative effort if they are to be successful because of the many contributions required -- installation of wells under WAPDA's Groundwater and Reclamation Division, electrification of wells by WAPDA's Power Wing, operation of wells by the Land and Water Develolment Board or the Agricultural Development Corporation, coordination of surface water supplies under the control of the Irrigation Department, concentration of extension effort by the Agriculture Department and distribution of farm inputs by various of these public agencies and by private enterprise. The need for coordination in planning also applies to the power sector; the Bank Group believes that WAPDA load forecasting and system planning should be much better coordinated both with similar work in KESC and with general economic planning and forecasting. Because plans must be constantly revised and updated long-term relationships are needed among these various bodies. Sometimes these relationships will best be handled by committees -- a joint economic and power group has been suggested, for instance, for work on load forecasting -- but often coordination among agencies will best be handled by the Planning and Development Department which has overall responsibility for the development effort. This Department needs strengthening in terms of numbers of technically and professionally qualified personnel to enable it to do a more effective job.

xliii. Installation of the public tubewells proposed by the Bank Group and their electrification account directly for some 15 percent of the total costs of the Action Program for Water and Power Development put forward in Table I. If this important component of the total program is to be implemented all phases of tubewell project work from initial identification and preparation to final connection of the wells with the electricity distribution system must be urgently streamlined. The program proposed foresees coverage of nearly 10 million acres by public tubewells between now and 1975, implying an average rate of completion of a little over one million acres a year. This rate of achievement, equivalent to about 1,600 public wells per year, has been recommended by others in the past. WAPDA's Master Plan envisaged a faster rate of accomplishment, reaching over 2,000 wells per annum by 1966. In practice less than 200 public wells were energized in each of the fiscal years 1964/65 and 1965/66, and the highest rate of achievement so far attained was 1,000 wells in 1960/61. This gives a measure of the improvement in organization required. Electrification of wells has been one important bottleneck in the past and some of the measures needed to break it were discussed above in connection with the general problem of expansion of the distribution system. But the other phases of project preparation and execution have also to be raised to a new plane of efficiency if the program is to be achieved. The experience that has now been gained in execution of public tubewell projects should make it possible to develop a standard routine for organizing much of the work. The smaller scale of the projects recommended by the Bank Group than of those undertaken in the past should also make their construction and completion on schedule more manageable.

xliv. The Bank Group attaches great importance to the development of management cadres and organizational structures for each tubewell project which will be able to put the wells into effective operation immediately upon completion; lack of these may in fact prove a more serious obstacle to progress than the difficulties on the construction side. Again the Bank Group does not believe that establishment of new organizations would serve much purpose; rather the existing project management institutions, such as the Agricultural Development Corporation and the Land and Water Development Board should be strengthened and improved. Initially the Bank Group strongly favors integrated project management with direct and undivided responsibility for increased supply of both water and other inputs like fertilizer and correct use of them. This may entail some difficulties arising from the corollary fact that responsibility for water supplies will be divided between the Irrigation Department responsible for surface water, and the local project management responsible for groundwater. But the Bank Group attributes such importance to improvement of farming practices and use of material inputs that it thinks the gains from strong integration at the project level will far outweigh the difficulties on the water supply side. Project Directors should be appointed early so that they can begin the very important task of monitoring progress starting from pre-project conditions. They will have to be supported by extension officers and technical specialists seconded from other Government departments but responsible to the Director while they work on the project. Once a project is well under way and operating smoothly the project management would withdraw in favor of an organization more representative of the farmers, and support functions would be performed by the line departments directly.

xlv. New agricultural inputs and improved farming practices will not be widely adopted, whether inside or outside the project areas, without a drastic improvement of the agricultural extension service. This service, which is the critical link in getting innovations to the stage of actual adoption and showing farmers how to make best use of new inputs, has suffered from inability to attract and hold well-qualified personnel. Halfhearted measures at improvement will not suffice. Sufficient numbers of agricultural personnel will probably be available from the agricultural universities under current expansion plans and from the training colleges for Field Assistants provided that the latter are expanded as recommended. But the quality of the education needs substantial improvement. At present, moreover, many of the best students who could be attracted into Government service in agriculture are lost because of more attractive opportunities elsewhere. To alter this situation -- and it is extremely important to alter it -- the Agriculture Department must be able to offer better career opportunities, involving more status, better pay and better working conditions. Relief from some tasks, such as the actual handling of plant protection materials which are not directly related to extension, and provision of improved facilities, such as transport, could greatly increase the effectiveness of the service. The extension service cannot be effective unless it is backed by a research branch that is imaginative and oriented to solving farmers' day-to-day problems. A dynamic research program is vitally needed to deal with such matters as continuing varietal improvement, more efficient treatment of insect infestation and plant disease, better understanding of soil, crop, water and fertilizer relationships and improvement of farm implements. Building an efficient and contributing research branch requires dedicated leadership, generous financial support, understanding of the uncertainties inherent in research and infusion of a spirit of service to the agricultural community. Immediate steps towards securing a greater contribution from research would be better pay and conditions, as with the extension service, and better coordination with the extension service in order to focus attention on farmers' urgent problems.

xlvi. Shortage of well-qualified personnel, especially at the lower levels, is of course a general problem and not one confined to agricultural services. Indeed the shortage of engineers may be more acute. It is estimated that at most about 3,800 engineers will graduate during the Third Plan period compared with a figure in the Third Plan document of 7,000 for the increase in requirements of graduate engineers over the same period. The Bank Group's consultants have estimated that the recommended program of irrigation and drainage development will require by 1975 1,000 engineers for project planning and construction activity and 300 engineers for supervision and operation of tubewell projects. More rapid expansion of engineering education is difficult, without sacrificing quality, because of the shortage of good teachers. The shortage of engineers for the program could be reduced by on-the-job training of promising young men who lack formal engineering education but could handle supervisory tasks well. More advantage could be taken of consultants for training purposes. Nevertheless there will continue to be serious shortages. Foreign consultants and contractors cannot fully make up for the lack of people with extensive local experience, but continuing heavy reliance will have to be placed on them.

xlvii. The shortage of good Government staff does emphasize the need for making as much use as possible of private enterprise. It is very important that public agencies do not try to undertake more than they can really achieve because, besides overextending their staff resources and making them less effective, they also thereby reduce the scope for private enterprise, whether in groundwater development or in promotion of agricultural inputs. As supplies of fertilizer increase maximum use should be made of both private enterprise and Government channels to spread it widely. Multiplication of improved seed on private farms and distribution through private enterprise channels will be essential means to securing rapid advances in the use of the new crop varieties now becoming available; the role of Government would be limited to production of basic seed stock and supervision of multiplication and distribution to ensure that quality is maintained down to the level of the individual farmer. Private enterprise could also gradually come to play a major role in distributing and encouraging use of other needed inputs like plant protection materials and agricultural machinery, under general Government supervision regarding quality and regarding regularity of service; this would help to leave the Government agricultural officers free for their main job of giving advice to farmers and breaking bottlenecks in supply of needed inputs. Subsidies will probably continue to be needed on fertilizer and plant protection materials, to encourage their adoption, but they should be arranged in such a way as to minimize the administrative burden on Government agricultural officers.

xlviii. The Bank Group also recommends a more positive Government effort to promote private tubewells. As pointed out, continued growth of private tubewells occupies a very important place in the recommended program for the coming years. Apart from the installation subsidy on wells put in by the Agriculture Department, the most significant Government contributions to private tubewell development so far have been rather indirect -- such as increasing imports of materials for tubewell manufacture, providing more funds to WAPDA for tubewell electrification, and reserving certain areas for private wells. The Government could, without interfering with private enterprise activity, do more to promote private tubewells and other forms of private water development and, since WAPDA will not be able to cover more than a limited area by 1975, it should do so. In particular farmers and landowners should be enabled to get advice easily regarding procurement and construction matters, types of equipment available and suitable, quality of groundwater underlying their farms, irrigation requirements and water management. The need for advice about ways to organize cooperative installation and use of wells will become more important as continued growth of private tubewells comes to depend more on the smaller farmers; credit will equally become important and a more aggressive credit policy on the part of the Agricultural Development Bank would help. The extension service should give special attention to farms with private wells, to help the farmers make best use of additional water supplies.

xlix. The Bank Group believes that provision of technical advice and assistance which would not otherwise be available is a better way for the public authorities to support private tubewell development than outright subsidies. The Bank Group is also very doubtful whether the subsidized price at which electricity is sold to farmers for pumping purposes has had much effect in promoting private tubewells. Since the Power Wing's rate of return on capital invested is already below what the Bank Group would consider a reasonable level, and since one of the most important factors limiting the extension of the distribution system for further tubewell electrification is shortage of funds, serious consideration should be given to raising the price charged the farmer for electricity. Subsidies on fertilizer, plant protection and improved farm machinery, on the other hand, do appear to play an important promotional role and, in consonance with its general emphasis on the maintenance of a price framework for farmers which gives maximum incentive to modernization, the Bank Group recommends retention of these subsidies until the value of the new inputs is so widely recognized among the farmers that they are prepared to buy adequate quantities at unsubsidized prices. Maintenance of a price structure for farm products that provides adequate returns to farmers for their effort and risk is also critical to success. In the view of the Bank Group a more appropriate way to increase public savings than reduction in subsidies on the new inputs or in farm product prices would be increased water charges. Water is an accustomed input, the critical importance of which is already widely understood by the farmers, so that increased water charges should have no disincentive effect. Indeed, higher charges for water, more commensurate than those presently levied with the heavy costs involved in building and operating the irrigation system, could help to improve the utilization of water just as the much higher costs of private tubewell water have apparently led to more careful and productive use of water obtained from that source.

l. Efficient operation of the irrigation and power systems becomes increasingly important as more money is invested in them and they become more tightly integrated and interdependent with one another. The Bank Group recommends that a Provincial Irrigation Authority be constituted at the highest level to give adequate recognition to the broad range of administrative, legal, sociological and technical considerations related to water resource policy. This body would be responsible for basic policy decisions on barrage allocations, reservoir release patterns and drawdown levels and other major policy issues such as the use of tubewell fields in relation to surface water deliveries, and it would be concerned with both power and irrigation aspects of these matters. Broad policies affecting the distribution of available water supplies have remained little changed for decades, but it is essential to subject them to thorough review in light of the existence of Mangla dam, the forthcoming completion of the IBP works, changes in the design discharges of canals and gradual expansion of the public tubewell system. These policies will need to be continually adjusted as the complex irrigation system evolves. Provision has now to be made, for instance, for the filling of Mangla Reservoir in kharif and allocations will soon be needed for diversion from the Indus and the Jhelum into the link canals to supply the needs of canal commands which have in the past depended on Sutlej and Ravi flows. Additional to its main interseasonal storage function, Mangla will be able to provide important benefits in the form of regulation of natural flows, particularly in the later part of the rabi season, to match them more closely to crop-water requirements; but securing these benefits will depend on careful operation of the reservoir. Stored surface water will yield highest benefits if it is released and allocated on a basis which recognizes the advantages accruing to power from keeping up the level of water in the reservoir for as long as possible, which considers irrigation releases in terms of the actual needs of canal commands rather than theoretical historic allocations, and which takes account of the extent to which these irrigation needs in different months can be met by groundwater pumping.

li. The Provincial Irrigation Authority would be charged with responsibility for ensuring that all Government agencies concerned with irrigation should cooperate in the framing of new policies for water allocations, but it would not itself be expected to undertake the detailed analyses of water distribution. The Bank Group believes that for this purpose there should be set up a semi-independent study group or working party staffed by, say, the Irrigation and Power Department, WAPDA, the Agriculture Department and the Planning and Development Department. The study group would need to be well staffed with technical officers competent to carry out the detailed calculations and analyses required and fully conversant with the practical problems of irrigated farming and of operating the irrigation system. It may require assistance from consultants during the early stages.

lii. Representation of WAPDA's Power Wing in the derivation of policies for operation of the works, such as Mangla Reservoir and the tubewell fields, which have implications for power as well as irrigation, will be important but improvement is also vitally needed in operations of the Power Wing less directly related to water resources. The chief dispatches of the power systems must be clothed with sufficient authority to direct the flow of electricity from generating stations to load centers as required and to order the start up or closing down of generating stations to meet fluctuating demands. After the power systems in the North and the South are interconnected by EHV transmission lines a central dispatching station will be needed. The Power Wing's billing, collecting and accounting procedures need improvement. The present accounting system does not provide management with sufficiently detailed and up-to-date statistics to analyze operating results and trends and to know where responsibility for successes and failures lies. Losses on the WAPDA systems are presently unduly high -- about 20 percent of the total energy sent out from the generating stations; even a small reduction could lead to substantial increase in net income, but a sizable reduction should be possible with improvement of the distribution system, better meter reading and billing procedures, and more efficient operation of a denser distribution and transmission network.

Irrigation and Agriculture Development after 1975

liii. In deriving the recommended program for development over the decade 1965-75 the Bank Group has given considerable attention to the longer term potential of the irrigation system, and the report discusses the main lines of development that should be followed after 1975, as far as can now be foreseen. Parallel improvements in the supply of water and of other agricultural inputs should continue through this period. There will remain substantial scope for increasing productivity by such means as greater use of fertilizer, development and wider distribution of improved seed varieties and more widespread adoption of effective plant protection measures. Mechanization should take place at an increasing rate.

liv. Completion of Tarbela in 1975 will mean a substantial increase in rabi water supplies and, if properly integrated with other sources of irrigation water, it would make it possible to match irrigation supplies to the water requirements of crops on an expanding cropped acreage to a much greater degree than will have been possible before 1975. Full integration of groundwater and surface water supplies should be achieved in the decade 1975-85. It is at this stage that coordinated control of the tubewell fields will become important in order to permit substitution of surface supplies by groundwater in some canal commands and reallocation of these quantities to other areas. The availability of more rabi surface water and the existence of effective water table control by means of public tubewells will make it worthwhile to expand the canal enlargement program substantially. As more areas with brackish groundwater are brought under development there will be increasing need for drainage works.

lv. The Bank Group's outline program for irrigation development after 1975 foresees coverage of virtually the entire area underlain by usable groundwater with public tubewell projects by 1980. This would mean construction of public projects covering about seven million acres between 1975 and 1980, additional to the twelve million acres which would be covered by 1975 under the recommended Action Program. Whether it will really be necessary to replace private wells with public wells in all areas in order to enable sufficiently integrated operation of the system in fact remains to be seen. The program envisages that once the usable groundwater areas needing public tubewells have been covered, then the tubewell construction program would shift to the saline groundwater areas. Not all of the 10 million acres of canal-irrigated area underlain by saline groundwater have aquifer of suitable characteristics for tubewell pumping, but generally in those areas where tubewells can operate effectively they would be installed for drainage purposes, while in other areas surface or subsurface drainage works would be required.

lvi. The availability of additional rabi water, from Tarbela, will make it possible to develop the areas not underlain by fresh groundwater to higher cropping intensity, but in most of these areas, where less use can be made of groundwater for irrigation purposes, the canals will need to be expanded to carry sufficient surface supplies. The long-term program envisages completion of canal remodeling in five million acres over the decade 1975-85 and in a further ten million acres before the end of the century. It appears that by the early 1980's an additional link canal across the Punjab will be required to deliver water from the Indus to the expanded canals in areas with saline groundwater in the eastern Punjab. The Bank Group's consultants have suggested that this new link canal should take off from the tail reach of the Chasma-Jhelum link, but its alignment would need to be further considered in due time.

lvii. In the Lower Indus the main work in the decade after 1975 would be canal remodeling, in connection with the expansion of tubewells and tile drainage in saline groundwater zones, and surface drainage works. Canal enlargement here hinges essentially on the Sehwan barrage project which was mentioned above for commencement of construction late in the

Fourth Plan period. As now proposed, the Sehwan Barrage and Sehwan-Rohri feeder are scheduled for completion in 1982, and the Rohri-Nara feeder is scheduled for completion after 1985. The very large Left Bank Outfall Drain which would have been started in the Third Plan period, would be brought to completion around 1985. A parallel drain on the right bank, which would drain the effluent of the Gudu and Sukkur Right Bank areas into the Indus downstream of Sehwan Barrage would be built over the years 1980-90.

lviii. As regards surface storage, the Bank Group believes that, following completion of Tarbela in 1975, additional capacity will not be required until the 1980's. In the early 1980's Sehwan-Manchar will add some 1.8 MAF of capacity. Around 1985 further large-scale capacity will be needed to meet growing irrigation needs and to help replace capacity lost by siltation at Tarbela. The need might usefully be met by raising the Mangla Dam to provide additional storage on the Jhelum. Alternatively it may then appear best to go straight to second-stage storage on the Indus, which will anyway be required by about 1990. The alternatives for second-stage storage on the Indus that the Bank Group envisages were discussed above in connection with the need for an early program of investigations. The amount of additional surface storage capacity required in this period will depend on the extent to which interseasonal underground storage, which would require canal remodeling in fresh groundwater zones, is found to be a feasible alternative.

Power Development after 1975

lix. The most important additions to the power system in the years following completion of Tarbela Dam will be generating units there and further 380-kv transmission lines linking Tarbela to the Northern Grid. The Bank Group's projections suggest that it would be worthwhile installing all 12 units at Tarbela by 1981. By that time, according to the proposed program, there would be three 380-kv transmission lines between Tarbela and the Upper Sind. These lines will not provide sufficient capacity to carry the full potential output of Tarbela during the flood months, but the Bank Group believes that the energy which they could not carry would have to be taken to Karachi to find a market and that it would not be worth installing additional lines for this purpose. Some years later the extra energy produced in the flood months could be absorbed locally or in the Northern Grid.

lx. At the same time as the Tarbela units are being installed it will be necessary to build additional thermal capacity that will provide megawatts in the spring when the reservoirs are fully drawn down and will also help to stabilize the EHV transmission line. This thermal capacity will operate at low load factor because Tarbela and Mangla would provide the largest part of the energy required at most times in the year. The Bank Group believes that, as far as can now be foreseen, this capacity would best be based on natural gas. The outline program for the post-1975 period includes additional thermal capacity on the gas fields in the Upper Sind and in Karachi, where it would be fired by

Sui gas. It is in this period that it might become appropriate to develop the Lakhra coal field for large scale power generation according to the Bank Group's studies, but the Bank Group is doubtful whether the scarcity of natural gas by this time will be sufficient to warrant a change to coal burning power plant with its higher capital and operating costs.

lxi. By the early 1980's there will be a strong case for extensive development of nuclear generation in the South despite its relatively high foreign exchange costs. Before 1980 nuclear plant would not appear very attractive chiefly because, even in Karachi, the availability of energy from Tarbela would be such that it could not economically be operated at the high load factor necessary to make nuclear generation competitive with alternatives. According to the Bank Group's forecasts and system studies loads in the South would be adequate by the early 1980's to give a 400-mw nuclear unit a load factor of better than 80 percent; and by 1985 a second 400-mw nuclear unit could have a load factor, even after absorption of substantial quantities of hydro energy, of nearly 70 percent. Moreover, by the early 1980's, loads on an interconnected system would be growing fast enough to absorb reasonably quickly units of 400-mw, which may be the minimum size at which substantial economies will be obtainable from nuclear plant.

I. INTRODUCTION

1.01 The subject of this Study is the Indus Basin of West Pakistan. The Indus River together with its six main tributaries -- the Kabul, Jhelum, Chenab, Ravi, Beas and Sutlej -- forms one of the greatest river systems of the world. Diversion of the waters of the seven rivers for irrigation purposes has been going on for more than 3000 years. Mainly over the last century a vast network of barrages, weirs and canals has been constructed so that the area irrigated from the Indus and its tributaries is now more extensive than that irrigated by any other single river system.

1.02 Partition of the Indian subcontinent, and in particular of the Punjab, in 1948 between Pakistan and India placed a major obstacle in the path of further development of the Indus River system. But a decade of negotiation between the two new countries led eventually to signature of the Indus Waters Treaty of 1960, which provided for peaceful division of the river system. There was to be a ten-year transitional period at the end of which Pakistan would have the right to full use of the Indus itself and the two "western tributaries" (Jhelum and Chenab) while India would be entitled to divert all flows of the "eastern tributaries" (Ravi, Beas and Sutlej) for her own use.

1.03 The engineering concept which underlay the treaty was a system of enormous "link" canals for transferring water from the Indus and, to a lesser extent, from the Jhelum and the Chenab, to meet the irrigation requirements of eastern portions of West Pakistan which had hitherto been served by the three rivers now made available in their entirety to India. To provide funds for implementing this concept an international agreement was signed, simultaneously with the Treaty, to establish the Indus Basin Development (I.B.D.) Fund. The World Bank was designated Administrator to the Fund. The parties to the Agreement were Australia, Canada, Germany, New Zealand, Pakistan, the United Kingdom, the United States and the Bank. The Fund represented the equivalent of US$ 895 million, including an equivalent of US$ 174 million to be provided by India under the Treaty and a loan of US$ 80 million from the World Bank. The I.B.D. Fund was estimated to be sufficient to cover the total cost, foreign and domestic, of the works to be constructed in Pakistan envisaged by the Treaty.

1.04 As engineers began to take a closer look at the proposed works following the Agreement, it became increasingly clear that the cost of the works would far exceed the resources of the I.B.D. Fund. Revised estimates indicated that the total cost of the Indus works would be not less than twice the amount available to the Fund for this purpose. Negotiations were undertaken with a view to increasing the resources of the Fund. However, the contributing governments were not ready to subscribe additional amounts to the full extent required. Furthermore, there were unresolved problems with regard to the precise works to be built under the Agreement.

1.05 As Administrator of the I.B.D Fund, the World Bank was directly concerned with finding a solution to this unsatisfactory state of affairs. The settlement finally worked out, in the latter half of 1963, was based on a prospective addition of US$ 315 million to the Fund -- assurances from the contributing governments of additional subscriptions amounting to approximately US$ 257 million plus a US$ 58 million pledge from the World Bank. The availability of the various subscriptions to the Fund was subject to satisfactory appraisal of the projects to be executed.

1.06 At the time that this financial settlement was reached an order of priority was also agreed upon for spending the available funds. First priority was given to the construction of an earthfill storage dam and related works on the Jhelum River (Mangla), link canals, barrages and other works set forth in Annexure D of the 1960 Agreement. Second priority was extended to a study of the Water and Power Resources of West Pakistan to be organized by the Bank as Administrator of the Fund. Thirdly, any remaining balance would go toward the foreign exchange costs of a dam on the Indus near Tarbela, if the Special Study proved it justified, or to other water projects agreed upon between Pakistan and the Bank on the basis of the Special Study.

1.07 A Memorandum of Understanding which outlined these arrangements was signed on November 14, 1963 by Field Marshal Mohammed Ayub Khan, President of Pakistan, and Mr. George D. Woods, President of the World Bank. After the Memorandum of Understanding had been approved by the contributing governments its substance was incorporated in the Indus Basin Development Fund (Supplemental) Agreement 1964. This Agreement, which was signed on April 6, 1964 by all parties contributing to the Fund, provided that Pakistan would accept the arrangements set forth as a full and complete discharge of all obligations, whether legal or moral, expressed or implied, of the other parties under the 1960 Agreement.

1.08 The study of Water and Power Resources mentioned in the Memorandum of Understanding and the Supplemental Agreement was to include a detailed survey of the basic water and power resources of West Pakistan and of farming conditions and prospects in the Province and it was to identify the most practical means of developing these resources in keeping with the needs of the Pakistan economy. The general character of the study was established in paragraphs 1 and 2 of the Memorandum of Understanding in the following terms:

> (1) The study would consist of a survey of the water and power resources of West Pakistan, primarily but not exclusively related to the potential for agricultural development. Its purpose would be to provide the Government of Pakistan with a basis for development planning within the context of successive Five Year Plans. It would be sufficiently detailed to assist the Pakistan Government in formulating a sound program for the systematic exploitation of the water and power resources of West Pakistan.

(2) While the study of the water and power resources of West Pakistan should be a continuing process, the Study presently proposed would be the initial stage and would serve to determine which of the several potential water and power projects are economically viable and feasible of execution during the next two Five Year Plan periods (1965-70 and 1970-75). The Study would take account of, and serve as a useful guide to the possible future development of water and power projects beyond 1975.

It was stipulated that the first objective of the Study would be the completion of an interim report covering the technical feasibility, the construction cost and the economic return of a dam on the Indus at Tarbela. The second phase of the Study was to deal in a more comprehensive manner with West Pakistan's water and power resources as a whole, giving full emphasis to the broader aspects of development planning and the identification of other projects besides Tarbela suitable for early development.

1.09 To set the Study in motion as rapidly as possible, the Bank Group, under the leadership of Dr. Lieftinck, set out first to establish what information already existed on potential development in the Indus Basin and where the efforts of the Study should consequently be concentrated. A preliminary reconnaissance dedicated to this task was carried out by consultants in February-March 1964 -- Sir Alexander Gibb & Partners covering irrigation and hydrology, Hunting Technical Services reporting on agriculture, Stone & Webster dealing with electric power, and Chas. T. Main covering dam sites. Reports on this preliminary reconnaissance led to preparation by the Bank Group of terms of reference for the major part of the Study. These terms of reference were agreed with the Pakistan authorities and consultants were appointed to start work on May 1, 1964 -- Gibb, Hunting Technical Services and International Land Development Consultants forming the IACA consortium to cover irrigation and agriculture aspects of the Study; Stone & Webster again covering power; and Chas. T. Main, dam sites.

1.10 The consultants' teams gathered in Lahore during May and June of 1964, building up to an eventual resident expatriate strength of about 40, supported by nearly 100 Pakistanis most of whom were assisting the agriculturists. Gibb established a coordinating office and handled the administrative side of the Study. Continuous liaison with the Pakistan authorities was maintained through the West Pakistan Water and Power Development Authority (WAPDA), the main agency responsible for water and power development, and more specifically through Mr. Monawar Ali, Director General of Planning and Investigations. A forum was provided by monthly meetings which were devoted to an exchange of information and ideas; these meetings were attended by representatives of various government departments and agencies, such as irrigation, agriculture, planning and development, and Agricultural Development Corporation (ADC), in addition to WAPDA. Members of the Bank Group maintained a fairly continuous contact with the consultant teams and visited them in Lahore on a number of occasions; it was at these times that the Coordinating Committees, providing the official link for the Bank Group, the Pakistan authorities and the consultants, were convened.

1.11 The consultants' first task, to prepare the special preliminary reports on the Tarbela Project, was completed in what must be considered record time. The consultants' reports were discussed with the Bank Group by a Pakistan delegation which visited Washington in early December 1964. The Bank Group's "Report on a Dam on the Indus at Tarbela" was submitted by Dr. Lieftinck, as Head of the Study, to the President of the Bank and by the President of the Bank to the President of Pakistan in February, 1965. The main conclusions of the report may be summarized as follows:

(1) That the Tarbela Project as envisaged was technically feasible and its estimated cost would be more than compensated by the agricultural and power benefits which Pakistan should derive from it.

(2) That the economic life of the Tarbela Project could beneficially be extended by the provision of side-valley storage or further development on the Indus main stem.

(3) That the financial requirements for construction of the project would amount to about US$ 900 million equivalent including the first eight power units but excluding transmission, and without allowance for Pakistan duties and taxes.

(4) That the Tarbela Project compared favorably with other studied alternatives for water storage on the main stem of the Indus and would yield an economic return in the form of agriculture and power benefits in the order of 12 percent.

(5) That both with and without additional surface water, very considerable agricultural benefits could be obtained by the application of higher inputs for raising the productivity of farm operations.

1.12 There were obviously certain difficulties involved in reaching judgment about a project that would have such far-reaching effects as Tarbela before completion of the comprehensive studies of the basin as a whole. When Dr. Lieftinck submitted the Bank Group's Tarbela Report to the President of the Bank he noted that "the obligation to study, as agreed, a specific project which would be part of a large and complex irrigation system before studying the system as a whole was rather cumbersome." To handle this problem certain priority areas were selected -- lower portions of Rechna and Bari Doabs and the Indus left bank from Khairpur to Bahawalpur for irrigation, and the Northern

Grid area for electric power -- and studied intensively as a basis for estimating the main power and irrigation benefits of the project; and extrapolations and adjustments were made to cover benefits from water and electricity supplies which could not be absorbed within these areas. The reports on this phase of the Study were thus largely concerned with quantifying the potential benefits of the Tarbela Project by comparing it with alternative storage projects and alternative means of meeting power and irrigation requirements.

1.13 In undertaking the second phase of the Study, the preparation of comprehensive programs for water and power development in West Pakistan, the consultants were not moving into entirely fresh ground; indeed, it was specifically indicated to them that they should make full use of existing studies and field investigations and avoid duplicating previous work. The Indus Basin has been the scene of major engineering works for well over a century, and a vast number of reports have been prepared on different projects. The establishment of WAPDA in 1958 led to a rapid acceleration of work on planning and project preparation. Many studies have been carried out by personnel of the Irrigation Department and WAPDA. In addition, WAPDA has received substantial assistance over the years from its general consultants, Harza Engineering Company International, who have prepared a number of studies on specific projects as well as having been responsible for master planning activities. WAPDA has also drawn upon the resources of a number of other international consultant firms for studies of individual projects -- such as Commonwealth Associates and Kuljian on the power side, and TAMS (Tippetts-Abbett-McCarthy-Stratton) for Tarbela.

1.14 A very important study which appeared when the consultants were commencing their field work was the report on Land and Water Development in the Indus Plain by the U.S. White House Panel, usually referred to as the Revelle Report. This report which proposed a massive program of public groundwater development as a means to increase irrigation supplies and overcome the problems of waterlogging and salinity was prepared by a panel of American experts headed by Dr. Roger Revelle. The panel had been assembled by President John F. Kennedy in 1961 following a discussion with President Ayub Khan.

1.15 Special reference should also be made to two other groups of consultants to WAPDA who were in the field throughout the year and a half that the Special Study consultants spent in Pakistan. One is the so-called LIP (Lower Indus Project) Group, made up of Hunting Technical Services Limited and Sir Murdoch Macdonald & Partners. These two firms had been working in the Sind, in the southern part of West Pakistan, since 1959; in 1962 they were given responsibility for preparing a regional survey (focusing on the development of irrigation and agriculture) of the whole of the Sind. The other consultant to WAPDA who had responsibilities of particular relevance to the work of the Special Study is Tipton and Kalmbach, Inc. of Denver. This firm has published a series of reports over the years on individual public groundwater projects -- the so-called SCARPs, Salinity Control and Reclamation Projects. In

May 1962, Tipton and Kalmbach were given a comprehensive contract for preparation of a regional plan for the Northern Zone, somewhat similar to that of LIP for the Sind. The Special Study consultants kept in close touch with both these groups throughout their stay in Pakistan. As regards agriculture and irrigation they concentrated much of their effort in the North and drew heavily on the work of LIP for the South. The LIP team submitted a comprehensive regional report including some project identification and project preparation during 1966. Tipton and Kalmbach have been more concerned with the individual SCARP projects and they did not produce a draft of their comprehensive regional plan for the North until February 1967, after most of the work on the Special Study had been completed.

II. THE DEVELOPMENT OF THE IRRIGATION SYSTEM

2.01 The Province of West Pakistan is bordered on the west and north by mountain ranges, with desert areas lying inside the mountains along much of the lower western portion. The common boundary with India on the east also consists of desert over roughly its southern half. The major agricultural areas lie within the basin formed by the Indus River and its tributaries, which run in a general northeast/southwest direction from the points where the rivers enter Pakistan to the mouth of the Indus at the Arabian Sea east of Karachi. Over the years the reliance on the major rivers as a source of water for irrigation has led to a high concentration of population, irrigation investment, infrastructure and markets in this basin.

2.02 The irrigation system which exists today has been built up over the course of more than a century by means of a series of engineering works, many of them unprecedented in the world at the time they were undertaken. The result of this lengthy effort has been to increase the area irrigated from something which must have been in the order of a few hundred thousand acres to a contemporary canal irrigated and cropped area in the neighborhood of 26 million acres. In the process of expansion the irrigation system has been totally transformed. Little more than one hundred years ago it consisted simply of a series of inundation canals which could capture some water for irrigation purposes when river stages happened to be high. Today it consists of some 38,000 miles of canals and a series of river barrages and canal headworks which control the diversion of river flows into the canals. Many of the canals are very large indeed; 15 of them have capacities of between 10,000 and 22,000 cusecs. The largest barrage, at Sukkur on the Indus, nearly a mile long and completed in 1932, alone diverts water into seven large canals, which currently irrigate some five million acres. Map 1, at the end of this chapter, shows the main canal system as it will be after works currently underway are completed, about 1970.

2.03 The most productive agricultural area in West Pakistan is the Punjab -- the northeast region watered by four important Indus tributaries, the Jhelum, Chenab, Ravi and Sutlej Rivers. This was the scene of the initial development of the modern canal system, under the auspices of British colonial administrators and engineers. The heartland of the Punjab is composed of three doabs (areas between rivers) the names of which are acronyms -- Bari, once between the Beas and the Ravi but now between the Sutlej and the Ravi; Rechna, between the Ravi and the Chenab; and Chaj, between the Chenab and the Jhelum. This was the most densely populated part of northwest India a hundred years ago and it included the administrative capital of Lahore. The tributary rivers, each with annual flows a fraction of those on the Indus, were easier to control. Moreover there were extensive areas of flat land in the doabs suitable for irrigation development; the land slopes towards the sea at about one foot per mile on average. These same advantages caused problems. The tributaries of the Indus are more dependent on monsoon rains than the Indus itself and consequently more variable in flow and subject to destructive flooding. The first major modern canal, the Upper Bari Doab Canal, took off from one of the most variable of all the rivers, the Ravi (the portion of this canal which lies in West Pakistan was renamed the Central Bari Doab Canal after Partition and is so shown on Map 1); it was originally designed to extend 247 miles through the northern part of Bari Doab but the minimum discharge of the Ravi had been considerably over-estimated and the canal had to be tailed out 100 miles short of its goal. It was finally opened in 1859, and irrigation began in 1861. Difficulties arose with siltation at the entrance to the canal and the canal itself had been designed with too steep a gradient so that it began to erode its banks. A design had to be developed which would minimize both the scouring that occurred when the gradient was too steep and the sediment deposition that resulted from too slight slopes. Nevertheless these and other problems were overcome and by 1900 canals had been built to command some five million acres of agricultural land in the doabs. When consideration was given to further expansion of the system it was decided to continue development in the same area rather than to attempt any work on the main stem of the Indus. In 1905 the Government of India approved the Triple Canals Project, a landmark because it included three canals (the Upper Jhelum Canal, Upper Chenab Canal and Lower Bari Doab Canal), each of which would take off from a western river, supply some water for irrigation purposes as it crossed the doab and finally discharge into the next river to the east, thus making available more water for irrigation in the eastern areas. The headworks on the Jhelum for this project were built at Mangla and the series of three canals in the project served in effect to transfer water from the Jhelum, where it was surplus, for use in the Rechna and Bari Doabs; this in turn meant that the flows in the easternmost rivers, the Beas and the Sutlej rather than being used to water land in Bari Doab, could be preserved for use in the independent states of Bikaner and Bahawalpur downstream. The Triple Canals Project clearly contained the essentials of the Link Canal concept later used to help solve the dispute between Pakistan and India.

2.04 Southwest of the Punjab, between the confluence of the Indus with its major tributaries and the Arabian Sea, lies the Sind. In those earlier years of canal development, the question of whether to build irrigation works on the Indus was essentially a question of whether to develop the Sind or Lower Indus area. The question was debated for decades. Almost a hundred years elapsed between the time that the Rohri Canal, now one of the longest and largest in the Province, was first mooted and the time it was finally built as part of the Sukkur Barrage Project, the first major development on the Indus itself, in the early 1930's. Many factors contributed to the delay -- the sheer magnitude of any barrage spanning the shifting beds of the Lower Indus and doubt as to the technical feasibility of such a project, shortage of funds for additional irrigation investment (and the early developments in the Punjab were not considered very remunerative), a feeling that Sind was receiving enough water from the Indus itself via inundation canals to support its relatively sparse population, and questions as to whether sufficient cultivators would settle in the area to make a heavy investment in irrigation infrastructure worthwhile. Attention was given to improvement of the old inundation canals, but no major engineering work was undertaken before the Sukkur Barrage.

2.05 Simultaneously with the massive Sukkur Project, designed to irrigate a culturable commanded area (CCA) of 7.5 million acres, work went ahead on a series of further irrigation developments in the Punjab, this time on the far eastern side, and in downstream Bahawalpur. The project, known as the Sutlej Valley Project, comprised nine separate major canals. The areas to be developed lay on either side of the Sutlej. It was the first irrigation project to include large areas -- some five million acres -- designated for non-perennial supply only. Canals supplying those areas would be open only during kharif season when river flows are high. Design of such a large area, some 60 percent of the total, for non-perennial canal irrigation was indicative of course of shortage of water in rabi season, but also of an important change in attitude; the pre-1900 canals had been mainly designed to encourage wheat production for use elsewhere in India, but the main crop that was expected to be grown in these non-perennial areas was cotton for sale abroad. In the event, flows in the Beas and Sutlej turned out to be even less than what the project had been designed for. This, together with the shortage of finance and the unwillingness of people to settle there in the disturbed state of affairs resulting from the world depression of the 1930's, led to abandonment of extensive portions of the project area.

2.06 Apart from the Sind and the Punjab there is one other important area of canal development, somewhat removed from them -- the Peshawar Vale in the northwest. It is much smaller in size but very important in the production of certain crops, such as fruits, sugarcane and tobacco. It draws water mainly from the Swat River, a tributary of the Kabul, which joins the Indus from the west. Canal development in this area dates from the 1890's. The Peshawar Vale, with its more northern and higher location has more plentiful rainfall and greater seasonal variations in temperature than occur in the other canal irrigated areas. In terms of relative levels of agricultural development it equals, or may even exceed the Punjab but it is of less significance because of its much smaller area.

2.07 Since World War II, Partition and Independence, the irrigation system has been greatly expanded, particularly along the main stem of the Indus. Some nine million acres have been added to the culturable area commanded by canals, new link canals have been built to transfer water from the Jhelum and Chenab to the Ravi and Sutlej, and the groundwater aquifer has been brought into extensive use as a source of irrigation water. Average annual irrigation diversions have increased from about 65 MAF to about 85 MAF, with most of the increase concentrated in the kharif (summer) season.

Table 1

Average Annual Irrigation Withdrawals from Rivers in West Pakistan
1947/48 to 1965/66
(MAF at Canal Head)

	Kharif	Rabi	Total
1947/48-1950/51	44.4	20.7	65.1
1951/52-1955/56	51.3	22.8	74.1
1956/57-1960/61	52.4	27.0	79.4
1961/62-1965/66	57.6	27.2	84.8

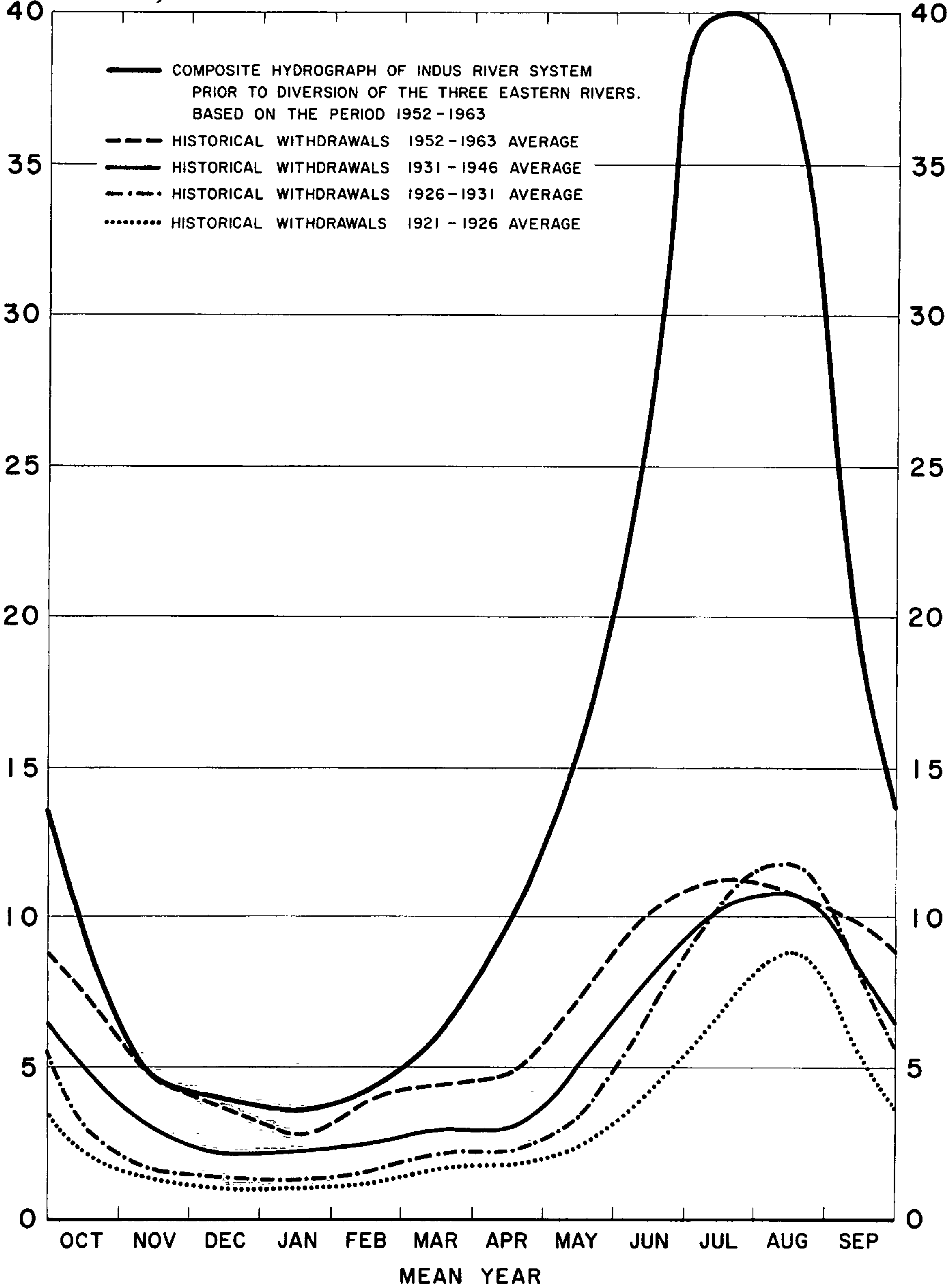
The table indicates that average kharif diversions have increased substantially over the last decade, while average rabi (winter) withdrawals have remained little changed. Rabi withdrawals in 1965/66 of about 25.8 MAF were actually almost the same as rabi withdrawals in 1956/57, of about 25.6 MAF. Figure 1, which illustrates the development over a longer period shows that average withdrawals between 1952 and 1963 in the rabi months between October and March were almost equivalent to the mean monthly flow in the rivers over the same period.

2.08 Before World War II a solution had been sought to the problem of water shortage in the Sutlej Valley Project in the form of additional canals to bring water from the west together with a dam and large storage reservoir at Bhakra on the Sutlej. Partition left Bhakra in India and aggravated the problem of shortages in the Sutlej Valley canals. The headworks of the old Upper Bari Doab canal at Madhopur and those at Ferozepore on the Sutlej had also been awarded to India. Pending final settlement of the Indus Waters Dispute it became a matter of urgency for Pakistan to move swiftly ahead with measures to secure some supply of water for the Upper Bari Doab and the Sutlej Valley. The 63-mile Marala-Ravi Link was built between 1954 and 1956, the 102-mile Bombanwala-Ravi-Bedian-Dipalpur Link between 1948 and 1959 and the Balloki-Suleimanke Link between 1951 and 1954, all as means of bringing additional water from the Ravi and Chenab to the east.

2.09 The main additions to the irrigated area have occurred in connection with the construction of four barrages on the Indus main stem. Jinnah Barrage, the furthest north of the existing barrages on the Indus, was completed in 1947 and feeds the Thal Canal which irrigates an extensive portion of Thal Doab, between the Indus and the Jhelum. Lower down in the same doab is the Muzaffargarh Canal, also fed from a barrage on the Indus at Taunsa which was completed in 1958. Some 70 miles upstream of Sukkur is Gudu Barrage, from which canals take off to left and right of the Indus to irrigate the most northerly part of the Sind; it was completed in 1962. Far downstream, close to Hyderabad, is the Ghulam Mohammed Barrage, completed in 1955. With the completion of Gudu Barrage in 1962 almost all the old inundation canals have been converted into more permanent structures controlled from headworks on the river; such conversion had become more and more necessary over the

HISTORICAL USAGE OF AVAILABLE SURFACE WATER IN THE INDUS RIVER BASIN OF WEST PAKISTAN

(FLOWS, WITHDRAWALS - MAF)



(2R)IBRD-3222A

years in order to provide any reasonable pattern of irrigation supply, especially in the Sind, because the increase in upstream diversions naturally resulted in a general lowering of downstream river stages. Large portions of the nine million acres which those postwar barrages and their accompanying canals were designed to command are still under development, but more than 50 percent of the total have been designated for non-perennial supply, indicating that on the Indus, as on the tributaries, virtually all dependable rabi flows have already been committed.

2.10 Besides the link canals of the 1950's and the Indus River barrages and canals a third important development since World War II has been a series of small hydroelectric projects on the canals and on some of the smaller rivers. In 1947 there was only about 70 mw total capacity installed in the public utilities of West Pakistan -- 20 mw in a hydroelectric station in the Malakand Hills northeast of Peshawar and all the remainder in small diesel and oil-fired plants at various of the more important towns in the Province. However the demand for electric power was growing extremely rapidly; it is estimated that total utility generation grew between 1950 and 1955 at a rate of about 30 percent per annum, and since supply was unable to keep up with the growth of demand, demand may in fact have been growing faster. To help meet the load growth the Malakand project was extended by construction of a long canal along the edge of the hills to carry water to a new 20-mw station at Dargai, from which the water discharges into the Swat River and canal system. In the 1950's and 1960's a number of small low-head hydroelectric stations were added to two of the canals originally built under the Triple Canals Project -- Upper Chenab Canal and Upper Jhelum Canal. These are perennial canals receiving fairly reliable supplies, and when the canals are running full the power plants can provide a steady base-load output. Hydroelectric capacity of much more significant size -- some 160 mw -- was introduced in the early 1960's at Warsak, a major multipurpose dam with a small storage reservoir on the Kabul River. Besides passing water through the turbines, the dam also serves to divert water into two canals, one on each bank, which are designed to bring an additional 120,000 acres under irrigation in the Peshawar Vale. By 1965 Warsak and the other small hydroelectric plants were generating some 40 percent of the total amount of electricity produced in the Province.

2.11 Not unrelated to these hydroelectric developments has been a fourth major development of the postwar period -- a tremendous upsurge in the exploitation of groundwater for agricultural purposes. Much of the most dynamic class of sales by the electrical utilities has been sales for agricultural purposes -- almost entirely for pumping groundwater by tubewells. Electricity used for pumping purposes rose from about 90 million kwh in 1960, or some 7 percent of total utility generation, to about 540 million kwh in 1965, or about 17 percent of total utility generation. The vast plains of the Indus Basin are covered with a deep layer of alluvial silt, sand and clay laid down by the Indus and its tributaries, and this alluvium constitutes a groundwater aquifer containing very large quantities of water and generally suitable for pumping. Groundwater has in fact been a traditional source of irrigation water, especially in the Punjab. Several methods of raising water from open wells were used, but the predominant method was their so-called Persian wheel; it is estimated that about 200,000 of these wheels still exist. A large wheel is placed vertically across the center of a shallow well and on it is suspended an endless chain of buckets. The wheel is connected with a drive shaft which is operated by draught animals walking round and round. The change which has come about in the last 10-20 years has been the introduction of the far more efficient tubewell. A Persian wheel can lift about one-tenth of a cusec (cubic foot per second) from 20-40 feet. One of the smaller modern tubewells can deliver one cusec with a well depth of about 100 feet, and the larger wells can deliver four or five cusecs with a well depth of 200-300 feet.

2.12 There have been two rather different types of tubewell development in West Pakistan, the first from an historical viewpoint on any significant scale being Government-operated or public wells. These are generally larger wells, ranging between two cusecs and five cusecs. A few were introduced prewar and a few more in the late 1940's and early 1950's; the first large-scale development came in 1959 with commencement of the Government's Salinity Control and Reclamation Project No. 1 (SCARP I) in central Rechna Doab. This project, as its name implies, was largely designed to overcome salinity in the soil which had made its appearance in many parts of West Pakistan but was particularly severe in this area; it would do this by pumping large quantities of water from the aquifer and spreading them over the land which would result in leaching down the surface salts. Since the water was being pumped from the aquifer this also meant that the groundwater table was being lowered. SCARP I was intended to be the first of a series of projects. Over the decades there had been a continuous debate about the merits and demerits of high groundwater. Some had emphasized the beneficial effects it could have on water supplies, particularly for rabi when river flows were low, by greatly increasing the potential of the Persian wheels with their shallow draft and by causing water which was stored in the river banks during kharif to percolate back into the river during rabi. Others stressed the dangers of waterlogging and soil salinization. Soil salinity is not in fact confined to areas of high groundwater table, but since it arises from the upward capillary action of moisture which contains salts and subsequent evaporation of this moisture near the surface, it tends to be particularly prevalent in areas of high groundwater. The debate about the pros and cons of high water table grew particularly strong when the first link canals were proposed around the turn of the century for these would cut across the natural drainage lines which sloped towards the sea. In any event the surface irrigation system was greatly expanded, as described above, and percolation to the aquifer is estimated today to be some three or four times what it was in the original state when some kind of natural equilibrium between recharge and discharge was maintained. As a result the water table has risen to within 10 feet of the surface over some 12 million acres of the canal commanded areas. Soil salinity is believed to affect some 15-25 percent of the canal commanded areas, sometimes so drastically as to put them right out of production, more commonly sufficiently seriously to have important yield-reducing effects. Evidence gathered by IACA and others suggests that there is no continuing net loss of land to salinity. Actual losses being more than offset by current efforts at reclamation, generally of small scale, and expansion of cropped acreage. Nevertheless waterlogging, salinity and the related problem of alkalinity do have severe effects on production in wide areas. Naturally they became major concerns of the Pakistan authorities, and the large program of SCARPs was initiated as the main effort to deal with them.

2.13 The other type of tubewell development which has occurred, primarily in the last seven years, or since SCARP I was initiated, was somewhat different in nature. It has been almost entirely the work of private enterprise -- on the part of small-scale manufacturers in the towns of the Punjab who produce pumps, engines, strainers and well casings, entrepreneurs who handle the well drilling with primitive rigs and farmers who pay for the wells and put them to use. The growth has been extremely dramatic; it is estimated that by 1965 private wells were producing some six MAF annually, more than twice as much as the public wells. Generally about one cusec in size, private wells have been installed by large farmers, by groups of small farmers and even by landless artisans who pump water for sale to farmers. The numbers of private wells apparently increased from about 5,000 in 1959/60 to about 34,000 in 1964/65. About 6,500 private wells are believed to have been drilled in 1963/64 compared with only a little more than 1,000 in 1959/60. Latest information, suggesting that about 8,500 wells were sunk in 1965/66, indicates no slackening in the private tubewell movement. Well development so far has been very heavily concentrated in the Bari and Rechna Doabs, the best and wealthiest farming areas, but beyond this general consideration there is no clear explanation of why wells grew rapidly in some areas and not in others; growth of wells has not shown much correlation with other data available about the farms in an area, such as farm size or land tenure structure. Initial development of private tubewells appears to have occurred mainly in areas which were close to power lines, but in the last four years large numbers of diesel-powered wells have been installed, and diesel wells, though they seem to be much more expensive to operate, now represent some two-thirds of the total number of wells installed. Private wells are installed according to the desires and capacities of individual farmers rather than in the coordinated pattern planned for the public tubewell projects; in some areas they appear to be quite dense, averaging one per 60 acres, while in other areas they are quite isolated. Reclamation of saline land or lowering of the water table appear to be relatively minor considerations for the private tubewell owner and they are generally achieved only to the extent that they are incidental to his main concern -- which is partly to increase the certainty of water supply, especially at certain critical moments in the farming cycle, and partly to permit an increase of the acreage which he crops each year.

2.14 Table 2 briefly summarizes the discussion in this chapter and shows the role of each of the major areas in the broad picture of agriculture and irrigation in West Pakistan. The areas covered by the Sutlej Valley Project are divided between those on the right bank of the Sutlej which lie within Bari Doab and those on the left bank which are grouped together. Areas commanded from Jinnah and Taunsa Barrages are grouped together under Thal Doab and Indus Right Bank. And the whole of the Lower Indus area is treated in one group.

2.15 The canal commanded area (CCA) indicated in this summary totals 29.4 million acres (18.6 million acres perennial and 10.8 million acres non-perennial) which is some four million acres less than the area actually officially designated as canal commanded (33.5 million acres, of which 20.3 million acres perennial and 13.2 million acres non-perennial). The 29.4 million acres constitute the canal commanded area used for purposes of analysis in this report, omitting 0.5 million acres of the present designated CCA which will be needed for roads and canals, etc., and another 3.5 million acres of presently designated CCA which the consultants believe is presently very largely underdeveloped, and which is basically unsuitable for development in conditions where water is the limiting factor. The LIP consultants maintain that about 3.5 million acres of the total designated CCA in the Sind is land of very inferior quality and has been abandoned or is basically unsuitable for development in conditions of water shortage. From a Province-wide point of view IACA found that in the long run there did not appear to be enough water, even with full development of all groundwater and surface water potential, to meet in full the irrigation requirements of all the presently designated CCA; it would of course be possible to spread the water more thinly to cover a larger area, but IACA contended that there are strong economic reasons for intensifying irrigated agriculture rather than extending it into new areas: primarily, reduction of the infrastructure needed and minimization of uncultivated and fallow lands within the cultivated area because they are particularly susceptible to soil salinization. Thus, while the area designated for canal irrigation might eventually be reduced from the current 33.5 million acres to 29.4 million acres, the area actually receiving irrigation supplies would increase from some 26 million acres to about 29.4 million acres in the long run and the cropped area watered by canals would increase from about 26.7 million acres to about 42.0 million acres. The Bank Group believes that decisions regarding the areas to be brought under canal irrigation should be based on conditions existing at the time when alternatives may come under consideration, but the limited extent of the water resources must be kept prominently in mind when planning for development.

2.16 Table 2 brings out the importance of the three oldest areas of modern canal development -- Bari Doab, Rechna Doab and Peshawar Vale -- in the total economic and agricultural activity of the canal-irrigated areas in the Province. They include only 38 percent of the total canal commanded area and they receive only 30 percent of annual canal water supplies, but they contain about 50 percent of the population of the canal-irrigated areas, 85 percent of the tubewells, and they are responsible for more than 50 percent of the total agricultural production in the canal-irrigated areas. On average, they have higher cropping intensities than other parts of the Province.

2.17 Table 2 shows the estimated distribution of irrigated water among the different parts of the Province, in terms of water actually available at the watercourse head, under mean-year river flow conditions with the irrigation system in the state of development reached by 1965. Within the canal commanded areas groundwater contributed some 9.7 MAF or about 15 percent of total irrigation supplies. The groundwater component is made up as follows: private tubewells 5.3 MAF, public tubewells 2.7 MAF, and Persian wheels 1.7 MAF. These figures illustrate the dominant position of private wells at the current stage of groundwater development. Private tubewells and Persian wheels also exist in some places outside the canal commands and it is estimated that they may supply about 1 MAF there each year, as indicated in Table 2.

2.18 The canal-irrigated areas already discussed account for virtually all the cash crops produced in the Province and for about 80 percent of food crops. The remaining 20 percent of food crops is produced in the three areas listed at the bottom of Table 2, which are also important in the livestock sector because of the extensive grazing lands which they provide. The least significant of these areas, areas outside the major canal commands but irrigated from small private dams, ponds, springs and hill torrents, probably account for barely more than one percent of food crop production. Somewhat more important is the riverain area, covering an estimated 2.9 million acres and extending up to a few miles on either side of the rivers; it may account for three percent of food crop production and it provides much good quality grazing land because of its proximity to the rivers. Being mostly on active flood plain, it is cultivated chiefly in winter, though some of the higher areas are cropped also in summer, sometimes with the aid of wells. Since they are so close to the river, these areas tend to suffer severely from the high floods in the rivers which result from periodic torrential monsoon downpours.

2.19 Most significant of the areas outside the canal commands, both in terms of extent and of agricultural production, are the areas of rainfed or barani agriculture. Some 10 million acres of barani land are believed to be cultivated, mainly in the northern Punjab, in areas around Peshawar and in some places to the west of the Indus. Together, these areas may be responsible for some 15 percent of total food crop production. They depend almost entirely on winter rains, which are not reliable, and the moisture-retaining capacity of the soils. Farming is consequently risky and, in addition, many of the barani lands are subject to erosion, which is a serious problem in the heavy rainfall areas of the North. Agriculture is much less developed than in the canal commanded areas. Crop yields are thought to be only about half those attained in the canal commanded areas. The average wheat yield in the barani regions, for instance, is believed to be about six maunds (500 lbs.) per acre compared to an average of twelve maunds in the canal commanded area. Nevertheless, these areas are important, supporting large numbers of people and of livestock. They are responsible for some 25 percent of total wheat produced, 50 percent of maize and 70 percent of millets. In some places rainfall is supplemented with water supplies from small wells, tanks (ponds) and streams, with privately built diversion systems, but the scope for tubewell development is limited due to the rapid drawdown of the groundwater table that typically results from pumping due to the nature of the aquifer in these areas.

STUDY OF THE WATER AND POWER RESOURCES OF WEST PAKISTAN
COMPREHENSIVE REPORT

INDUS BASIN - LOCATION OF CANALS AND LINKS

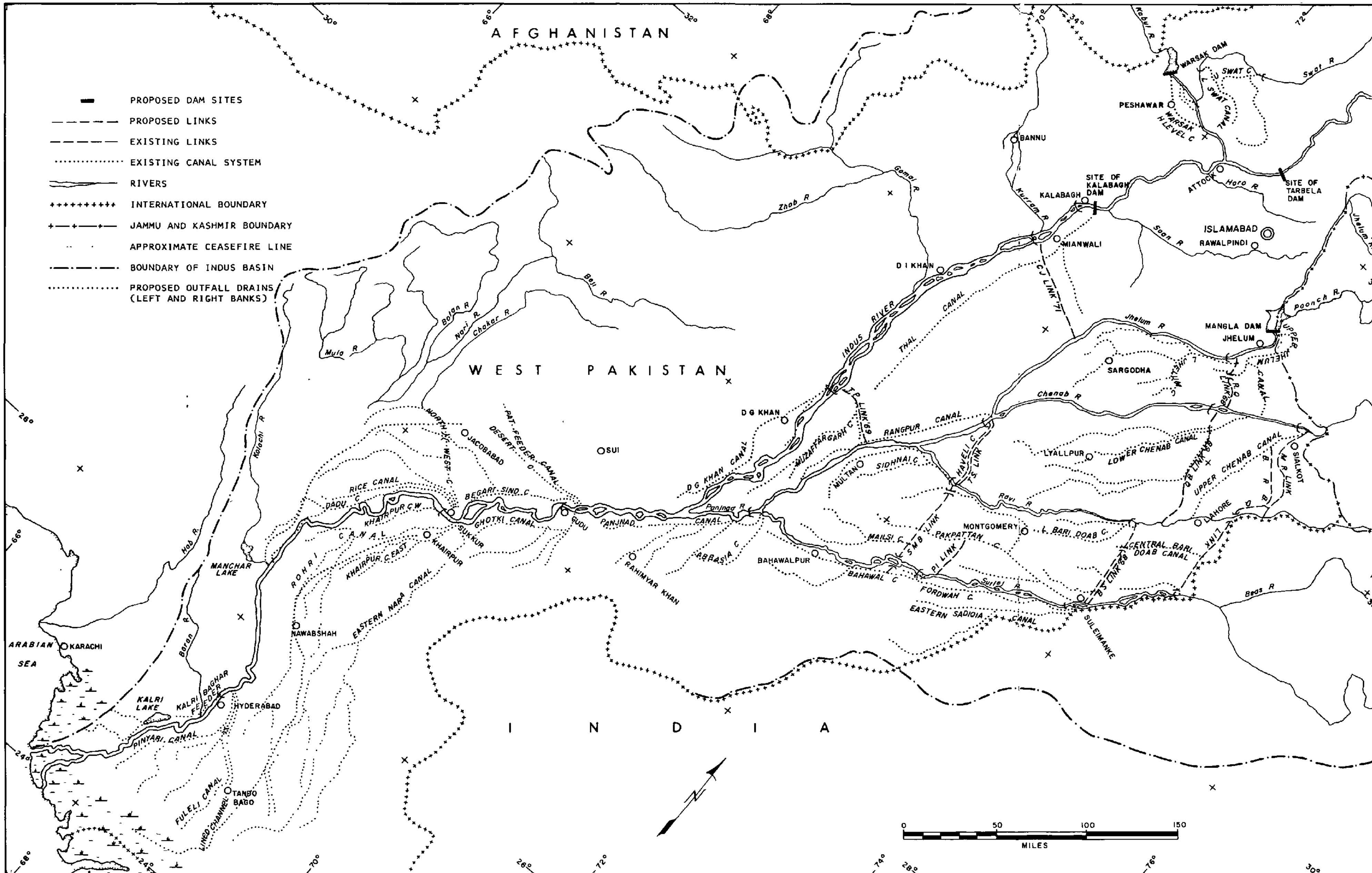


Table 2

Agricultural Regions, 1965

	Population (1965) (Millions)	Gross Area (Mln. acres)	Year of initial modern canals	Canal Commanded Area, 1965 (Mln. acres)	Area Cropped (1965) (Mln. acres)	Cropping Intensity (1965) (%)	Water Supply, 1965, at watercourse: Ground-water (MAF)	Surface-water a/ (MAF)	Total a.f. per cropped acre	Number of tubewells in existence	Value of Agricultural Production (PRs mln.)
Bari Doab	8.8	8.2	1859	5.9	6.0	102	3.1	9.0	2.0	15,000	1,677
Sutlej/Panjnad Left Bank	3.0	5.1	1926	3.5	3.2	92	0.6	6.4	2.2	1,400	744
Rechna Doab	8.0	7.9	1892	4.7	5.0	106	4.6	6.6	2.3	12,000 b/	1,409
Chaj Doab	3.6	3.7	1915	2.0	2.1	104	0.6	3.2	1.8	1.100 c/	609
Thal and Indus Right Bank	3.0	7.9	1947	3.6	2.3	64	0.7	5.6	2.7	1,200	449
Peshawar and Swat	2.4	1.2	1890	0.7	0.9	135	-	1.7	1.8	-	307
Lower Indus (Sind)	10.2	13.0	1932	9.0	6.0	67	0.1	25.5	2.9	700	1,575
Subtotal, canal-irrigated	39.0	47.0		29.4	25.5		9.7	58.0		31,500	6,770
Other Irrigated Area	)	)			1.6		)			)	)
Riverain Area	) 12.0	) 24.0	-	-	2.9	-	) 1.0	-	-	) 5,000	) 1,928
Barani Area	)	)			10.0		)			)	)
Total	51.0	71.0		29.4	40.0		10.7	58.0		36,500	8,698

a/ These are notional figures, derived by IACA on the basis of actual canal diversions in recent years, and supposed to portray the situation in a mean-flow year.

b/ Including about 2,200 SCARP I wells.

c/ Including about 300 SCARP II wells.

III. THE INADEQUACY OF THE PRESENT SYSTEM

The Lag in Agriculture

3.01 Despite the tremendous investments which have been made over the years in irrigation works, agricultural production has grown slowly -- to the point that in recent times West Pakistan, though more than 50 percent of her labor force is employed in agriculture, has had to import an increasing proportion of her food requirements from abroad. Between 1950 and 1965 the real income of West Pakistan grew at an average annual rate of about four percent per annum, or some 1.5 percent faster than the population of the Province; but agricultural output grew less rapidly than the population, at only about 2.3 percent per annum. Table 3 illustrates some of the implications of this lagging agricultural growth rate.

Table 3

West Pakistan: Growth of Per Capita Output, 1950-65
(Constant prices of 1959/60)

	1949/50	1954/55	1959/60	1964/65
Gross Provincial Product (PRs)	342	354	366	428
Food Grains Production (kg)	188	144	151	153
Total Agricultural Output (PRs)	187	174	171	181

Agricultural output per head of population declined seriously in the early 1950's and by 1965 it had still not regained the level reached in 1950. The figures also show that total output of goods and services per head of population in West Pakistan has risen throughout the 15-year period, but much more rapidly in the last five years when agricultural production also moved ahead at more than twice the pace achieved in the 1950's.

3.02 The most serious deficiency in agricultural production has been in the production of food grains. Table 3 suggests that production of food grains per head of population has fallen from nearly 190 kilos per annum in 1950 to an average of about 150 kilos per annum over the Second Plan period (1960-65). The lowest level of production per head of population may in fact have been reached during the mid-1950's; since that time production of food grains appears to have increased slightly faster than the population. But this has not prevented the need for continuing increases in food imports, for nonagricultural incomes have been increasing and high proportions of additional income have been spent on food. Table 4 shows the trend of wheat imports over recent years.

Table 4

West Pakistan's Average Annual Wheat Imports

Period	'000 Tons	Imports as % of Provincial Production
1950-54	330	10
1955-59	522	14
1960-64	1,025	25

Thus this part of the Indus Basin, which was formerly called the granary of India and which exported wheat outside the subcontinent, is now not feeding the 54 million people of West Pakistan.

3.03 To some extent deficiencies in wheat might be considered an indirect result of the fact that wheat was generally available on relatively easy terms from the United States throughout the period covered by the above table. Efforts were made to produce other crops for which West Pakistan was also well suited that could be sold abroad for hard currency. Recent years have seen some concentration on rice, with this point in mind, for West Pakistan's top quality rice is highly desired in certain parts of the world, and exports of rice have risen from little or nothing in 1959/60 to about PRs 120 million in 1964/65. Nevertheless rice remains a small export compared to cotton, the export staple of the Province, and cotton, when examined in the same time perspective as wheat in Table 4, shows very much the same picture.

Table 5

Pakistan's Average Annual Production and Exports of Cotton
('000 long tons lint or lint equivalent)

	Production	Net Foreign Exports (all forms)
1951/52-1954/55	266	190
1955/56-1959/60	290	132
1960/61-1964/65	350	131

Cotton production has grown at an average annual rate of a little more than three percent over these years, slightly faster than the population is assumed to have increased. Nevertheless exports have fallen. Actual exports have in fact fallen more sharply than the above table implies, but there has also been a major transition from a state in which Pakistan exported raw cotton and imported cotton manufactures to a situation where Pakistan manufactures most of the cotton goods it needs and also manufactures a portion of the cotton it exports. Therefore the above Table 5 shows Pakistan's exports of cotton, raw and manufactured, net of all imports of cotton, raw and manufactured. Pakistan exports and imports are taken in this case, because East Pakistan produces virtually no cotton and West Pakistan must supply the east wing with cotton manufactures. Net exports of cotton appear to have fallen substantially through the mid-1950's. Since that time growth of domestic consumption has effectively taken up all the increased production of cotton. Figures prepared by the International Cotton Advisory Council suggest that per capita consumption of cotton in Pakistan rose from an average of about 1.5 kilos per annum in the first five-year period to about 2.4 kilos per annum during the Second Plan period, or at an average rate of some 5-6 percent per annum. The figures of Table 5 also suggest that consumption of cotton is growing fast, perhaps three times as fast as population.

3.04 The specific cases of cotton and wheat are merely illustrative of the basic problem. Population in West Pakistan is growing rapidly, between 2.5 and 3.0 percent per annum. In addition the current level of living is very low, with a per capita income at the official foreign exchange rate of about $90; as a consequence a relatively high proportion of any additional income is spent on agricultural commodities. It follows that agricultural output must grow nearly as fast as the total output of the economy as a whole simply to meet increasing domestic demand; if it grows at less than this rate, then domestic consumption eats into the surpluses that were previously available for export. It is estimated in Chapter X that the expenditure elasticity of demand for directly consumed agricultural products is in the neighborhood of 0.85. This in turn implies, according to the Bank Group's analysis, that if provincial income grows at 6 percent per annum then value added in agriculture must grow at about 5 percent per annum simply to keep up with the growth of domestic demand. Agriculture in West Pakistan has not grown since World War II at this rate; between 1950 and 1960 it grew at about 1.5 percent while provincial product grew at about 3.2 percent, and between 1960 and 1965 it grew at about 3.8 percent while provincial product was growing at nearly six percent per annum. The latter rate of growth in provincial product cannot be sustained for very long without a substantial step-up in agricultural production, unless foreign aid is made available in amounts and on terms that are, in the current world situation, becoming more and more difficult to sustain.

The Shortage of Electric Power

3.05 The electric power sector of the West Pakistan economy has grown rapidly in recent years, but not rapidly enough to keep up with the growth of demand; shortages of electricity have recurred frequently and, in most parts of the Province, the capacity of each new generating set added to the system has been fully absorbed almost within a matter of months of its completion. The recurring shortages have had an unfavorable effect on the growth of industrial production and, to the extent that they continue, they would have increasingly serious effects on agricultural production as electrified tubewells become more widespread.

Per capita consumption of electricity remains extremely low -- at about 70 kwh in 1964 -- but this compares with only about six kwh in 1950. Electricity production grew between 1950 and 1965 at an average rate of about 20 percent per annum; the rate of growth slowed down somewhat between 1955 and 1960 but it has been boosted again in recent years by the great increase in demand for electricity for agricultural pumping purposes.

3.06 The availability of electricity in the Province is still largely confined to the towns and to the areas surrounding them, so that most of the villages and most of the farmers have to rely on kerosene for lighting, dung and firewood for heating and cooking, and animal power or diesel oil for wells. Kerosene and diesel oil are costly in foreign exchange, firewood is becoming rapidly more scarce as the population grows and the use of dung for fuel deprives the fields of needed organic material. Stone & Webster estimated that some five percent of the houses in rural areas (defining rural, or non-urban, as any place with less than 25,000 inhabitants) are connected to the electricity distribution system. Most of the rural electrification that exists is the work of the last 12 years; between 1955 and 1960 many villages in the Peshawar area were electrified in connection with the hydroelectric projects there. Between 1960 and 1965 many villages in Chaj Doab and parts of Rechna Doab were electrified in connection with the public tubewell program. By 1965 about 2,000 villages throughout the Province had been connected to the electricity distribution system out of an estimated total number of villages in West Pakistan of about 40,000. All the public tubewells are operated by electricity, but only about one-third of the private wells: taking account of the assumed numbers of public and of private wells in existence, it can be estimated that about half of the total amount of groundwater pumped is raised by diesel-powered wells. Provision of diesel fuel for these pumps probably cost about PRs 20 million in direct foreign exchange expenditure in 1966.

Crop Yields and Agricultural Inputs

3.07 One aspect of the lag in agriculture in West Pakistan is the very low level of yields obtained on most crops, whether in irrigated or unirrigated areas. Table 6 presents some comparative data in this regard. The yields presented for other countries are national averages, covering irrigated and unirrigated areas combined, so that they are most comparable with the Province-wide average for West Pakistan, given in the first line of the table.

Table 6

Comparative Average Crop Yields
(Maunds/acre)

	Wheat	Rice a/	Cotton b/	Maize	Sugarcane c/
West Pakistan					
Province-wide average (1962/63-1964/65)	9.2	10.3	2.9	11.5	376
Irrigated d/					
Peshawar	12.0	14.0	2.3	16.5	360
Punjab Cotton Region	13.5	14.0	3.0	13.0	360
Sind Cotton Region	10.6	13.0	2.6	6.0	220
Other Countries (national averages) e/					
Japan	21.7	51.8	-	26.0	1,760
Egypt	-	36.3	5.9	24.5	-
Mexico	19.5	-	5.9	9.2	590
USSR	10.5	23.5	6.8	11.7	-
USA	16.6	41.4	5.2	40.5	670
Punjab Progressive Farmers					
Average	25-35	30-40	5-7	20-30	600-800
Maximum	66	80	13	84	1,900

a/ Unhusked.
b/ Lint.
c/ Cane.
d/ IACA estimates for 1965.
e/ Averages 1961-63 from FAO Production Yearbook 1965.

The last two lines of the table present data collected by IACA on the yields now obtained by a small number of progressive farmers in the Punjab. The table suggests both that current average yields in West Pakistan are among the lowest in the world and also that it is perfectly feasible to obtain high yields which compare well with those obtained in other countries.

3.08 There is universal agreement that a large part of the reason why yields are currently so low is poor farming and irrigation practices and inadequate use of agricultural inputs such as fertilizer and plant protection. Insufficient attention is given to land leveling, seed-bed preparation, post-planting cultivations and weed control. The soils of the plains are generally well suited for irrigated agriculture. But illustrative of the need for careful seed-bed preparation is the fact, for example, that in some areas where fine silts are present a crust can form which interferes with water infiltration and so with seedling emergence. As far as the chemical composition of the soils is concerned, there is a widespread deficiency of nitrogen and organic matter, as is typical of countries with the hot dry climate of West Pakistan. Experiments with nitrogenous fertilizer have shown high response rates in both Sind and Punjab, particularly with certain crops such as wheat. Phosphate, when used in combination with nitrogen also gives a good response, particularly in the Punjab. Yet phosphatic fertilizer is scarcely employed at present and use of nitrogenous fertilizer, though it has expanded rapidly in recent years, remains at very low levels. Application of nitrogenous fertilizer was estimated at about 90,000 tons nutrients in 1965/66 or, assuming that virtually all was applied to irrigated areas, an average of only nine lbs. per cropped acre, which is less than five percent of the level applied in Japan and Taiwan and hardly ten percent of use in such countries as Ceylon, Egypt and Korea. Plant protection, which is particularly important for certain crops such as cotton, rice, and sugarcane, is provided almost entirely by the Agriculture Department and according to the observations of IACA much of it is ineffective because of wrong timing or inadequate number of applications. The quality of the seed typically used at present also leaves much to be desired; even when it goes under the name of an improved variety, it frequently has low germination rates due to adulteration and improper handling of the seed.

3.09 There is no doubt that improved farming, together with greater use of farm inputs, could produce substantially greater output from the existing cultivated area with its current water supply, and subsequent chapters of this report make some general recommendations regarding ways in which the adoption of improved practices and inputs can be stimulated. Major efforts are currently being made by the public authorities in Pakistan to promote the use of fertilizer and of the improved wheat, rice, and maize varieties which are being developed. There are signs that an increasingly large number of farmers are reacting to profitable opportunities here with something of the same alacrity with which they have taken to private tubewells in recent years. Nevertheless it would be misleading to plan on the assumption of widespread adoption of new inputs, and of all the improved cultural practices that must go along with them for best results, in the near future. Even the tubewells are still only affecting a relatively small proportion of the farmers; there may be about 50,000 private tubewells in existence in West Pakistan now and some of the wells are providing water to several farmers, but there are about 5,000,000 farmers in the Province. The modernization of agriculture will likely be achieved by means of a gradual increase in the use of some of the inputs, with particular emphasis on one or two inputs at a time. Adoption of the practices that should accompany use of such inputs would gradually follow. To secure these increases on any large scale tremendous improvement will be required in both Government and private services responsible for agricultural research and extension work and procurement and distribution of farm inputs, as made clear in later chapters. If large numbers of farmers are to take the steps necessary to increase yields, they must be informed of the proper steps, and by people who can demonstrate convincingly the reliability of the information they convey. Such people are presently in very short supply.

The Need for More Irrigation Water

3.10 Greater and more regular supplies of irrigation water, lack of which is another major factor accounting for the comparatively low crop yields in West Pakistan, are also urgently needed by the farmers. The most obvious evidence of this is the demand for water which has translated itself into installation of private tubewells. The amount of water pumped by private wells probably increased from about one MAF in 1960 to about 6.5 MAF in 1965, despite the fact that private tubewell water is much more expensive than canal water. It is hard to make a direct comparison between the cost of canal water and the cost of tubewell water since farmers are charged for canal supplies (at rates that appear uneconomically low for modern conditions) on the basis of acres of individual crops planted and harvested rather than the amount of water actually used. Cotton is an important cash crop, for which water charges are relatively high and to which the farmers tend to give priority in use of available water. Water charges for an acre of cotton are about PRs 11, and a reasonable average figure for the amount of water required is about two acre-feet. For this crop then the average cost of an acre-foot of canal water is in the neighborhood of PRs 6. The actual cost to the farmer, including capital costs amortized over 10 years with eight percent interest, of an acre-foot pumped by a diesel well is about PRs 26 and the cost of an acre-foot pumped by a private electric well (at the subsidized price for electricity) is about PRs 13. These figures can only be rough, but the relative prices together with the great increase in use of the more expensive source of water give some indication of the strength of demand for water. The facts about actual private tubewell development, however, cannot show how many farmers there are who want water but are unable to install private wells because the aquifer is unsuitable, the necessary equipment is unavailable, loans cannot be obtained at a reasonable interest rate, etc. Water is an input to which the farmers of West Pakistan are very accustomed; they realize its value and they are ready to pay quite a high price for additional supplies.

The Choice Between Water and Other Inputs

3.11 Demand for more water is undoubtedly great and there is also evidence of heavy demand for larger supplies of certain farm inputs in some areas. At the same time Government funds and foreign exchange are in short supply, so that the public authorities face a choice, and sometimes a very clear choice, between investing funds in water development and investing them in provision of additional farm inputs. Seen in this light, moreover, the choice as to budgetary allocations is very hard to make, for the costs and likely benefits of each type of investment probably vary greatly among different areas, are hard to forecast and are not really indicated by any market mechanism.

3.12 As a practical matter, however, there are very definite limits to the range of choice that exists between expenditures to increase supplies of farm inputs and expenditures to increase irrigation water deliveries, and this is so for a number of reasons. There is no doubt that the farm inputs discussed are essential ingredients of the modernization of agriculture and that they should be given much more emphasis than in the past; just because they are new and unaccustomed to most farmers in Pakistan a major extension and demonstration effort is needed to apprise farmers of profitable opportunities for their use. The relative novelty of the improved techniques also means that the pace of progress is limited by constraints which are real, though hard to define with precision: first, an organizational constraint limiting effective expansion of the extension and distribution services and, second, an absorption constraint, resulting from lack of knowledge and financial resources on the part of the farmer, limiting the rate at which he will respond to the new opportunities as they become available. Therefore, while the maximum effort that is feasible in terms of administrative and educational resources is made with farm inputs, there is still a need for a major effort with the traditional input, water, which the farmers already know how to handle. Farm inputs -- other than water -- alone cannot increase the rate of agricultural growth to the levels required for balance with the rest of the economy, let alone increase the foreign exchange earnings of the agricultural sector to the extent required.

3.13 The constraint of absorption capacity suggests the need for allocation to water development of resources left as a residual after a maximum effort has been made with farm inputs; but in fact the range of choice between public efforts on water and on farm inputs is further limited by technical complementarities between water and other inputs at the farm level. On most farms of the Province shortages are such that increased water supplies and increased applications of farm inputs yield best results when used together. The complementarities apply whether additional water is used to expand the cropped acreage by increasing cropping intensity or whether it is used to increase the irrigation applications to the existing cropped acreage. The typical response of the farmer so far to increased supplies of water, either from canals or from private tubewells, has been to extend the acreage which he crops each season by reducing fallow or the land which in the past he left totally unused, rather than to increase the water delta applied to the acreage he was already cultivating. Agronomic studies suggest that, as long as traditional crop varieties are grown and little use is made of other agricultural inputs, production can be increased more by bringing additional land under cultivation than by concentrating the water -- at least in the short term before prolonged under watering leads to salinization of the top soil. Reduction of fallow in areas of high water table, for example, is also attractive because fields left uncultivated and therefore unwatered are particularly prone to salt efflorescence, which tends to reduce yields or even make land uncultivable. But to sustain a higher cropping intensity over a period of years means to reduce the time given to land for rest, and so chemical supplements in the form of fertilizer have to be applied to the soil to maintain its fertility. As more fertilizer and other farm inputs come to be used the need for additional amounts of water per acre cultivated increases. For example, for a variety of reasons, acreage under new crop varieties such as Mexican wheat yields best at higher applications of water per acre than the old varieties. In addition, as more money is invested by a farmer in inputs which require additional water to interact with one another to best effect, it becomes more important to increase the water delta on each acre. Table 7 compares the estimates of current irrigation water availabilities in different areas, presented in Chapter II, with IACA's estimates of the average annual amount of water required per cropped acre for best results with full recommended supplies of other farm inputs.

Table 7

Approximate Indication of Water Supplies Available Now and Needed with Inputs

	Acre-feet per Cropped Acre	
	1965 Condition	Ultimate
Bari Doab	2.0	3.0
Sutlej/Panjnad Left Bank	2.2	3.4
Rechna Doab	2.3	2.6
Chaj Doab	1.8	2.6
Thal and Indus Right Bank	2.7	2.8
Peshawar and Swat	1.8	2.3
Lower Indus (Sind)	2.9	3.5

The table suggests that there are wide variations in the adequacy of water supply in different areas. Thal and Indus Right Bank are reasonably well provided for their existing cropped acreage because of the relatively recent start to development there although the water available is ill-distributed between the months of the year and in the different parts of the region. The figures for Rechna Doab show the effects of heavy public and private tubewell development there. Bari Doab and the Sutlej and Panjnad Left Bank show up as the areas of most serious water shortage in these very global terms. The table also brings out the relatively higher requirements of canal irrigation water per cropped acre in the more southerly portions of the Basin than in the North, due to lower rainfall and higher evaporation in the South.

3.14 While these figures show the general technical inadequacy of current water supplies for supporting an improved agriculture they fail to bring out what may be the most critical aspect of irrigation in West Pakistan at the present stage -- the unreliability of water availability at particular times during each cropping season. To make it worthwhile investing in other inputs the farmer must be assured that he will receive the amounts of water needed to realize the benefits of the inputs and hence a good return on his investment; and the water must be available in sufficient quantity at certain critical times of high crop-water requirements. Watercourse studies undertaken by the irrigation and agriculture consultants brought out strongly the obstacle that insecurity of water supply is to acceptance of other inputs. Many farmers, for instance, were found to be sowing at much below recommended densities, because of uncertainty as to whether or not sufficient water would be available at critical times. It was mentioned before that one of the most important purposes of the private tubewells appears to be to ensure the reliability of total irrigation supplies. Available evidence suggests that there has been quite a strong correlation between acceptance of new inputs such as fertilizer and installation of a private tubewell.

3.15 Thus the effect of water shortages is actually considerably more severe than would be the case if these shortages were spread evenly over the year and over large areas as the rather global estimates in Table 7 imply. The general period of water shortage, it is true, is the rabi season when most of the available river flow is already being used. But the shortage tends to be more acute in some months than in others, depending on varying crop-water requirements and year-to-year fluctuations in the time pattern of river flows, and it also affects kharif crops in a number of areas because of the need for irrigations, overlapping in time with rabi irrigations, at the time of sowing of kharif crops and at their final maturing. When the Sukkur Barrage was built large areas on each bank of the Indus that had previously depended entirely on inundation canals and therefore received little but kharif water were converted into perennial areas; and there was a large expansion of the acreage cropped in rabi. But the more critical contribution of the Sukkur Barrage was actually in lengthening the kharif season for these areas. To secure the best flowering and boll formation cotton needs to ripen when temperatures are still moderately high and days long but nights are still cool; cotton does best in the Sind, therefore, when planted relatively early, between late April and late May. Sukkur served to increase substantially water supplies in this period, at the very beginning of kharif, and so it made possible earlier planting of cotton and better harvests. The critical periods for water supply remain a few months in the year -- particularly those around the beginning of each season, when water is required for preplanting and sowing irrigation and at the end of each season when water is required for final maturing. October is a critical month because it represents the time when most kharif crops, particularly cotton, are maturing and many rabi crops, particularly wheat, are beginning to be sown. March is also a critical month because it represents the time when final waterings are being given to the wheat crop. The extent to which water requirements are peaked in different months is of course intimately dependent on the crops and the varieties of crops grown; new varieties, with shorter growing seasons or requiring different planting and harvesting conditions, can have an important effect on the pattern of water requirements over the year.

The Effect of the Indus Basin Works

3.16 The largest water development works presently underway in West Pakistan are those provided for by the Indus Waters Treaty of 1960 as a means of maintaining irrigation supplies to those eastern parts of the Punjab which have in the past depended on the flows in the Ravi, Beas and Sutlej. The total measured discharge entering the Indus Plains in Pakistan and India averages about 175 MAF per year. At present, about 167 MAF enters West Pakistan, of which some 70 MAF remains unused and discharges into the Arabian Sea. From March 31, 1970 -- or from some time between then and March 31, 1973 if Pakistan decides to make use of the extension of the transition period provided as a contingency in the Treaty -- India will have the right to divert virtually all the flows in the Ravi and Sutlej, which have an average annual discharge of 25 MAF. Thus the average annual flows remaining available to West Pakistan will be 142 MAF, in the Indus, Kabul, Jhelum and Chenab. Some supplementary supplies will inevitably be provided from occasional flows in the Ravi and Sutlej Rivers and there will also be minor contributions of a few MAF each year from lesser tributaries within West Pakistan; flows from these two sources will fluctuate greatly from year to year being very dependent upon monsoon rains and they are unlikely to occur to any significant extent in the winter. The lowest combined flow of the Indus, Kabul, Jhelum and Chenab which has been experienced within the last 40 years are 116 MAF in 1961/62.

3.17 There are two main components of the Indus Basin Works, as now being implemented -- on the one hand, a number of barrages and link canals designed to transfer water from the Jhelum below Mangla and from the Indus to the eastern tributaries and, on the other hand, the Mangla Dam Project. The following description of the works, which is inevitably rather complicated, is illustrated by the pull-out map at the end of this chapter. Three of the link canals are remodeled and enlarged versions of those built by Pakistan in the 1950's, close to the Indian border, between the Chenab, Ravi and Sutlej -- Marala-Ravi (22,000 cusecs), Bambanwala-Ravi-Bedian-Dipalpur (5,000 cusecs) and Balloki-Suleimanke (18,500 cusecs) (see Map 2). A new barrage is also being built at Marala because, although not originally included in the Treaty, it was found that this would be cheaper than remodeling the old one. Two more of the link canals give the Balloki-Suleimanke link a direct supply from the Jhelum; they are Rasul-Qadiribad (19,000 cusecs) and Qadiribad-Balloki (18,600 cusecs); a new barrage at Qadiribad was provided for in the Treaty and it was subsequently found that a new barrage was also necessary at Rasul, a short distance downstream of Mangla. Two other links are designed to convey water from the Indus to the Jhelum: Taunsa-Panjnad (12,000 cusecs) in the south a short distance upstream of the confluence of the Indus with its tributaries and, the largest link, Chasma-Jhelum (22,000 cusecs) just below Jinnah Barrage. It was originally envisaged that the Jinnah Barrage at Kalabagh would form the terminus of this link on the Indus, but careful investigation showed that even if remodeled it could not perform this function efficiently in addition to serving the Thal canals. So it was decided to build another barrage under the Treaty, at Chasma, and to take the link off from there. The last of the eight links referred to in the Treaty was one between the Chenab, Ravi and Sutlej which would be able to transfer Indus water delivered by the Kalabagh-Jhelum link across the lower parts of Rechna and Bari Doabs to the heart of the Sutlej Valley Project area. It was described in the Treaty as the Trimmu-Islam link (11,000 cusecs) with two new barrages, one on the Ravi and one on the Sutlej. Further studies led to various changes in concept, and the project finally built was the Trimmu-Sidhnai-Mailsi-Bahawal link, with a new barrage at Sidhnai on the Ravi and a syphon for transferring water overhead, known as the Mailsi Syphon, on the Sutlej. Most of these works have now been built, and the links from the Indus should also soon be completed -- Taunsa-Panjnad in 1969 and Chasma-Jhelum in 1971.

3.18 The other main component of the Indus Basin Works, Mangla Dam, the largest dam of its type in the world, is being brought in largely to replace the historic deliveries from the Ravi and the Sutlej to the canal commands in Bari Doab and on the left bank of the Sutlej in the rabi season. October-April flows on the Ravi and the Sutlej average about 4.2 MAF. With an initial live storage of about 5.3 MAF (with drawdown level of 1040 feet), or more than 20 percent of the average annual discharge of the Jhelum of 23 MAF, Mangla Reservoir will greatly alter the pattern of flows on the river. By transferring this amount of water from kharif to rabi, it will result in more than doubling mean-year discharges in the rabi season and it will increase discharges in this season under critical year conditions by some 130 percent. Quite apart from its function of transferring the availability of water to the season when it is in short supply, Mangla will also play a very important role in regulating the discharges of the river over the course of each season and particularly the rabi season. The Jhelum, being quite heavily dependent on monsoon rains, is an exceedingly variable river. Annual recorded flows on the Jhelum at Mangla range between 65 percent and 135 percent of the mean flow of 23 MAF, and this variability operates in the rabi season as much as in kharif. Recorded discharges between the beginning of October and the end of March range between 65 percent and 165 percent of the mean of 4.7 MAF. Variability of discharges in a single month is of course even greater, as implied by the following table.

Table 8

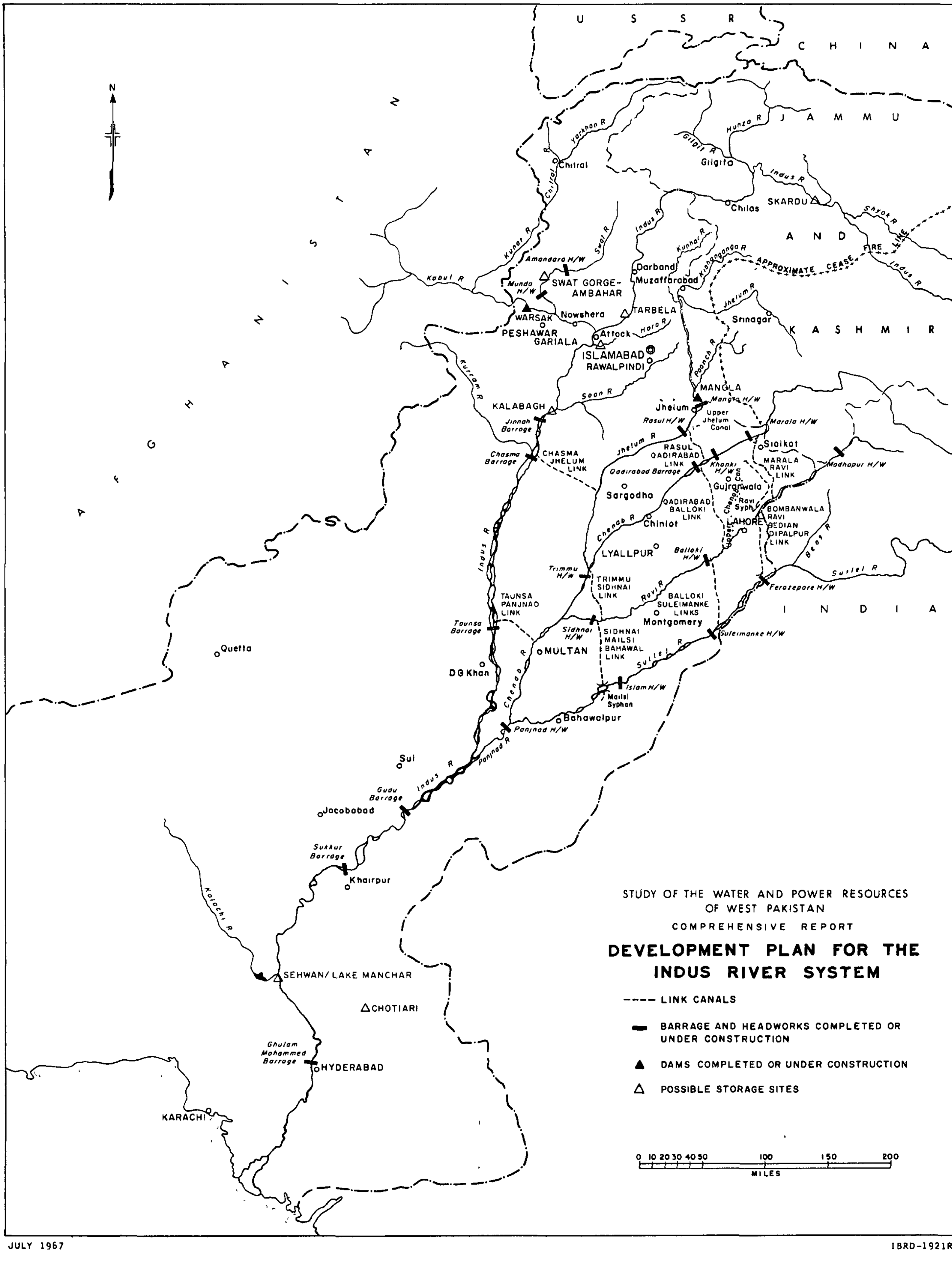
Recorded Rabi Discharges of Jhelum at Mangla, 1922-63
(MAF)

	Mean	Maximum	Minimum
October	0.85	1.78	0.49
November	0.54	1.57	0.34
December	0.48	1.64	0.32
January	0.53	1.06	0.34
February	0.73	1.94	0.33
March	1.56	2.99	0.68

Maximum recorded flows in a month are in some cases as much as five times minimum flows in that month. From the point of view of agriculture it is the availability of water at a particular time which counts. The barrages have been able to even out water deliveries to some minor extent, but Mangla will make it possible for the first time to control a sizable proportion of the total flow.

3.19 The other major contribution to economic growth in West Pakistan which will be made by the Mangla Project is in the form of electric power. The Indus Basin Development Fund Agreement included provision for installation of the first three units. Two units each rated 100 mw have come into operation during 1967; the large fluctuation in reservoir content and consequently in the head on the turbines over the course of the year will cause the capability of each unit to vary between a minimum of about 45 mw in the spring when the reservoir is fully drawn down and a maximum of about 135 mw in the summer after the monsoon floods have refilled the reservoir. But flows will be sufficient to generate a large amount of base load energy throughout the year; the first two units will produce about 1,800 million kwh under mean year flow conditions or nearly 50 percent of the total amount of electric energy generated in West Pakistan in 1965. The rapid growth of electricity consumption in the Province means that most of this output will soon be absorbed, and additional units will have to be added. The powerhouse is presently being built for eight units, but there are five tunnels and since each tunnel is designed to take two units the ultimate installation could be 10 units, with a combined minimum capability of about 450 mw and a combined maximum of 1,350 mw; together these units would be able to use virtually all the water passing through the dam for power generation, except at times when the reservoir is very low or when floods are exceptionally high, and they would produce an average of about 6,000 million kwh per year.

3.20 Completion of Mangla Dam makes it possible to store a large proportion of the summer flow on the Jhelum which is surplus to kharif irrigation requirements. Indeed in years of low kharif flow it will store virtually all of the surplus. As irrigation develops further



JULY 1967

IBRD-1921R3

and kharif requirements increase, the margin of surplus will fall and a choice will arise between filling the reservoir so as to ensure greater availability in the following rabi season and allowing more of the kharif flow to go straight through the dam for immediate irrigation use. If all conceivable kharif irrigation obligations, even those which have not generally been met in the past, were to be taken into account then this choice would be real in some hydrological years even now. Mangla Dam has been designed and constructed in such a way that it could be raised 50 feet and the live storage capacity of the reservoir consequently increased 3.5 MAF; clearly the larger reservoir would be filled less frequently than the existing reservoir, given the same kharif irrigation requirements, but at some stage it might become attractive to accept this situation and to develop the full potential storage capacity of Mangla so that water could be held over from years of high flood for use in low-flow years.

3.21 From the point of view of the development of the irrigation system the main importance of the Indus Basin Works is in making traditional water supplies fully secure, initiating a new direction of development in the form of interseasonal surface storage and offering scope for further development. The works have been designed to be adequate for meeting their primary purpose of replacing historic deliveries from the Sutlej and the Ravi -- Mangla providing the rabi water and the links serving to transfer water from there in rabi and from the natural flows of the Indus and the Jhelum in kharif. They do add considerably to the flexibility of the system. The link canals built under the Treaty will provide a total capacity of 2.0 MAF/month for transfers from the Indus to the Jhelum and Chenab, while they, together with the canals built earlier under the Triple Canals Project (see Chapter II) will provide 4.2 MAF/month capacity for transfers from the Jhelum and Chenab to Bari Doab and the Sutlej Left Bank. They will make it possible to compensate to some extent for hydrological fluctuations in flows on the Jhelum and Chenab by transfers from the Indus. Mangla, operated in an integrated fashion with the link canals, will enable deliveries from the rivers of the Punjab to be matched more closely to the time pattern of crop-water requirements than has been possible in the past. The flexibility added by these works will become increasingly valuable as the integration of the system is tightened by further development. The hydroelectric plant at Mangla should provide a cheaper and more reliable source of electricity than has yet been available in the Province, and this will be especially important in connection with further tubewell development. Nevertheless most of the water storage and transfer capacities of the Indus Basin Works will be required for their main purpose of replacing flows released for use by India. Therefore, the works in themselves leave unresolved the fundamental problem of the inadequacy of irrigation water supplies for supporting the kind of modernized agriculture that West Pakistan so urgently requires.

IV. FOUR TECHNIQUES OF WATER DEVELOPMENT

4.01 With the Indus Treaty Works nearing completion as a means of ensuring that West Pakistan will continue to receive the irrigation supplies that have been available in the past, this report addresses itself to assessing the next steps that should be taken in development of the Province's water resources. As noted earlier, the main water resources available, apart from rain falling directly on the irrigated lands, are surface water -- of which some 142 MAF will be available in a mean-flow year following full implementation of the Indus Waters Treaty -- and groundwater. The Indus Plain is underlain by a very extensive groundwater aquifer, of a gross area of the order of 40 million acres. The groundwater aquifer is believed to exceed 1,000 feet in depth over much of the area. It is estimated that about 14 million acres of the canal-irrigated area lies over groundwater of sufficient quality that it can be used directly for irrigation, while another five million acres have groundwater that is low enough in noxious chemical elements that it can be used for irrigation after mixing with surface water. The uppermost 100 feet of the usable groundwater aquifer in the irrigated areas contain about 300 MAF of usable water. The physical characteristics of the aquifer are generally favorable to groundwater development, except in parts of the Lower Indus Region (Sind) where it has low permeability and the groundwater is generally saline.

4.02 Of the various ways in which water resources can be developed, there are four, shown in Table 9, which are particularly important to West Pakistan at its current stage of development. While the following pages make some reference to other techniques which may play some part, especially in later years, they focus primarily on the four -- canal enlargement enabling increased natural flow diversion, interseasonal surface storage, private tubewell pumping and public tubewell pumping to balanced recharge. All four modes of development are to some degree interdependent: none can be adopted alone without eventually creating the need to embark on one or more of the others. Each is in addition subject to administrative and technical constraints which limit the speed with which it can be pursued. Nonetheless, an impression of the relative cost of the four different techniques and the ultimate scope for each can be gained by examining the tentative projections made by IACA. The unit cost of an acre-foot of water made available by each technique is roughly estimated by discounting to 1965 at eight percent both the costs and the water yield at watercourse head of projects or programs recommended later in the report using each of the four modes of development. The corresponding 'ultimate' potential is taken from IACA's projections for the reference year 2000.

Table 9

Four Techniques of Water Development

	Economic Costs (PRs/acre-foot)	'Ultimate' Potential Water	Land Supplied
Surface Storage (total reservoir volume)	63	26 MAF/yr.	-
Canal Remodeling (carrying capacity)	19	5 MAF/mo.	16 mln. acres
Private Tubewells)) (mean annual output) Public Tubewells)	16	44 MAF/yr.	19 mln. acres

The surface storage cost is estimated on the basis of the full development program set out in Table 48 of Chapter VII, using the total costs of the reservoir works and the amount of stored water which is estimated to be delivered directly to watercourses from storage over the years. Each of the figures in the table is discussed in greater detail later in the report, but they are presented here together for rough comparative purposes. There is one other aspect of water development which is very important in West Pakistan but cannot be presented in a PRs/a.f. context; this is drainage, which is related to all the modes of increasing water supply listed above and it will receive considerable attention later in this chapter.

Canal Remodeling and Enlargement

4.03 Gradual expansion of the modern canal system into new areas has been the traditional form of development over the last century and it is continuing into the present day in certain areas, such as from Thal, Gudu and Ghulam Mohammed Barrages on the Indus. However, it was indicated at the beginning of Chapter II that in recent years development on the Indus, the last of the rivers to be brought under barrage-controlled development, was having now to follow the course already trodden in the past on the tributaries: more and more of the development had to be designated non-perennial, since most of the rabi river supplies were already committed. Table 1 in Chapter II showed that while total canal diversions had increased substantially over the last 20 years, rabi diversions had increased little -- and scarcely at all over the last decade. Several consultants have recommended in favor of reducing rather than further increasing the area designated for canal irrigation supplies.

4.04 In practice, canal diversions have today to be rationed in most years by a tighter system than the perennial/non-perennial distinction, since flows are seldom adequate to maintain delivery of the quantities of water that were originally allocated. The main lines of this rationing procedure are laid out in a document known as the

Sind-Punjab Draft Agreement which was prepared by the Chief Engineers of the Sind and the Punjab in 1945; it was never ratified, because agreement could not be reached on financial implications and then Partition ensued, but it is still closely observed. Under this Agreement it is generally the areas of longest established irrigation that have first claim on available flows. First right to the flows on the Jhelum and the Chenab, for instance, goes to the three canals built under the Triple Canals Project of 1905 (Upper Chenab Canal, Lower Bari Doab Canal and Upper Jhelum Canal) and to the two major canals in the vicinity which were built before them (Lower Chenab and Lower Jhelum Canals). These, together known as the five linked canals, supply all the CCA in Chaj Doab, almost all the CCA of Rechna Doab and about a quarter of the CCA in Bari Doab. Monthly withdrawals by these five canals are generally within about 10 percent of mean levels. The remainder of the Bari Doab and all the area on the left bank of the Sutlej, forming essentially the Sutlej Valley Project area, depend primarily on the Sutlej but also receive supplementary supplies via the link canals. Nevertheless, the flows available for transfer down these links are often inadequate to make up the deficiency, and monthly withdrawals by the canals in the Sutlej Valley Project area often diverge by more than 30 percent from the mean levels. On the main stem of the Indus the picture is similar: Thal Canal at Jinnah Barrage, furthest upstream, plus the canals at Sukkur Barrage and certain channels which used to receive supplies from old inundation systems share first priority and deliveries to the areas served by these canals are maintained at fairly consistent levels. The newer canals at Taunsa, Gudu and Ghulam Mohammed Barrages have lower priority and tend to bear the brunt of shortages on the Indus.

4.05 Some indication of the declining effectiveness of the perennial/non-perennial distinction is given by the fact that it seems to bear extremely little relationship to the existing pattern of crop production. One would expect that the areas allocated perennial canal supply would show a substantially higher cropping intensity in rabi season than those with non-perennial supply; or that, even if no difference was to be found in intensities, yields would be higher in areas benefiting from regular canal supplies in rabi. IACA found in general rather little difference between the rabi intensities in the non-perennial and perennial areas in the Punjab or between equivalent areas in the Sind. Actually, of nine agricultural regions into which they divided the irrigated area for purposes of analysis the area with the highest rabi intensity and the highest overall intensity is the non-perennial area on the right bank of the Indus commanded from Gudu and Sukkur; rabi crops are grown there largely on the basis of residual moisture remaining in the soil at the end of kharif (quite high because the main kharif crop is rice which has high water requirements) or on the basis of one watering just before the canals are closed at the end of kharif. Rabi yields in this area are, it is true, quite low. But in the North there was not even noticeable difference in yields. What IACA did find were some indications of higher intensities in the areas with priority in water allocations -- such as the Chaj, Rechna and Upper Bari Doab areas and some of the areas commanded from Sukkur.

4.06 Even those areas with the highest priority for use of the available flow in the rivers suffer from an inadequate supply of canal water. Table 7 of Chapter III, which compared current water supplies per cropped area with the amount of water needed to support a modern agriculture, showed that all areas suffer from lack of water -- and the shortage appeared to be particularly acute, for instance, in Chaj and Bari Doabs. The current supply figures given there included water pumped by tubewells and Persian wheels, and if these were omitted, the shortages would of course appear greater. The rights to withdrawals from the rivers which have been built up over the years are in fact almost everywhere below actual water requirements. The reason for this is that the rights of each area were established on the basis of the original design of the various canals, and most of the canals were designed to support a much lower cropped acreage than has in fact come to be cultivated. Typical design cropping intensities were in the neighborhood of 80 percent, whereas actual cropping intensities in many of the older-established areas of canal irrigation are around 100 percent. With adequate waterings and applications of fertilizer, it is believed that most of the canal-irrigated area could support an intensity of 150 percent and in some areas more. There appear to be various reasons why the canal systems were designed for cropping intensities so much lower than the land was capable of supporting. The British colonial administrators were concerned with settling large numbers of people and also with showing a good financial rate of return on their canal investments. Financial returns came mainly in the form of land revenue, the per-acre tax on land which was higher for irrigated areas, and proceeds of sales of Crown Land. Thus, to settle more people and raise more revenues there was advantage in designing for low cropping intensity or, in other words, for spreading the water thinly over the Basin. But there was another factor that also played some part in their considerations: realization that design for a higher intensity and subsequent heavier deliveries of canal water to a limited area would lead more quickly to waterlogging.

4.07 The canals in the best agricultural areas might now be expanded to give them sufficient delivery capacity to provide water for the much higher cropping intensities that these lands are capable of supporting, but this would be no solution, primarily for two reasons. In the first place, as pointed out earlier in connection with extension of the irrigation system, most of the river flows except in a very few months of the year are already committed. The present withdrawal capacity of the canal system is about 13.3 MAF/month and this equals or exceeds the combined natural mean flow of the Indus, Kabul, Jhelum and Chenab in all months except June, July and August. In those months flows are substantially larger -- often more than double. There are a few weeks in May and in September when river flows are also sometimes in excess of canal diversion capacity. But three to four months in the summer are barely sufficient to mature most summer crops. In the second place, the water table has indeed risen to high levels in extensive areas, especially in some of the older-irrigated areas, and it is doubtful whether they could cope with additional large supplies of surface water unless extensive drainage works were also provided.

4.08 The real scope for improving water supplies by canal remodeling occurs in close coordination with tubewell development. Tubewells can deal with both the problems mentioned in the preceding paragraph, for they can provide drainage and, in the extensive areas where the groundwater is usable for irrigation, they can provide irrigation water in the months when river flows are already fully committed thus making additional canal deliveries in other months far more useful than they could otherwise be.

4.09 When the scope for canal remodeling is examined in this light there is another aspect of the original design of the existing canals which becomes very important because it serves to limit the need for canal remodeling in the near future. Detailed crop-water requirements were not estimated in quite the precise way that is used today, but the requirements of the main crops like rice and cotton in kharif and wheat in rabi were carefully established. It was found that there were large differences between the amount of water required for a crop in winter and the amount required in summer. Temperatures in the Indus Plains range from mean monthly minima of 40 degrees Fahrenheit during December and January to mean monthly maxima in excess of 100 degrees in June and July. They are generally higher in the Sind, particularly in the Upper Sind which does not benefit from the sea breezes which extend north of Hyderabad; Jacobabad, for instance, northwest of Sukkur, has one of the highest average temperatures in the world, reaching a mean maximum of 114° Fahrenheit in June. Temperature is the main determinant of evaporation and thus of the water requirements of a plant. Rainfall is of importance in some areas, but it is largely confined to the summer, when the southeast monsoon drops in the Punjab what remains to it after its long journey across the Indo-Gangetic Plain in India and the southwest monsoon delivers to the Sind a small rainfall from the Arabian Sea. When the rain does come it is not uncommon for it to be either so light that it evaporates before reaching the crop roots or so torrential that it runs off the fields. Table 10 gives a broad indication of the seasonal and regional variation in evaporation and in estimated effective rainfall.

Table 10

Computed Evaporation and Effective Rainfall
(in inches -- rainfall in parentheses)

	North	South
Winter (October to March)	18 (3.6)	27 (0.8)
Summer (April to September)	41 (15.6)	49 (2.6)
Annual Total	59 (19.2)	76 (3.4)

The table indicates that evaporation net of effective rainfall is in each season almost twice as high in Sind as in Punjab and Peshawar and that in all parts of the Province it is nearly twice as high in summer as in winter. These are broad averages but they indicate why the amount of canal water needed to grow an acre of crops is significantly larger in Sind than in Punjab and why it is also much larger in kharif than in rabi.

4.10 These variations in requirements of canal water had to be taken into account in design of the canals, as did another fact, namely that the canals of West Pakistan, running on a principle of hydraulic equilibrium, were best operated either close to full or not at all. Taking account of both these considerations, the perennial irrigation projects were generally designed for a rabi cropped acreage between 1.5 and 2 times as great as the kharif cropped acreage; thus with an annual 80 percent cropping intensity, the design kharif intensity would be between about 27 and 32 percent. The non-perennial areas, on the other hand, by way of compensation for the fact that they had a right to canal supplies only in one season of the year, were generally given canal capacities sufficient to support a somewhat higher kharif intensity, typically in the order of 30-40 percent. Thus the canals which exist today are generally larger and have greater delivery capacity per acre of canal-commanded area in the non-perennial than in the perennial areas.

4.11 In the areas of more recent development, moreover -- and it was shown in Chapter II that almost all the non-perennial development has taken place since 1920 -- areas designated for non-perennial canal supplies have generally been located where the groundwater was sweet, while perennial supplies have been allocated to areas with poor quality groundwater. This approach was adopted because it was considered that in areas of fairly shallow, fresh groundwater, Persian wheels and other wells could be used for both drinking water and for rabi irrigation, as previously practiced in the inundation canal commands. This distinction between perennial supplies for areas with poor groundwater and non-perennial supplies for areas with fresh groundwater was especially important in the design of development in the Sutlej Valley, which constitutes a large proportion of the total non-perennial area in the Basin.

4.12 The result of this combination of circumstances is that there are extensive areas of fresh groundwater in West Pakistan which already have sufficient canal capacity to permit very large increases in irrigation supply to be obtained simply by the installation of tubewells. Since most of the recharge to the aquifer currently comes from canal seepage, these areas of non-perennial supply tend to have higher recharge in kharif per acre of crop land than the areas of perennial supply with their smaller canals. By concentrating pumping in the months when existing canal capacities are the constraint (e.g. the overlap months between kharif and rabi) and in the rabi season when surface supplies are scarce, it is possible to produce enough water from surface and groundwater resources together in each month of the year to permit a significant increase of cropping intensity. IACA estimated, for instance, that sufficient water could be provided by this means without any canal remodeling to meet full irrigation requirements at average cropping intensities of about 135 percent in Rechna and in Bari Doabs, very large proportions of which are underlain by fresh groundwater. Altogether the areas with fresh groundwater where the aquifer could be developed sufficiently to permit obtaining a high intensity -- close to 150 percent -- without any canal remodeling are estimated to cover about 13 million acres, almost entirely in the Punjab. These high intensities would be obtained partly with the aid of additional surface supplies in the winter, in order to provide sufficient recharge within existing canal capacities.

4.13 Where canal remodeling is essential to gain any significant increase in timely irrigation supplies is in the areas not underlain by fresh groundwater. In these zones the groundwater is either not usable at all for irrigation purposes, because it is too saline, or it must be mixed continuously with fresh water before it can be applied to the crops. As pointed out, these are the areas which in general tend to have rather less existing canal capacity per acre of canal commanded area. This combination of characteristics obviously makes them somewhat less attractive for development than the fresh groundwater areas discussed, but they are extensive (some 15 million acres) and could support much higher agricultural production if additional water were made available. They will be discussed more in connection with public tubewells below.

4.14 The large program of canal remodeling foreseen in Table 9 above -- 16 million acres before the end of the century -- covers virtually all the zones without fresh groundwater in the 29-million acre canal commanded area which has been adopted for planning purposes; it covers very few of the fresh groundwater areas. The unit cost of PRs 19/a.f. derived for water made available at watercourse head by means of canal remodeling refers to the estimated cost of this program. The cost figure may not be very reliable because, despite the enormous experience that Pakistan has had in the extensive enlargement of complete canal commands, there has been very little experience in enlargement or large-scale remodeling of existing canals. Canal remodeling will in fact be a most complex and difficult process, particularly as regards acquisition of additional land in areas which, being near to canals, are often densely cultivated (though sometimes also waterlogged and useless), and as regards maintenance of essential water supplies to farmers during the time that the work is in progress. IACA thought that it would generally be easiest and most economical to build an entirely new canal alongside of, and eventually linked with, the existing canal whenever any extensive degree of canal enlargement was required. Preparation and design of any work in large-scale canal remodeling could not be done quickly.

4.15 While canal remodeling is not a prerequisite of substantial increase in irrigation supply and in cropping intensity in the areas underlain by fresh groundwater it could also be carried out there. The purpose would be not so much to increase irrigation supplies within these areas themselves as to release the surface water supplies that they had been receiving in rabi for use elsewhere. Enlarged canals would enable more surface water to be brought in during kharif or when river flows happened to be high; the recharge to the groundwater reservoir would thereby be increased and all water requirements in the remainder of the year could be supplied from pumping. These areas would thus be rendered completely independent of rabi river flows. Canal remodeling of this sort, enabling underground interseasonal storage, could be an alternative to some extent to surface storage. It would be a moderately expensive alternative, involving not only canal enlargement but also pumping for each additional acre-foot produced to replace surface water deliveries from storage.

Surface Storage

4.16 Figure 1 in Chapter II pictured the high peak of flood flows on the rivers of West Pakistan between June and September and demonstrated that in the past a large proportion of this water resource has gone unused. Because that figure referred to past history, the composite hydrograph shown included the flows in the Ravi and Sutlej as they enter West Pakistan. Total river flows, including those in the Ravi and Sutlej, have averaged somewhat more than 130 MAF in the five months May-September, of which some 50 MAF have been diverted into canals in recent years. Deduction of the Ravi and Sutlej will leave Pakistan with a mean-year flow in these months of about 110 MAF. Completion of Mangla Dam and use of its reservoir for transferring flows from kharif to rabi will take about 5 MAF of kharif flows. Thus about 55 MAF, or half the total available in the rivers in a mean year, will still remain unused.

4.17 Most of this unused water will be in the Indus River itself. Of the three western rivers allocated to Pakistan under the Indus Waters Treaty the Indus (at Attock) itself represents about 65 percent of the total mean annual flow, but 70 percent of the mean flow in the four months June to September. The Indus is more highly peaked than the other two rivers, as illustrated by Figure 2 which shows the hydrographs of the Indus, Chenab and Jhelum separately. About 67 MAF, or 72 percent of the mean flow on the Indus occurs in the four months June to September. Flows in the Indus also vary proportionately much less from year to year than do those in the Jhelum and Chenab, as indicated by the following table.

Table 11

Average Annual Discharge of the Indus, Jhelum, and Chenab Rivers (1922-63)
(MAF)

River	Location	Discharge Mean	Discharge Minimum	Discharge Maximum
Indus	Attock	93	72	110
Jhelum	Mangla	23	15	33
Chenab	Marala	26	19	37
		142		

Annual mean flow on the Indus at Attock is about 93 MAF and the range of flows recorded between 1922 and 1963 is from about 75 percent to nearly 120 percent of this. The greater regularity of Indus flows from year to year shows up especially in the rabi season. Where the maximum flows recorded in several rabi months on the Jhelum are as much as five times the minimum flows recorded in the same month, as shown in Table 8 of Chapter III, the range between maximum and minimum is far less on the Indus, generally in the order of 3:1 or 2:1 in rabi months. Only in March and some of the early kharif months does the range of variation recorded parallel that experienced on the Jhelum. The greater reliability of the Indus is attributed mainly to its higher dependence on snowmelt from the Himalayas. The importance of snowmelt from the mountain peaks also accounts for the fact that the Indus typically begins to rise toward the end of February, about a month later than the Jhelum. Peak flows on the Jhelum tend to occur in July, peak flows on the Indus in August.

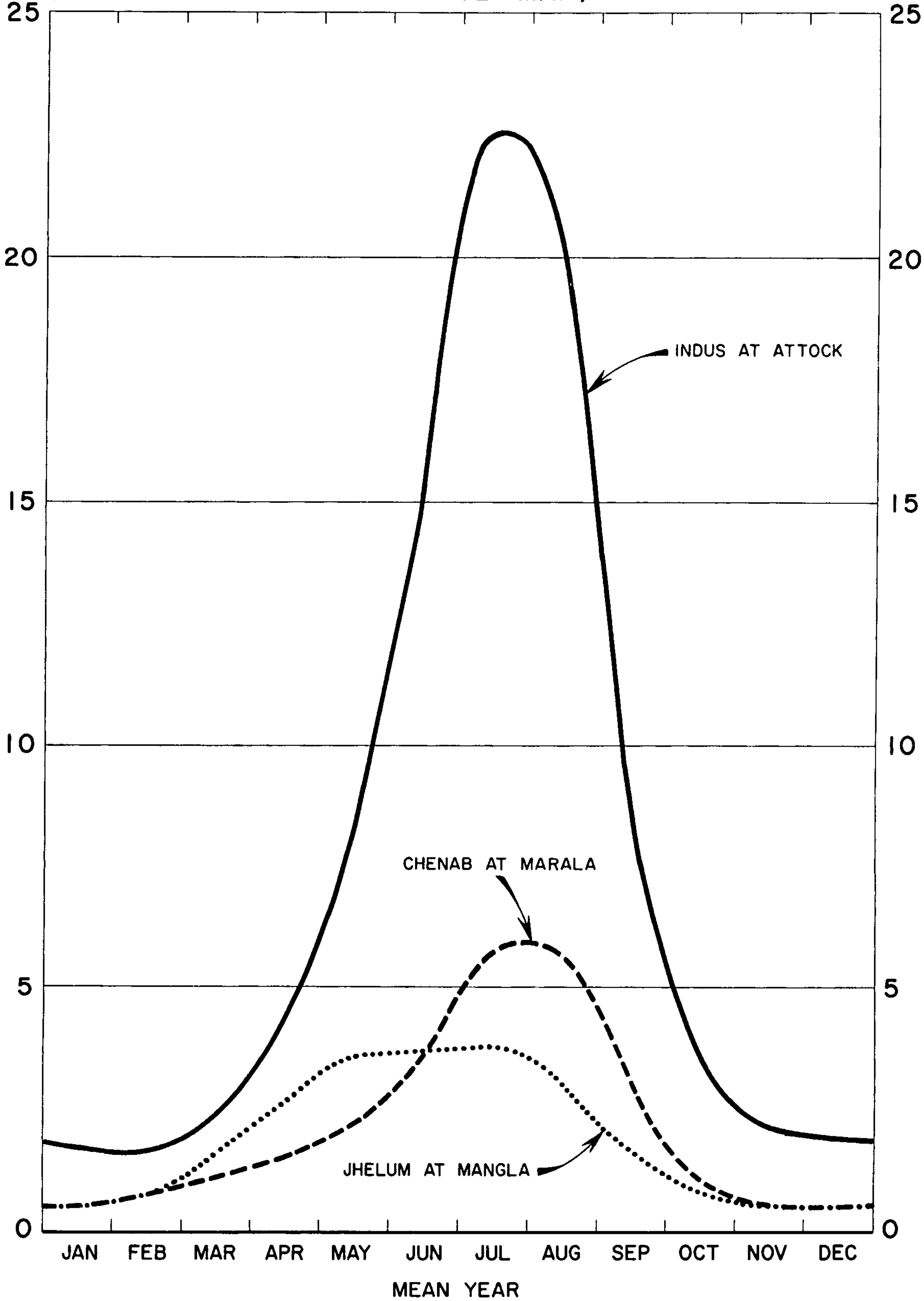
4.18 The massive extent of the kharif surplus on the Indus and the relative reliability of this surplus suggest that the next site for storage development, following completion of Mangla, should be on the Indus. However, the river presents no sites that, with present techniques of dam construction, would be both cheap to develop and capable of providing large storage capacity. The 2,000-mile long Indus rises in Tibet and traverses some 500 miles of Tibet and disputed territories in Kashmir before entering West Pakistan. Some 100 miles after crossing into Pakistan territory it enters the steep 300-mile long Indus Gorge between Skardu and a point some 30 miles downstream of Tarbela. After being joined by the Kabul River it enters the lower Indus Gorge which cuts through the soft sedimentary rocks of the Attock hills and the Salt Range between Attock and Kalabagh. At Kalabagh the river breaks out on to the vast, flat plains of the Punjab and the Sind which extend some 700 miles to the sea; here the river is very broad and runs in many shallow channels dug and redug in the silt which it deposits. Sites with potential for construction of a dam that would create large-scale storage on the main stem are few, and each has its own disadvantages. The available sites are discussed in Chapter VII.

4.19 The Tarbela site was selected for detailed studies and design work in 1961 after consideration of a number of other sites over several years and thorough investigation of a 20-mile stretch of river around Tarbela. The dam which has now been designed would provide a reservoir with some 11 MAF gross storage capacity and up to 9.3 MAF live storage capacity. The cost of water from Tarbela Reservoir delivered at the watercourse, calculated in a similar way to the figures presented in Table 9 would be about PRs 93, which means that it is expensive compared to the other ways of making water available mentioned in the table.

4.20 There is a number of factors accounting for the costly nature of surface water storage in West Pakistan. Sites with potential for construction of dams backing up large storage tend to be very broad, valley topography is generally such that the dams have to be unusually

MEAN MONTHLY DISCHARGE: INDUS, JHELUM AND CHENAB RIVERS*

(AVERAGE MONTHLY DISCHARGE - MAF)



* Based on the period 1922-1963.

(2R)IBRD-3220

high relative to the storage capacity created, and foundation conditions pose considerable difficulties. Both Mangla and Tarbela Dam Projects will be earth and rockfill structures and each consists of one main dam, two auxiliary dams and two spillways. Table 12 presents some of the main statistics regarding the two projects.

Table 12

Principal Features -- Mangla and Tarbela Projects

		Mangla	Tarbela
Maximum Initial Live Storage	(MAF)	5.3	9.3
Length of Reservoir	(Miles)	40	48
Site Excavation	(mln. cu. yds.)	55	95
Earth and Rockfill	(mln. cu. yds.)	122	178
Main Dam			
Earth and Rockfill	(mln. cu. yds.)	78	159
Maximum Height	(feet)	380	485
Crest Length	(feet)	11,000	9,000

Another major component of the Tarbela Project is an impervious earth blanket which will be continuous with the imperious core of the dam and extend upstream for about one mile covering the river bottom.

4.21 Apart from the size of the valleys where each of the two projects are sited and the general scale of works required in each case, another major factor accounting for the high costs of surface water storage is the large amount of spillway capacity that has to be provided. Though for somewhat different reasons on each project, this represents a very significant item of total cost in both cases: about 20 percent of the main civil engineering contract in the case of Mangla (or $90 million) and only a slightly lower proportion for Tarbela (about $95 million). Table 13 gives some details of spillway capacity on each of the two projects, the floods against which they were designed and the maximum flood of record.

4.22 The table illustrates the fact that despite the higher design flood and higher recorded peak on the Jhelum at Mangla, nevertheless spillway capacity required is somewhat less. As pointed out, the Jhelum River is considerably more variable and unpredictable than the Indus, and it is more highly dependent on monsoon rain. The high design flood at Mangla results from the possibility of simultaneous occurrence of heavy monsoon storms in the upstream catchments. High floods which should be relatively rare will be handled partly by the spillways but to an important extent by superstorage in the reservoir; between full supply level of 1202 feet and elevation 1228 there is about two MAF superstorage capacity at Mangla.

Table 13

Floods and Spillway Capacity, Mangla and Tarbela

	Mangla, Jhelum	Tarbela, Indus
Maximum Flood of Record (cfs)	1,100,000	875,000 a/
Date	August, 1929	August, 1929
Design Flood (cfs)	2,600,000	2,127,000
Spillway Capacity b/, total (cfs)	1,130,000	1,410,000
Main Spillway (cfs)	900,000	615,000
Auxiliary Spillway (cfs)	230,000	795,000
Reservoir Full Supply Level (feet SPD)	1,202	1,550
Height of Main Dam (feet SPD)	1,234	1,565

a/ Indus at Attock, after confluence with Kabul; it will have been somewhat less at Tarbela.
b/ Discharge capacity at normal full supply level.

At Tarbela the main component of the design flood is again the maximum probable monsoon storm, but substantial allowances had also to be made for late snowmelt runoff from the Himalayas and for the possibility of a natural dam break upstream. Natural dams have formed fairly frequently in the past on the Upper Indus and its tributaries, due to glacial movement or avalanches; the flood of August 1929 on the Indus occurred in connection with the breaking of a natural dam on the Shyok River. Despite these additional components, the design flood at Tarbela is considerably lower than that at Mangla. However, because of the high concentration of Indus flows in a few summer months and the relative regularity of the river, the floods of an average year will approach much more closely the design flood. The spillways will be the main means of dealing with floods, rather than superstorage -- capacity for which is much more limited at Tarbela -- and it is estimated that even in the initial years of the project's life the spillways will carry some 40 percent of the river's annual discharge in the two or three flood months of the summer.

4.23 The other noteworthy factor accounting for the high cost of water stored on the Indus is the siltation that is expected to take place in the reservoir and consequent rather rapid depletion of live storage capacity. The average annual sediment load of the Indus at Tarbela is estimated at 440 million short tons and almost all of it is borne by the summer flood flows. The sediment load can reach 10 million tons a day. Little is known about its origin, but it appears that some of it is due to current glacial action and avalanches in the upper reaches of the river and its tributaries while some is due to landslides and river scouring in the vast piles of debris built up in the lower parts of the Upper Indus by past glacial movement and silt deposition. The Jhelum also has a sizable sediment load, although much smaller (about 70 million short tons per year) than the Indus. However, the sediment load on the Jhelum appears to be the result of human activities to a much greater extent than that on the Indus, and it has been estimated that about 30 percent of it could be eliminated by conservation measures and erosion control. Sediment on the Indus, being apparently much more the result of geological forces, may be harder to reduce.

4.24 Siltation is not an unfamiliar problem in West Pakistan, but it has never been dealt with on the scale that will be involved by a permanent dam across the Indus. It was a serious difficulty on the early barrages and canals. Soon after a permanent weir had been built across the Ravi in 1870 at the head of the Upper Bari Doab Canal, the first major modern canal, the canal intake became seriously silted up. Various attempts were made to solve the problem, and the design finally chosen is basically the one that has since been used: a divide groyne was built out in an upstream direction from the weir spanning the river, thereby creating a pond of relatively calm water in front of the intake to the canal, in which silt could settle. High flood flows would be allowed to pass the weir and with them they would carry silt deposited in the pond. Sluicing in this manner serves to keep the barrages reasonably free of silt. The barrages have virtually no storage capacity and so flood flows have anyway to be passed through. The problem is obviously different with storage works, the purpose of which is to capture flood flows and hold them for later release. Warsak Dam on the Kabul River, completed in 1960, was not built for its storage but mainly to use run-of-river flows for power generation; however, the storage is useful -- and would be more so after completion of Mangla -- to make the power plant more flexible and enable its use to a larger extent for peaking, but the initial live storage of 23,000 acre-feet has already been greatly reduced and is expected soon to reach a residual minimum of about 10,000 acre-feet. One solution to the problem of siltation at a storage dam on the Indus would be to take advantage of the very large amount of surplus summer flows by building a dam with sluice gates, similar to a barrage, sluicing through the early flood flows and storing on the receding flood. But there are severe disadvantages to such a procedure -- in particular the fact that power capability is eliminated at the time of sluicing -- and it is also difficult to find sites on the Indus which are accessible, have the necessary surrounding topography for forming a reservoir, and are at the same time underlain by rock sufficiently hard to carry the stresses to which such a sluicing structure would be subjected.

4.25 Thus planning to date has had to be carried out on the assumption that an average of about 70 million tons of sediment will be deposited in Mangla Reservoir each year and about 440 million tons in Tarbela Reservoir. 440 million tons is equivalent to about a quarter of a million acre-feet compacted volume, and, allowing for a portion of this to be deposited in the live storage area, it is projected that Tarbela Reservoir will be fully silted up, except for a residual 1 MAF of live storage volume, in about 50 years, whereas Mangla Reservoir, though of much smaller size, would only lose about 30 percent of its initial capacity over the same period. The heavy silt load of the water does of course have other implications besides those for the life of storage dams. It will cause problems of abrasion, for instance, of uncertain severity, on the spillways, tunnels and turbine blades, and this will require added maintenance attention. These factors, the designs adopted to minimize problems of abrasion and the limited life that is anticipated for storage projects on the main stem of the Indus do add to the cost of stored water. But they also mean that the cost of water stored on the Indus will, other things being equal, be somewhat less when a second dam is added either downstream of Tarbela and protected by Tarbela, at least for a number of years, or upstream of Tarbela and therefore protecting Tarbela; this is a part of the reason why the cost per acre-foot of stored water delivered at the watercourse is substantially less when a long-term program is considered as a whole than when Tarbela is considered on its own.

4.26 For all its high cost, water added to rabi supplies by means of storage from the kharif flood season does have considerable advantages not shared by other means of making water available at that time. It should prove relatively easy to use effectively since it represents an addition to a customary source of water -- from canals -- of assured quality at a time of year when shortages are currently felt acutely. It also has great flexibility in use, in that it can be diverted via the complex canal distribution system wherever it is required. Mangla water, as pointed out, can be carried to practically any part of the Punjab and Tarbela water can be supplied to the western and southern Punjab and all the Sind; by substitution, the effects of Tarbela may be felt in the northern Punjab since it could replace downstream deliveries from Mangla and leave more of Mangla's water available for use upstream. The flexibility of stored water will be of considerable importance in connection with the tubewell program, since it can be taken to those areas in which the need, under the hydrological conditions of the year in question, is greatest. For instance, the areas where the groundwater requires continuous mixing or is too saline to be used for agricultural purposes will require a steady supply of fresh surface water, and the contribution from Tarbela will be especially important to them. But areas of fresh groundwater that absorb some additional surface water in rabi (so that the need for canal remodeling is postponed) may be able to pump more water in poor hydrological years to ensure a continued supply to the areas with groundwater of lesser quality. The possibility of ready transfer of surface water among different areas is particularly important under such conditions.

4.27 Despite the clearly indicated demand for additional stored water there is one important factor which, under present circumstances, limits the areas in which it could wisely be used. As with canal remodeling for increasing kharif supplies, simple addition of stored water to rabi supplies of surface water, unaccompanied by other measures, could exacerbate the problem of waterlogging and high groundwater table -- and the related problem of salinization of the top soil. To specify quantitatively the extent of this hazard or the area which has the canal capacity to receive additional surface supplies and a sufficiently low groundwater table to make it safe to deliver such supplies is extremely difficult. The waterlogging problem is very much a localized one affecting small parts of one canal command and large parts of another, and there are no clear criteria which can be universally applied to distinguish between areas which could and those which could not receive additional surface water without the groundwater table being brought too close to the surface. The following table gives a broad impression of the extent of canal-irrigated areas having groundwater table at different depths under present conditions.

Table 14

Depth to Groundwater in Canal Commanded Areas
(Million acres)

	Usable Groundwater (0-3,000 ppm)		Saline Groundwater (above 3,000 ppm)	
	Less than 10 feet	More than 10 feet	Less than 10 feet	More than 10 feet
Punjab	6.1	8.6	1.2	2.6
Sind	1.1	1.2	3.9	2.9
Total (excl. Peshawar)	7.2	9.8	5.1	5.5

The table suggests that there are about 15 million acres with groundwater table at more than 10 feet from the surface, but this does not mean that there is anything like this extent of area which can safely receive additional surface supplies on a sustained basis without measures to improve drainage: some of these areas are already receiving rabi canal supplies up to canal capacity, 10 feet is already on the high side from the agricultural viewpoint considering the effect that summer floods may have, and the water table, though apparently stabilizing in the areas with highest existing level, is still rising in areas where the present levels are deeper.

4.28 The most that it seems possible to say on a general plane is that in almost all areas improved subsurface or surface drainage is needed before substantial additional quantities of surface water can safely be applied. The necessary drainage can be performed by tubewells, surface drainage channels or underground tile drains. There is very little experience in Pakistan with building either of the latter two types of drains. Tubewells, in all areas of usable groundwater, have the great advantage that they can provide additional irrigation water at the same time as fulfilling the drainage function, and they can be run in a fashion which integrates their irrigation supplies with surface water supplies, as will be elaborated below. In areas underlain by saline groundwater, conditions vary considerably and each drainage technique may be appropriate in different places. Tubewell drainage of saline water has the advantage that it can be easily controlled -- and this could become important, as irrigation diversions increase and river flows become confined to a few months in the year, in those areas where the river constitutes the only outlet into which drainage water can be discharged. In extensive areas of saline groundwater in Sind the aquifer is unsuitable for tubewell pumping, and there horizontal drains may be the best solution. These are estimated to cost about the same as tubewells per acre drained. In areas where the groundwater is saline, and where a crop such as rice that benefits from a fairly high groundwater table is grown, open surface drains may be most appropriate. These would be consistent with maintenance of the high groundwater table and they would leave the more saline deeper groundwater underground.

4.29 Extensive drainage work is thus an essential accompaniment of surface storage, as it is of canal enlargement. It will enable additional areas to benefit from the increased rabi supplies, but to the extent that it is performed by tubewells in certain usable groundwater areas it will also increase the proportions of the stored water that can be beneficially used. Between Tarbela and the farmers' watercourses a very large proportion of the stored water released -- about 40-45 percent -- will be lost to seepage from the river and, more especially, from the canals, and to evaporation. These losses were taken into account in calculating the figure of PRs 93 given for the cost of an acre-foot of stored water at the watercourse head; that figure corresponded to a cost of PRs 53 per acre-foot of water released from Tarbela Reservoir. However, seepage from the river and the canals constitutes additional recharge to the aquifer and to the extent that it occurs in usable groundwater areas covered by tubewell fields it can be recovered at relatively low cost and applied to the crops.

4.30 There is also another benefit of storage development which is extremely hard to quantify but can be of considerable importance. Storage capacity has been discussed so far as a means of converting excess floods in the kharif season into useful irrigation supplies in rabi. But it was pointed out that irrigated agriculture depends not only on adequate total supplies over the course of a season but adequate supplies in each month -- and particularly in some months. Even within a season, and especially in the rabi season, the presence of storage capacity on the system can help to bring natural river flows more into line with the time pattern of crop-water requirements. This potential benefit depends on the careful integration of reservoir releases in each period from both natural inflow and from storage with downstream crop-water requirements and on the adequacy of knowledge regarding natural river flows to be expected in the latter part of the season. For the rabi season it is known as the intra-rabi regulation benefit.

4.31 Provision of additional water from storage in the form of useful recharge or of more timely water during the rabi season would help to lower the true unit cost of stored surface water, but the most crucial element of exaggeration in the PRs 93 cost figure is the omission of power benefits. It was shown in Chapter II that the demand for electricity in West Pakistan has been growing very rapidly, and that a large portion of the increase in demand in recent years was due to the tubewell installations. The growing requirements of electric power have been met partly from various small new hydroelectric stations, more from gas-fired thermal stations. Since natural gas was first discovered in West Pakistan in sizable quantity in the early 1950's most of the major generating sets in the Province have been converted to use it and all the new large thermal stations rely primarily on gas. Of the 3.7 billion kwh generated in West Pakistan in 1965 some 50 percent was produced from natural gas, 40 percent from Warsak and the other small hydroelectric stations and the remainder from petroleum fuels, most of them imported, and to a very minor extent from indigenous coal. The growth of demand for electricity may slacken somewhat from the 20 percent per annum rate experienced in recent years, as growth of the tubewell load begins to stabilize and once the backlog of past growth in demand is caught up, but the rate of growth in energy consumption will probably remain in the order of 14 percent per annum up to about 1970, and it is unlikely to fall below 10 percent per annum within the foreseeable future.

4.32 Meeting these loads will involve very heavy investments in generation and transmission equipment and if Pakistan is to meet them from her own indigenous energy reserves there appear to be only two possible sources of importance -- natural gas and hydroelectric potential. West Pakistan is known to have some coal reserves but they are generally of rather low quality -- more lignite than coal -- and rather inaccessible; there is one coal field, in the south of the Province, which might become useful for large-scale production of electricity but it could never meet more than a small portion of the total requirement. The natural gas reserves of the Province are considerably larger than the coal reserves and much easier to develop. However, as was pointed out, soils in West Pakistan are seriously deficient in nitrogen, which can be produced most easily in usable form from natural gas. In 1965 about 50 percent of the natural gas consumed in the Province was used for power generation and about 5 percent for nitrogenous fertilizer production; most of the current fertilizer supplies have to be imported. However a large new nitrogenous fertilizer plant is due to come into production in 1968 and several other plants are at more or less advanced stages of planning. Production of fertilizer from gas should grow to very significant proportions in coming years. Use of gas for power generation thus competes directly with conservation of the gas for production of fertilizer and other purposes for which gas is more suitable than alternative fuels available. The hydroelectric resource of West Pakistan is large -- larger than any other known energy resource -- but it is expensive to develop with present technology. It is primarily concentrated in the 300-mile long main Indus Gorge. Full hydroelectric development of the Gorge and of other minor sites on the Indus tributaries might ultimately be some 35 million kw, capable of producing annually an amount of energy equivalent to about one-fifth of the total known gas reserves in the Province. This would probably be a far greater amount of energy than West Pakistan could absorb annually even 50 years from now, but early development of a portion could make a very sizable contribution to meeting growth of the power load. Perhaps some 15 percent of the ultimate hydroelectric potential mentioned will be developed before the end of the century; Tarbela, with 12 generating units installed, would represent about six percent of that ultimate potential.

4.33 The hydroelectric facet of surface storage can thus make a major contribution to meeting the power load imposed by the tubewells, at the same time conserving much of the natural gas reserves for manufacturing fertilizer to make up the nitrogen deficiency of the soil and to permit the reduction of fallow with its unfortunate tendency to promote salt-efflorescence. Estimates given in Chapter VII suggest that Tarbela's power benefits may be about one-quarter of total benefits; and estimates in Chapter VIII suggest that these power benefits may be even higher if adequate allowance is made for the saving in natural gas that the hydroelectric plant would make possible. Attribution of three-quarters of the cost of Tarbela Dam to its irrigation function would mean that the average cost of stored water delivered to the watercourse would be about PRs 70 per acre-foot rather than PRs 93. Some adjustment can also be made for the addition to useful recharge made by conveyance losses on water released from storage at Tarbela. Adjustments to the above figure, allowing for the time pattern of such recharge (small initially because only a few of the areas affected may have tubewell fields and tailing off in the last years of the century as Tarbela's live storage declines) and for the costs of pumping such recharge, suggest that this would reduce the average cost of stored water from Tarbela delivered at watercourse head either directly by canals or indirectly by pumping from the aquifer to about PRs 61 per acre-foot.

Private Tubewells

4.34 So far private tubewell development has been largely confined to the Punjab and to areas underlain by fresh groundwater there. Out of the total number of private tubewells in existence in 1965 about 30,000 were believed to be in the canal-irrigated areas. Since tubewells in those areas are providing water supplementary to canal supplies they are believed to serve relatively large acreages -- on average about 100 acres each. This would mean that the private tubewells were providing supplementary irrigation supplies to about three million acres.

4.35 Private tubewells have in fact been much the most rapidly expanding source of increased irrigation supplies in recent years. Their contribution is estimated to have increased from about one MAF in 1960 to more than 5 MAF in 1965. The wells are cheap in terms of capital cost -- about PRs 7000-9000 ($1500-1900) each. Operating costs are quite high, and the wells are not very efficient, often being poorly designed for the aquifer conditions in which they are set, so that the effective economic cost per acre-foot works out about the same as an acre-foot pumped by a more expensive and more efficient public well. Private wells, however, have the great advantage that they lay no burden on public finances -- except for electrification, in the case of electrified wells -- and, in the case of the diesel wells, the foreign exchange burden of the fuel. However, the diesel wells do make a substantial contribution to Government tax revenues.

4.36 It was pointed out in Chapter II that little success has been had in trying to explain why private tubewells have grown very rapidly in some areas, such as Bari and Rechna Doabs, and relatively little in other areas that would appear to have equally suitable aquifer conditions. As a result it is very difficult to make any well-founded prediction as to the likely future growth of private tubewells. There are about 14 million acres within the canal-irrigated area underlain by fresh groundwater, 12 million of them in the Punjab. All these areas are believed to have aquifers with good permeability characteristics. If three million acres have already been covered by private tubewells and another three million acres of fresh groundwater area have already been, or will soon be, covered by the public SCARP tubewells there clearly still remain large fresh groundwater areas open to private development. In projecting future development one might suppose that private tubewells would continue to grow most rapidly in those areas where they are already widespread and well-known; equally it could be argued that these are the very areas where the farmers who have the interest and the money have already installed wells, so that development will tend to slow down there and pick up elsewhere. It does appear that in some areas most of the larger and wealthier farmers have already installed wells; however the growth of wells is still being sustained in those areas by smaller farmers, sometimes clubbing together and building a well for joint use.

4.37 From the point of view of the total irrigation system, the role of the private tubewells appears to be as a rapid, but rather uneven and unpredictable, means of overcoming the constraints set by limited canal capacities and limited river flows. They are used intensively in certain months when crop-water needs are high relative to canal supply. And it is probable that they are also used more intensively in years when river flows and canal deliveries are low. It is noticeable how carefully the farmers use the water from private tubewells. In this sense the tubewells are automatically integrated with the rest of the irrigation system. There is also evidence that in some areas wells are now located sufficiently close together that they may have started to lower the water table and thus carry out some of the drainage needed before additional surface supplies can be brought in. However, the capabilities of the private tubewells in these directions under present circumstances are clearly limited. Being located haphazardly and operated according to the needs of the individual farmers, they are unlikely to be able to provide uniform water table control over any large area. Since some farmers will continue without private tubewells and since canal water is provided at a price so much below the cost of water pumped by private tubewells, it will be hard if not impossible to cut off surface water supplies to an area where the aquifer has been privately developed even though other areas may have much greater need for the surface water temporarily. It is also doubtful whether private wells will be established in areas that require extensive reclamation. Private tubewells are also not very suitable for areas where close control is needed to ensure that groundwater is mixed with fresh surface water in the right proportions before application to the crops. These technical problems are important in quite large areas; nevertheless there are also very large areas where they are more or less absent and where private groundwater development could probably continue to make a large and early contribution to increased irrigation water supply.

Public Tubewells

4.38 Although it has been discussed for more than a decade, public tubewell development is still largely confined to a relatively small area -- about 1.5 million acres -- in the northern Punjab. A number of other SCARP projects -- in Rechna, Chaj and Thal Doabs in the Punjab and at Khairpur in northern Sind are under way. Though some of the wells were in fact sunk in the late 1940's and early 1950's the SCARP I project in Rechna Doab has been in operation as a unit only since 1961. The water table in the area has been lowered and a certain amount of land reclamation has been carried out.

4.39 The potential strengths of public tubewell development are its capability to provide large increases in irrigation supplies, its flexibility for handling technically difficult groundwater and aquifer conditions and the feasibility of fuller integration of public wells than of private wells in the overall operation of the irrigation system. Irrigation supplies could be substantially increased by public tubewell development in virtually all areas that have groundwater of usable quality. Applying their judgment to the information they were able to gather, IACA chose certain criteria regarding the quality of groundwater at a depth of 300 feet for distinguishing between areas with usable and unusable groundwater. Fresh groundwater was defined as water with less than 1,000 parts per million (ppm) Total Dissolved Solids (TDS) and IACA took the view that this could be applied directly to the crops provided it was made available in adequate quantity. Zones with groundwater of between 1,000 and 3,000 ppm TDS were defined as Mixing Zones, in which the groundwater would have to be mixed with fresh surface water before application to the land. Groundwater over 3,000 ppm TDS was considered unusable. These categories applied to the Punjab; somewhat stricter limits were selected for the Sind, partly because groundwater there is little known and may have a higher admixture of other noxious chemicals such as sodium at any given level of TDS and partly because surface water tends to gather some salt on its passage through the Punjab and thus to be somewhat more saline in the Sind than in the North, where it is generally in the order of 250 ppm. Mixing zones in the Sind were defined as those with groundwater between 1,000 ppm and 2,000 ppm TDS, and groundwater of more than 2,000 ppm TDS was categorized as unusable. Table 15 shows the extent of these areas by regions.

Table 15

Regional Groundwater Quality Zone Areas
(Million acres of development CCA)

Region	Fresh	Mixing	Saline	Total
Vale of Peshawar	0.58	0.10	-	0.68
Thal Doab and Indus Right Bank	2.03	0.99	0.60	3.62
Chaj Doab	1.19	0.36	0.49	2.04
Rechna Doab	3.37	0.84	0.49	4.70
Bari Doab	3.95	1.34	0.54	5.83
Sutlej and Panjnad Left Bank	1.29	0.47	1.75	3.51
Lower Indus	1.81	0.45	6.72	8.98
Total	14.22	4.55	10.59	29.36

The table shows that some 19 million acres are underlain by groundwater of usable quality, nearly 17 million of them in the Punjab and Peshawar.

4.40 Since the groundwater aquifer is very deep in most areas -- estimated at over 1,000 feet -- it would be possible to sink deep wells and to "mine" the groundwater reservoir so that the water table would gradually fall. The Revelle Panel recommended groundwater mining for a 30-year period, over which the groundwater table would be lowered to about 100 feet below the surface. The alternative would be to pump out only "balanced recharge" or the amount of groundwater that annually seeps into the aquifer from rivers, canals, watercourses and fields. IACA studied these alternatives and found that pumping to balanced recharge at a groundwater table of about 15 feet would cost about PRs 16 per acre foot -- the same as private tubewell pumping; the higher initial capital cost of the large public well would be offset by higher utilization, better hydraulic efficiency, longer life and lower costs for electricity distribution lines. Groundwater mining would require the installation of deeper wells and also considerably more electric power for raising the water from a greater depth. On a comparable basis the cost of an acre-foot mined, with the groundwater table finally stabilized at 100 feet, would average PRs 64. Mining to lesser depths would cost less, because of the smaller quantities of electricity involved. However, besides being relatively expensive, mining of groundwater in West Pakistan would raise some technical problems -- in particular the danger of migration of saline water into the freshwater aquifer, once its level was substantially lower than that of neighboring saline aquifers.

4.41 Without prolonged mining, however, the groundwater reservoir could be used, under public development, as a flexible "buffer" in integration with surface water supplies, particularly in areas underlain by fresh groundwater. The public tubewell project would be designed in grid fashion in such a way as to give complete coverage of an area and to bring the groundwater reservoir under full control. Initially, because of the need in most areas for drainage and lowering of the groundwater table, the aquifer would be "mined" but only down to a depth of about 15 feet. Thereafter, pumping would be concentrated in those months and seasons when canal capacity or river flows were inadequate to meet irrigation requirements. This would make it possible to maximize the water supply assured to the farmers without necessitating any canal remodeling, as pointed out at the beginning of the chapter, and in most fresh groundwater areas to produce sufficient water to meet full crop-water requirements at cropping intensities of 150 percent, which was generally regarded as a reasonable planning target from an agricultural viewpoint. Many of the areas where this would be feasible would be non-perennial. But in some perennial areas, such as part of the perennial portion of Upper Chenab Canal Command, SCARP IV, it would be feasible and then it might be possible to release existing rabi canal supplies, replacing them with water pumped from the groundwater aquifer which would be fully replenished from seepage from the rivers and from kharif surface water supplies. In the case of SCARP IV it would be possible to release about 0.75 MAF of current rabi canal supplies. But beyond this integration between surface and groundwater over the course of a year, there would also be possibility of stretching the balanced recharge concept and pumping more than recharge in a low-flow year to ensure continued availability of full irrigation water supplies, making up the overdraft on the aquifer by pumping less than recharge in high-flow years. Thus the groundwater reservoir could be used as the buffer against hydrological uncertainty, eliminating the need for provision of expensive reserve capacity at the surface storage reservoirs.

4.42 Mixing zones would not be so flexible in this manner and their development to a high cropping intensity would be somewhat more complicated, but since they generally represent portions of canal commands that are predominantly underlain by fresh groundwater they would be gradually brought under development along with the fresh groundwater areas. This has been the case with SCARP I. IACA's research led it to establish the following criteria for mixing groundwater with surface water: groundwater of between 1,000 and 2,000 ppm TDS would be mixed in a 1:1 ratio with fresh surface water, while two-and-a-half parts of surface water would be added to every one part of groundwater of 2,000-3,000 ppm TDS before application to the crops. It would be important to apply such mixed water to the crops in adequate quantities to ensure that salts would not collect at the surface. IACA also estimated that about five percent of the mixed water might have a hazardous alkali content, which if it were allowed to remain in the topsoil would cause soil conditions to deteriorate, reduce soil permeability and adversely affect plant growth. Although further research is required on the alkalinity problem the application of sufficient water should contribute to reducing its severity. The mixing of surface and groundwater would need to be continuous, and hence supplies of surface water would be needed at all times before the groundwater could be used -- and they would generally be needed in larger amounts than current canals in the areas would be able to carry. It will be recalled that these zones of saline water were generally designated perennial at original development and hence given smaller canal capacity per unit of area than the non-perennial areas. Requiring larger canal capacities, they would also require larger supplies of canal water than they have had in the past. Hence their development would be particularly closely dependent on the availability of additional rabi supplies from surface storage.

4.43 Zones underlain by groundwater above 3,000 ppm TDS would be entirely dependent for additional irrigation supplies on surface water since their groundwater is not considered usable for irrigation at all. Table 15 shows that these areas are not very large in the Punjab, except on the left bank of the Sutlej and Panjnad, but they are extremely important in the Sind. They would require tubewells or surface drainage channels to provide drainage before they could absorb significant additional quantities of surface water. Drainage from the Sutlej/Panjnad Left Bank might be into the neighboring Thar Desert, but in the Sind it would require very large channels running through the canal commands on each side of the Indus discharging into the lower reaches of the Indus or the sea. To provide additional quantities of surface water canal remodeling would be required in virtually all these areas. It is also in these saline groundwater areas that canal lining might prove justified. At present almost none of the canals in West Pakistan are lined. Normally canal lining gives a high capacity for a given size of canal, by allowing increased velocity, but in West Pakistan this advantage is generally slight because of the extreme flatness of the land. The main benefit of canal lining would occur in the form of reduced seepage; but the cost of water saved in this way, according to calculations by IACA on a comparable basis with those cited in Table 9, would be PRs 110 per acre-foot. Only in the saline zones would the cost be less -- about PRs 65 per acre-foot, because there canal lining would reduce not only seepage losses but also the related drainage pumping. Lining could in fact only be carried out after the groundwater table had been lowered, because otherwise the lining would not stick, and in general it would be difficult to carry out except on new canals because otherwise it would involve complications due to interruption of canal supplies. Thus lining of canals would be complicated and relatively expensive but it might make a small contribution to additional supplies to the saline groundwater areas in later years. The main additional supplies of water to the saline zones will be from the river flows in kharif and from Tarbela and any water released by public tubewell development in fresh groundwater areas in rabi.

4.44 From a purely technical standpoint it is thus clear that substantial increases can be made in irrigation water supply in the fresh groundwater zones by means of public tubewells without running into bottlenecks due to lack of development in other facets of water development, whereas increase of water supply in the mixing zones and saline zones is a much more complex matter, depending on interdependent enlargement of canal capacity and increased supply of surface water in the rabi season, as well as provision of drainage. Simply with the installation of tubewells and the provision of electric power in sufficiently large quantities, the irrigation supplies in the fresh groundwater areas can be greatly expanded.

4.45 The difficulty is that the executive and administrative capacity for the still complex task of designing tubewell projects, carrying them through from initial land acquisition to final electrification, and operating them efficiently is limited; and so too are the funds for these purposes. These problems of implementation capacity are discussed in greater detail in Chapter IX. Their consequence is that it is necessary to ration out the public effort very carefully, allocating it to areas where public development shows the greatest advantage over what could occur simply with continued private tubewell development -- rather than to those areas which might show the greatest benefit to public development per se. This will make it possible to bring additional water supplies to much wider areas than would be possible if all development depended on the public effort alone. It also means that the public development effort may be placed in areas involving greater difficulties and complexities than would be the case if it had to be confined to areas where development meant simply putting in tubewells to pump fresh groundwater. Moreover, these selections of areas with priority for public and for private groundwater development have to be made with a view to the projects in other fields of water development, such as surface storage and drainage, that will ensue and with a view to the ultimate need for integrated operation of West Pakistan's water resources.

CHAPTER V

PROJECT IDENTIFICATION AND SELECTION

5.01 The preceding chapters have described past development in the use of water resources for irrigation and generation of electric power in West Pakistan and they have outlined the chief alternative means of future development to meet the needs of the Pakistan economy. This chapter discusses the analyses that were undertaken in the course of the Study with a view to selecting among these alternatives those that would be appropriate for inclusion in the proposed programs for irrigation, agriculture and power.

5.02 The methodology of the Study, as formulated by the Bank Group and agreed with the Government of Pakistan, stressed the comprehensive nature of the task. Analysis was to start on a basinwide scale, within the framework of development planning in West Pakistan. The review of resources for power development would cover all aspects from water power to the energy of gas, oil and coal, as well as the potentials of nuclear power. A general comprehensive review would be made of the main factors governing agriculture, particularly irrigated crop production, including land, population, ground and surface waters and crop yields. Specific attention would be paid to identifying the development potential of the various regions of the Indus Basin and the steps needed to realize that potential. Specific project proposals for water and power development fully integrated into a comprehensive program were to be the end product of the Study.

5.03 Originally it was envisaged that selection of projects for irrigation development would be mainly a matter of reviewing the priority status and technical aspects of projects already formulated by the Pakistan authorities. In the course of the Study it became apparent that -- apart from Tarbela and the Sukh Beas Drainage Scheme -- there were virtually no projects prepared and formulated for which financial commitments had not already been obtained or were being negotiated and which were thus "ongoing" projects and, as such, outside the purview of the Study. As a result the scope of IACA's assignment had to be broadened to include in addition to review of existing project proposals the identification and tentative formulation of new projects. It was decided early in the Study that IACA would have to assign about three-quarters of their strength to project work in order to make up for the lack of existing project proposals.

5.04 Because the consultants were instructed to concentrate their initial efforts on subjects and areas which were important for planning purposes but which were not being investigated intensively by others, the direction of their effort was influenced by work already underway. For example, the scope and magnitude of the work being done by the LIP consultants on the development of irrigation and agriculture in the Sind suggested that it would not be a fruitful use of manpower of the Bank Group consultants to undertake intensive field activities in this area. Thus the proposals for irrigation development in the Sind in this report are largely based on a critical review by IACA and by the Bank Group of the program prepared by LIP.

5.05 It was clear that an important step in the preparation of a basin-wide program for irrigation development would be correct assessment of distinctions among areas and regions regarding the present state of agriculture and the potential for future growth of productivity. Therefore several major efforts were undertaken to gather data about different regions, additional to information already available from Government sources or from other consultants. The main gap in existing knowledge concerned the current state of agriculture. LIP had begun to remedy this in the Sind with an intensive study of selected watercourses. For detailed study in the Punjab IACA chose 20 watercourses, each of about 300 acres, on the basis of ground reconnaissance and aerial photographs of sample areas which had been made by the Government of Pakistan's mapping organization at the request of the Bank Group. Field observers were established on each selected watercourse to record on a daily basis all agricultural activities over one full kharif season and two partial rabi seasons. The aerial photographs were also useful for comparison with those made a decade before, in 1953/54, under a Colombo Plan Survey in order to indicate changes in land use, with special reference to land which had gone out of cultivation, land which had been reclaimed, new land which had been developed, and changes in cropping intensity.

5.06 As a further means of increasing their knowledge about farmers and agriculture in general, the consultants organized questionnaire surveys in three selected zones. A special study, using a similar survey technique, was also made with a view to identifying the changes which had resulted from the first of WAPDA's Salinity Control and Reclamation Projects (SCARP I). Besides these agricultural studies IACA also undertook detailed soil surveys as part of the watercourse studies, primarily to give information on the relationships between yields and soil. Permeability and infiltration rates were also covered. In addition, two somewhat less detailed soil surveys were carried out for a 240,000-acre area in the northern parts of Rechna and Chaj Doabs. Some direct experimentation was undertaken on the reclamation of saline and alkaline soils in these areas.

5.07 While the irrigation and agriculture studies required sizable data collection efforts, including the abovementioned surveys, to close important gaps in knowledge, the studies of dam sites and power required much less new field investigation. Major field work was in fact excluded under the terms of reference, as formulated by the Bank Group, to expedite execution of the Study. However some aerial photography was undertaken of areas on the Indus, including sites at Chasma and Kalabagh (for backwater studies), the confluences of the Soan and the Haro with the Indus (for studies of side valley storage), and the Skardu area. Considerable attention was given to backwater studies for a dam at Kalabagh and to the approximate location, length and size of conveyance channels that would be required for side valley storage on the Haro (Gariala) or on the Soan (Dhok Pathan). Rough preliminary designs were made for a number of sites, particularly Kalabagh. Independent studies of the engineering design of Tarbela were not made, but the progress of designs and the program for constructing the project were reviewed on a number of occasions with the designer, TAMS.

Identification of Irrigation Projects

5.08 With the requisite basic data in hand the first step towards formulation of a basinwide program for irrigation development was analysis of alternative possible modes of development in different areas. For purposes of analysis the 42 principal canal commands in the Indus Basin in West Pakistan were subdivided according to the partitioning of commands that arises from the Indus Basin Works and following proposals made by the LIP consultants for the Sind. Further subdivision was made for technical reasons related to the design capacities of canals. These considerations resulted in the adoption of 61 units of analysis which became basic to the basinwide planning as well as to project formulation. Each unit of analysis was at various stages of the Study further subdivided and treated separately for four groundwater salinity zones -- fresh groundwater, two mixing zones of intermediate salinity and a saline (unusable groundwater) zone.

5.09 Irrigation water requirements, determined by three factors -- cropping pattern, crop water requirements and cropping intensity -- were projected for each of these 61 areas. Cropping patterns (proportions of each area devoted to each crop in kharif season and rabi season) were projected on the basis of a number of factors, such as present cropping patterns, the quality of climate and soils in each area, anticipated increases in crop yields, estimated future national requirements of food and fiber, the farmer's preference for growing certain crops when more water becomes available and the possibilities of concentrating production of certain crops in areas with an absolute advantage in their production. Observed trends in areas benefiting from groundwater development suggest that increases in water supplies would tend first to be used mainly on cash crops. A general increase in fodder acreage is expected in order to feed the livestock required to meet growing demand for milk and meat. With regard to wheat acreage a substantial increase is projected by 1975, after which date the growth of yields due to widespread acceptance of Mexican wheat varieties and fertilizer would probably be sufficient to permit a gradual reduction in wheat acreage with a corresponding increase in land planted to cotton. The result of these various trends would be, in basinwide terms, a slight reduction in the kharif-rabi ratio between 1965 and 1975 followed by a gradual increase through the year 2000, as shown in Table 43 of Chapter VII below.

5.10 Monthly crop water requirements were estimated for each crop in the cropping pattern in each canal command. IACA assessed water requirements in terms of the full amount that they believed to be needed, under conditions obtaining in the different areas, to support modern agricultural techniques, including the use of technical inputs like fertilizer. This is the concept of 'full delta' and it represents rather more water for each acre of crop than the farmers are currently receiving, as pointed out in Chapter III. 'Full delta' is defined as the summation of (a) the net consumptive use of water by crops after making allowance for effective rainfall, (b) an allowance for pre-planting, (c) an allowance for soil moisture retention, and (d) an allowance for seepage loss which also provides for leaching of salts. In computing the full delta water requirements at watercourse head the consultants have totaled items (a), (b) and (c) above, and adjusted this sum upward by assuming that item (d) involves a loss of 37 percent, including conveyance losses in the watercourses.

5.11 For most areas the maximum cropping intensity that would be attainable, if all the water that was needed could be delivered, was assumed to be 150 percent. Theoretically it would be possible to reach a cropping intensity of 200 percent, or full use of all the CCA in an area in both rabi and kharif seasons. For a variety of reasons this theoretical ceiling does not appear to be a feasible target for development. The physical difficulty of growing certain crops -- such as cotton and wheat -- in succession is one reason. But overlap in growing seasons is not the only obstacle. Shortages of animal power or labor may make it impossible for some farmers to complete the harvesting and marketing of one crop in time to prepare the land for a succeeding one. Some portion of the CCA, moreover, should be considered reserved for livestock and not available for cropping. On some farms or some watercourses an intensity over 150 percent might be reached, but IACA concluded that the average intensity over areas as large as canal commands would not rise above this level. The only exception to this was in the Peshawar Vale canal commands where the special combination of crops grown, in particular the importance of perennial crops, might permit an ultimate cropping intensity of about 175 percent. In a portion of the Ghulam Mohammed Barrage Command in the Sind not suitable for perennial cropping it was assumed that the maximum attainable intensity would be 130 percent.

5.12 The time required to reach these target intensity levels will vary among different canal commands depending partly on the availability of water but also on a number of other factors. Among these other factors IACA attributed importance to the starting intensity in each area and the extent of soil salinity. The starting intensity gave an indication of the change in agricultural practices which would have to take place, whereas the prevalence of soil salinity indicated the extent to which soil reclamation was needed. The following table gives the results of the consultants' studies in the form of the average time they believe would be required to reach the target level from different starting levels and under various salinity conditions, once water supplies were increased.

Table 16

IACA's Average Projection of Growth in Cropping Intensities in Terms of Time Required to Reach 150 Percent

Starting Intensity (Percent)	Salinity Category a/ I	II	III
	---- (years) ----		
135	5	- b/	- b/
120	6	10	- b/
110	7	10	- b/
100	8	11	15
90	9	11	15
80	10	12	16
70	11	13	16
60	12	14	17

a/ Salinity categories are defined as follows:
I: 15 percent of CCA requires reclamation.
II: 30 percent of CCA requires reclamation.
III: 45 percent of CCA requires reclamation.
b/ No cropping intensity this high in the salinity category.

5.13 Canal command irrigation water requirements, as determined by crop water requirements, cropping patterns and cropping intensities feasible from the agricultural point of view, were employed in a computer simulation of canal command operation which served to show the extent to which the irrigation supplies required at the maximum attainable intensity could be provided by the various techniques of water development outlined in Chapter IV. The most important role of the simulation model was in the analysis of the potential for integrated use of groundwater and surface water because this required that certain feedback effects, such as that arising from the need to pump annual recharge, be taken into account. The information provided by this analysis was essential to the formulation and design of the public tubewell projects proposed. Formally, the simulation model worked in such a way as to maximize the intensity level in each of the 61 canal commands in the reference years 1975, 1985 and 2000 subject to the following constraints:

(1) The cropping intensity in the particular reference year is not to exceed that which is judged to represent the agriculturally feasible maximum discussed above.

(2) The required surface water deliveries cannot exceed the delivery capacity of the existing canal system.

(3) Groundwater use is not to exceed the annual recharge to the area's aquifer.

(4) Groundwater use up to the extent of the usable part of annual recharge will always precede additional surface water use.

(5) For groundwater between 1,000 and 3,000 ppm TDS, mixing ratios with surface water have to be observed.

(6) In the fresh groundwater zones, the greater part of the pumping would be in rabi, to economize in the use of scarce surface water at that time and to overcome canal delivery constraints during seasonal overlaps in irrigation requirements.

It should be noticed that the fourth constraint listed is based on the premise, discussed in Chapter IV, that in each canal command the least costly source of increased irrigation supplies, namely groundwater, will be fully developed before the next source of increased supplies -- canal remodeling and/or supplies from storage -- is brought into play.

5.14 Beyond this basic analysis of potential public groundwater development, a number of additional variants were tested. The simulation model was used to show the maximum full delta cropping intensity that would be attainable if the only irrigation supplies available were historic surface water deliveries (i.e. generally the average of those over the period 1952-63), or if such deliveries were supplemented by supplies from private tubewells. An analysis was also made for the assumption that surface water deliveries and their monthly pattern would be limited not to their historic levels but simply by existing canal capacities. Another analysis was made simulating operation with integrated use of surface water and groundwater under the assumption that canal capacity would be increased to the extent needed to enable the 150 percent cropping intensity to be reached without mining the groundwater aquifer.

5.15 The case involving private tubewell development, as an alternative to integrated operation with public wells, was critical to the choice of areas for inclusion in the proposed public program because of the need, discussed at the end of Chapter IV, to allocate public tubewells to areas where they would show the greatest advantage over likely private development rather than the greatest absolute rate of return. The quantification of this likely private development was therefore very important. At the same time large-scale development of private tubewells is of such recent origin that it was difficult for IACA to find a reliable basis for projection of future growth. They considered the data available regarding the number of private tubewells estimated to exist in different areas in 1963, 1964 and 1965; these years were considered most relevant because it was apparently only after 1962 that diesel wells became widely accepted. IACA developed a general trend of future private tubewell development on the basis of the relationship between achieved levels of private tubewell development and the change in their density as observed in these years. From this general trend a projection for each area was derived, related to the prevalence of large farms and of owner-occupied farms. These two factors were intended to serve as proxies for more general determinants such as farmers' enterprise and financial resources. IACA expected private tubewell development to be most rapid in Bari and Rechna Doabs and slowest in the relatively backward areas of the Lower Indus and in Thal and Indus Right Bank. In all areas, however, the general pattern would be a slow initial development stimulated by the most enterprising farmers and supported by the Department of Agriculture, and then a more rapid development as farmers appreciate the profitability of private tubewells, leading to a declining rate of installation as the constraints of farm size, land tenure and finance become more operative. The table below shows some samples of their projections of private tubewell growth in the absence of public development.

Table 17

Selected Projections of Private Tubewell Growth
(Numbers of wells)

	1965	1970	1975	1985
Dipalpur above BS Link (Bari)	860	1840	2470	3115
Rohri North (Sind)	100	300	800	1600
Panjnad-Abbasia (Sutlej Left Bank)	615	1990	3230	4570

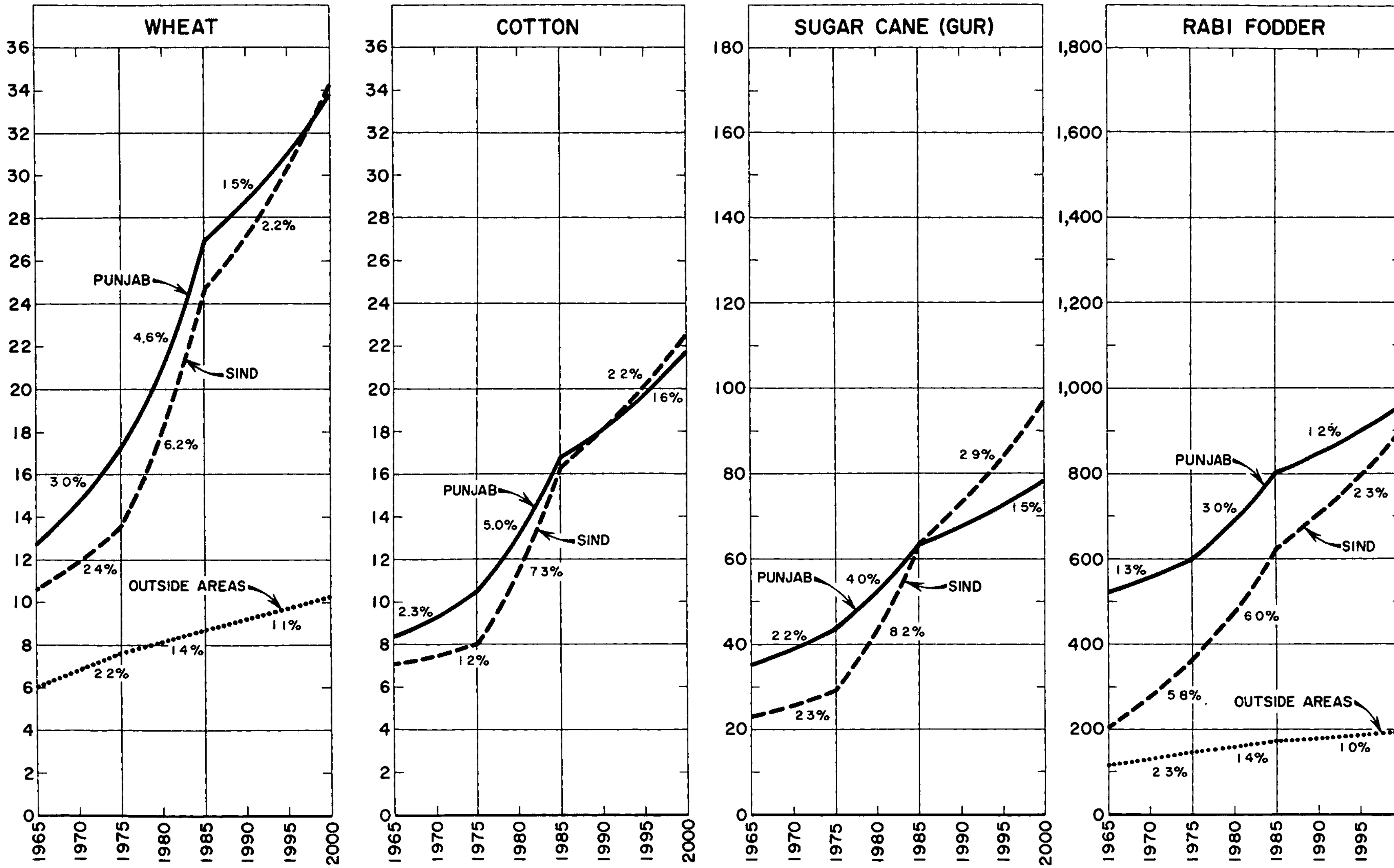
Ideally the uncertainty which attaches to the projections of private tubewell growth should have found expression in the use of a range of private tubewell projections rather than one single projection per area; the complexities of the Study precluded this approach within the context of the basinwide determination of project priorities. However in the individual project reports by IACA and in the Bank Group's reviews attention was given to the sensitivity of the project's priority to alternative projections of private tubewell growth.

5.16 The most important output of the canal command simulation is a water budget reflecting a particular mode of irrigation development and indicating the maximum cropping intensity attainable with this type of development. It corresponds in effect to a hypothetical water development 'project'. The water budget would show, for instance, depending on the type of development to which it related, the amount of public tubewell capacity required per acre of CCA, the quantity of scarce rabi surface water required, the extent to which canal capacity had to be increased to permit attainment of 150 percent cropping intensity, and the amount of horizontal drainage capacity needed in the more saline zones to preserve a stable water table with increased surface water deliveries. To each of these items there corresponded a certain cost, so that the total cost of the hypothetical 'project' could be estimated. To each water budget there also corresponded a certain full delta cropping intensity, as pointed out, and this constituted one dimension of the benefits of the 'project'.

5.17 To derive a full picture of the benefits of agricultural development it was necessary to examine the likely growth of crop yields. IACA considered that key factors accounting for current low yields are unreliable and inadequate water supplies, waterlogging and salinity, limited use of fertilizers and pesticides, and the poor quality of seed. It was their belief that increased irrigation supplies would not only have a direct effect on yields but would also act as a catalyst in the adoption of these non-water inputs. Projections of average crop yields were prepared showing a threefold increase over the period 1965 to 2000. In projecting the transition from the present to the ultimately attainable yields the consultants assumed that the farmers will first concentrate inputs and attention on cash crops and wheat. After reasonable levels have been reached for these crops then the improvements would be extended to other crops, particularly fodder and maize. The basic yield projections derived for each canal command from a regional average with allowance for local differences in climate, soils, standard of farming, etc., applied to areas with full water supplies and adequate drainage; adjustments had to be made where water shortage was expected to continue or where there were serious problems of soil salinity and waterlogging. In areas which were waterlogged and suffered from soil salinity yields were assumed to be some 45-55 percent below normal by 1975 in the absence of water development and reclamation in the interim. For the case of water shortages IACA assumed that over the short term there is advantage to be gained by extending, through underirrigation, the area cropped, as long as traditional crop varieties are cultivated and no fertilizer is applied. To allow for the additional production that would be associated with this practice IACA added 10 percent to the output of minor crops that they estimated would occur if available water were concentrated on the area it could cover at full delta supply. In the case of major crops IACA assumed that in areas where underwatering prevailed provision of additional water would give the same increase in consumption whether it was used to increase water deliveries per cropped acre to full delta or to expand acreage cultivated at less than full delta irrigation supply. Furthermore, it was assumed that if additional water were made available then yields would be increased almost instantaneously by the degree to which underwatering was corrected. For example, if the increase in irrigation supply were sufficient to raise the irrigation level from 80 percent of full delta to full delta, then yields would increase automatically some 25 percent. Figure 3, which shows the yield growth for four major crops in the Punjab, Sind and areas outside the Indus Basin that IACA anticipated would accompany the execution of their total proposed program for development of irrigation and agriculture is indicative of the specific yield increases which they projected. The very sharp rises shown in the figure between 1965 and 1985 reflect in part their assumption that yields would increase markedly as soon as additional water is provided.

5.18 Yield projections derived in this manner were combined as appropriate with the cropping intensities derived from the canal command analyses to show the gross benefit streams of the different hypothetical water projects. An allowance was added for increased production of livestock products which IACA projected would occur with the increased amount of feed that would be available from additional fodder output and increased crop residues and with a gradual improvement in the productivity of the animals. Gross benefits were converted to net benefits by deduction of on-farm costs, including allowance for wages of hired labor. Very little is known about present levels and composition of on-farm costs, but some estimates were prepared for

DERIVED AVERAGE YIELDS FOR REFERENCE YEARS
(MAUNDS PER ACRE)



(R)IBRD-3287

VOLUME I
FIGURE 3

different levels of intensity and yields on the basis of detailed farm budgets built up by the consultants for different regions of the Indus Basin.

5.19 Having generated a number of alternative water budgets and related estimates of benefits which summarize the potential consequences of public and private investment in different areas, IACA went on to aggregate the projects and to test them within the context of the irrigation system as a whole. As pointed out, the canal command analyses were based on the premise that the least costly water source (groundwater) would be used to the maximum possible extent before the next source would be tapped. In this way the requirement for stored water, the more expensive source, was determined as a residual rather than a foregiven quantum. Determination of storage requirements was one of the main purposes of a second computer model which IACA used, designed to simulate the operation of the entire irrigation system of the Indus Basin in West Pakistan. Canal command irrigation water requirements were accumulated up to the rim stations and to Mangla and Tarbela Reservoirs, with allowances for seepage and evaporation losses from the link canals and river reaches as well as for time lags between the release of water from a reservoir and its arrival at a major distribution point. Another important purpose of this simulation model was to indicate link canal capacity requirements. As with the canal command studies, the analysis was carried out for a number of reference years up to the year 2000. It was generally conducted in terms of mean-year river flows. However, studies of aspects such as the monthly pattern of water releases required for irrigation purposes from Mangla and Tarbela Reservoirs were conducted in terms of various combinations of main stem and tributary low flows.

Selection of Irrigation Projects

5.20 Out of these simulation studies there developed increasing sensitivity to the implications of alternative patterns of water use so that more refined choices could be made among the various alternative types of water development considered for each canal command. At the same time IACA also reached the conclusion that there were certain limits, set by implementation capacity (further discussed in Chapter IX below), to what could be expected to be achieved in water development by 1975. IACA defined these limits specifically as a maximum of 20,000 public tubewells completed in the period 1965-75 and a maximum of one million acres in which canal remodeling could be carried out over the same period. Preliminary estimates of the increase in agricultural output attainable with a water investment program up to these limits and with expansion in the use of non-water inputs up to the limits of the absorptive capacity of the agricultural sector also suggested to IACA that growth in agriculture would fall short of the rates projected in Government planning documents. It appeared to them, moreover, that these specific scarcities -- limited absorptive capacity and limited implementation capacity -- would prove more restrictive on development than any global resource constraint such as availability of foreign exchange or of development finance. Development should proceed at the maximum pace possible within these specific constraints; therefore, in the preparation of the development program, it was necessary to focus on the allocation of the scarce factors among areas with different development potentials in such a way as to maximize the return to these factors.

5.21 Selection of public tubewell and canal remodeling projects within these limits of implementation capacity was based on a number of technical and economic criteria. From the technical point of view areas which were underlain by usable groundwater but which also had water table within 10 feet of the surface were considered to be of high priority for public tubewell development. Among these areas the first place in the program should go to those underlain by fresh groundwater which could be applied directly to the crops; second place should go to those where the groundwater required mixing with surface water and where, as pointed out in Chapter IV, there would generally be need for canal remodeling as well as additional surface water deliveries in order to permit attainment of a high cropping intensity at full delta irrigation. The reliance on public tubewells to accomplish subsurface drainage in areas of high water table reflects IACA's considered judgment of the limited dewatering capability of private tubewells. Again from the purely technical point of view the areas which seemed most suitable for deferment of public projects in favor of continued private tubewell development were those underlain by usable, especially fresh, groundwater and with water table more than 10 feet from the surface.

5.22 On the basis of these technical criteria the more promising areas for public tubewell development and canal remodeling were identified. However, the implementation of public tubewell projects in all of the areas so selected would have required a public tubewell program during the Third and Fourth Plan periods beyond the specified limit of 20,000 wells. Therefore, a further analysis was made giving explicit recognition to the limitation upon the size of the public tubewell and canal remodeling program during the period up to 1975. This analysis focused its attention on the timing of public tubewell development in the various groundwater quality zones of the 61 canal commands. To simplify the calculations the alternatives were specified as public tubewell installation in the period up to 1974, in the period 1975-79, or in the period 1980-84, plus the possibility of canal remodeling. Canal remodeling would take place either parallel to public tubewell development or at a deferred date. Finally, rabi surface water was incorporated as an additional limiting input in the years 1972, 1973 and 1974. For other years the surface water used in conjunction with the various 'projects' was assigned an imputed cost which corresponds to the estimated scarcity value of rabi water in the system. This analysis, which in effect compared the various tentative 'projects' for each area which had come out of the canal command simulation, was designed to show how the limited numbers of public tubewells and amounts of canal remodeling considered feasible could be allocated among areas, taking account of the prospects for private tubewell development in each area, in such a way as to maximize the net present worth of output in irrigated agriculture in the Indus Basin. The outcome of this analysis was a list of priority areas for public tubewell development and canal remodeling in the three periods specified.

5.23 Despite the complexity of the various analyses described, they oversimplified reality. Putting alternative 'projects' on a standardized basis for use in formal analysis of priorities over the whole Basin, for instance, meant that many individual peculiarities of a project area had to be ignored -- the quality of the soil, specific drainage problems, variation in farm size and tenure, location of canals, etc. Thus more detailed investigation of priority areas identified had to be carried out. Even the scope of some projects had to be changed because, for practical purposes, they could not be smaller than the smallest controllable surface water distribution unit. This was usually a distributary. In some cases this necessitated the inclusion of areas underlain by groundwater of lower quality or even zones of unusable groundwater; the need for canal remodeling in some of these areas in connection with groundwater development in turn affected the composition of the canal remodeling program. Detailed phasing and integration of all development activities for inclusion in the recommended program also had to be performed outside the formal analyses on the basis of the technical and economic criteria used and by considering, in addition, the state of project preparation as well as technical and operational interdependencies. The latter were of particular importance in the cases where the implementation of one priority became a prerequisite for the execution of another priority activity, e.g. drainage before canal remodeling in areas with saline groundwater and high water table.

5.24 Thus, through a series of approximations the various possible means of irrigation development analyzed with the aid of the simulation models were reduced to a single program consistent with implementation capacities as determined and internally consistent in terms of availability and usage of surface water and groundwater. Project priorities established on the basis of the formal analyses and adjusted as necessary in light of practical problems were integrated into a phased development program. Irrigation and drainage aspects of the program are discussed in Chapter VI below. Surface water storage aspects are discussed in Chapter VII, which shows the projection of storage capacity requirements that came out of the simulation analysis of total irrigation system operation described above.

5.25 The largest component of the proposed program for irrigation and drainage development up to 1975 is 13 public tubewell projects additional to those which are presently underway. These projects differ in a number of ways from those which have been begun in the past as a direct result of the approach to project selection adopted in this Study. First, because the analysis was concerned with maximizing the contribution to agricultural growth from both public and private tubewells, it indicated a need for public tubewell projects covering smaller areas so as to leave maximum scope for private enterprise development wherever it could occur. Second, because the net present worth approach to evaluation of benefits gives priority to areas where returns from investment can be expected sooner rather than later, the proposed projects imply greater emphasis in the early future on development of usable groundwater in areas where it can be applied immediately to increase crop production, and less emphasis on reclamation of saline lands and water-table control in non-usable groundwater zones. Third, the proposed public tubewell projects have been selected and designed with a view to their integration into the overall irrigation/power system. Pumped water has so far been regarded largely as a supplement and not a substitute for canal supplies, with the result that total water supplies are now sometimes more than adequate in tubewell areas while elsewhere crops are suffering shortages. The canal command and irrigation system simulations, as pointed out, were intended to show results obtainable with integrated use of surface and groundwater. Slight additions were also made in the course of project design to the tubewell capacity which was shown by the canal command analyses to be required; the additions were partly to ensure the availability of sufficient pumping capacity in a project area for full irrigation requirements to be met from groundwater and surface water combined in any month in four years out of five of river flow conditions experienced; they were also partly intended to provide sufficient pumping capacity so that the wells could be shut off at the time of evening peak on the power system without reducing the amount of water that could be pumped below requirements.

Sequential Analysis

5.26 Because of the problems and uncertainties created by variations in river flows a detailed reexamination of the proposed program was undertaken on the basis of a variety of different river flow conditions. The basic analyses had all been made in terms of reference years and generally on the assumption of mean-year river flows. However, special hand adjustments had been made to allow for other hydrological conditions, such as the addition to pumping capacity mentioned in the preceding paragraph for coping with temporary surface water shortages. In years of shortage groundwater pumping would be temporarily increased beyond the balanced recharge level, and the consequent overdraft on the aquifer would be replaced by reducing pumping and increasing surface supplies during periods of above-average surface water availability. This form of integration was one of the most important proposals implicit in the recommended program. In order to assess in detail the operational implications of using groundwater to compensate for surface flow variations through temporary pumping in excess of recharge, the then Chairman of WAPDA (Mr. Ghulam Ishaq) suggested that the development program proposed by the Bank's consultants be subjected to a behavior trial utilizing the sequential model of irrigation and power systems operations developed by WAPDA's general consultants, Harza Engineering. The Bank's coordinating consultant, Sir Alexander Gibb & Partners, with the cooperation of Harza executed this additional study in which the operation of the water and power system during the period 1965 to 1985 was simulated under the assumption that IACA's program would be carried out as recommended. This behavior test demonstrated in detail how the irrigation system as a whole would meet the water requirements of each area unit under various sequences of river flow conditions over the course of 20 years. The test led to the conclusion that the proposed program and each component thereof is operationally feasible provided the existing pattern of water distribution is gradually changed so as to establish, step by step, the fully integrated system of groundwater and surface water use which the program envisages.

Project and Program Review

5.27 As the Study progressed the Bank Group subjected the emerging program for irrigation development and its project content to systematic and detailed review. In order to test the economic efficiency of the project priorities proposed by IACA in a basinwide context the Bank Group employed a linear programming model that focuses upon those overall resource constraints which, in the judgment of the Bank Group, would control strategically the complex phenomenon of development of irrigated agriculture. The linear programming analysis made use of IACA's projections of output responses to water and other agricultural inputs and their judgment about the importance of implementation constraints in the field of public tubewell development and canal remodeling. However, use of the linear program provided an opportunity to give fuller attention to the various constraints on development and to variations in the specific values attributed to these constraints. About 500 water 'projects', based on the water budgets produced in the consultants' canal command simulation, were considered. The alternatives for each area -- public tubewells, private tubewells, canal remodeling, increased supply of regulated surface water in the rabi season by construction of further storage reservoirs and improvement in drainage by installation of drainage wells or tile drains -- were considered for execution in each of the two time periods 1965-75 and 1975-85 either singly or, where appropriate, in combination with one another. The special value of the linear program lay in its ability to take into account simultaneously a variety of constraints on development, their interaction, and the possibility that they may change over time. Specifically, five resource limitations were selected: foreign exchange, availability of surface water supply during rabi, construction and project-management capability in regard to implementation of public tubewell projects, the same limitation for canal remodeling projects, and the availability of budgetary resources to support groundwater development. The explicit consideration given to the availability of rabi surface water supplies meant that the linear programming analysis was also useful for study of the size and composition of the proposed surface water storage program.

5.28 While elaborate testing of the basinwide implications of the proposed water development program continued till the end of the Study, each of the priority projects proposed by IACA was also subjected to most detailed scrutiny. As noted before, the consultants devoted a very large part of their effort to selection and study of specific projects for early execution and since these projects were one of the most important outcomes of the Study, the Bank Group also devoted a major effort to appraising them. In its review of the economic justification of the projects the Bank Group made an attempt to quantify those aspects of the projected cost and benefit streams on which it diverged from the views of the consultants. On the whole, these adjustments tended to strengthen the case for private groundwater development. In contradistinction to the approach of IACA, the Bank Group has in its project reviews attached an economic value to the additional surface water use occasioned by a tubewell project and subtracted that from the gross benefits of the project. For purposes of determining the rate of return on public tubewell investment the Bank Group has assumed that the rates of increase in the use of non-water inputs would be similar whether or not the public project were undertaken. The Bank Group also checked the proposed projects against the alternative of stimulated and accelerated private tubewell development wherever this was deemed technically feasible.

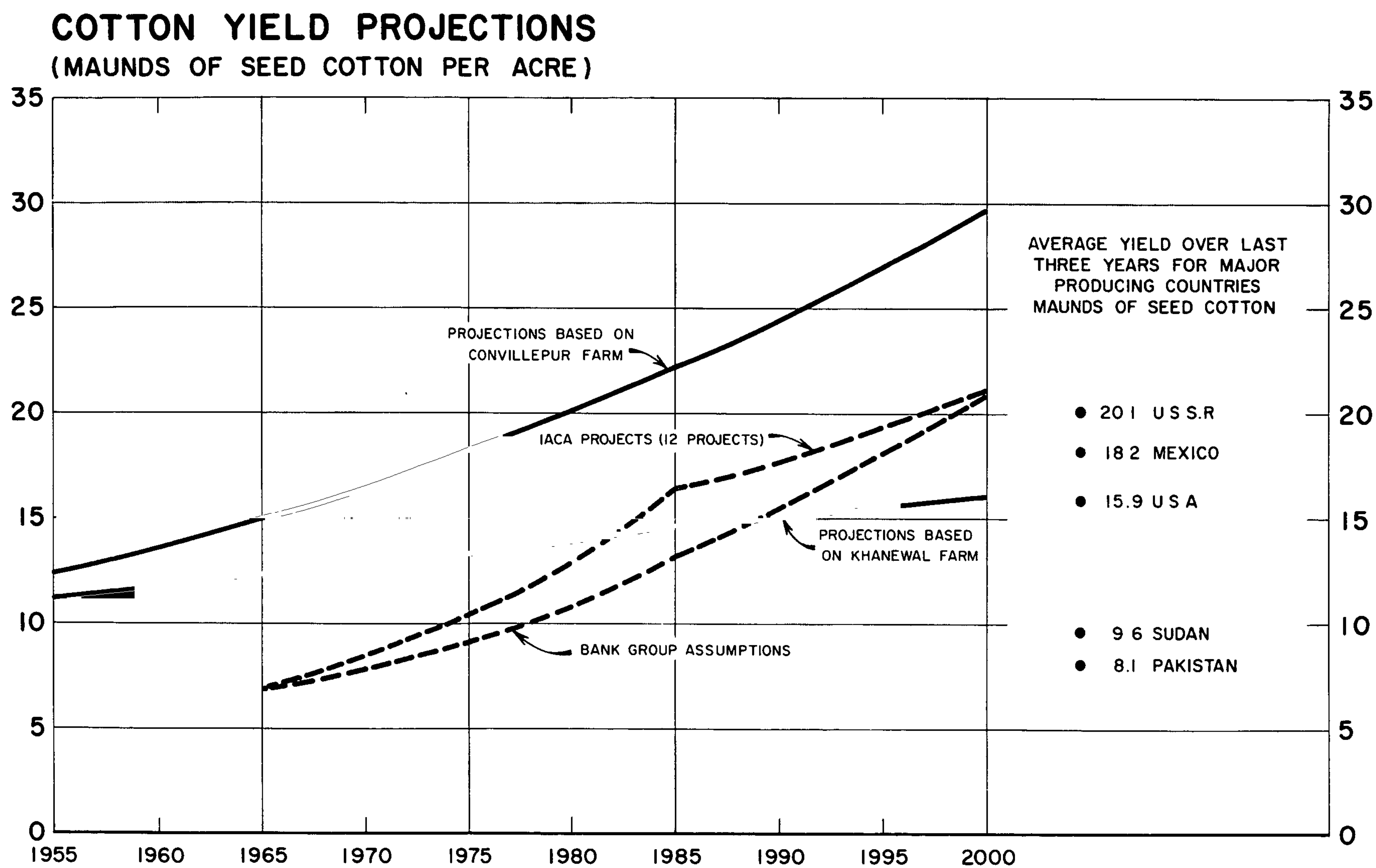
5.29 One important matter of divergence between the Bank Group and IACA concerned future crop yields. In its review of the consultants' studies the Bank Group recognized the need for adequate water application to meet both crop consumptive use and to maintain the long-term productive capacity of the soil, but it considered that the full delta concept may have been too rigidly applied by IACA, particularly for the conditions likely to prevail during the early years of project development. As noted in discussion of the consultants' yield projections above, it was assumed by IACA that a sudden increase in water supplies up to full delta would be accompanied by a sudden increase in yields of the same magnitude. It was the view of the Bank Group that it might take considerable time to organize the higher level of non-water inputs required to match the increase in water. In practice the probable course of development would be a simultaneous increase in acreage as well as an improvement in delta and inputs. This implies for some time a larger cropped acreage at a lower level of production per cropped acre than assumed by IACA; overall production would be higher. Figure 4 is representative of the effect of the Bank Group's adjustments on the crop yield side. It shows the average yield increase for cotton projected by IACA for the twelve selected tubewell project areas and the Bank Group's modified projection for these same areas. The figure also shows projections based on the continuation of past performance on two large, well-managed commercial farms in the Punjab.

Agricultural Development

5.30 IACA did not formulate any non-water development activities in the form of projects, but they did prepare a general program for agricultural improvement, closely interlinked with the proposed irrigation development program. Preparation of this program involved study of the technical feasibility of using different levels of farm inputs in areas with water supplies of varying adequacy, their cost and an assessment of the contribution that they would make to the growth of agricultural production. The chief inputs covered were improved seed varieties, fertilizer, insecticides, chemicals for land reclamation, various measures for improvement of animal husbandry and improvement in farming and irrigation techniques and equipment.

The Formulation of the Power Development Program

5.31 Parallel to the formulation of the irrigation development program and closely interlinked with it, the Study was to prepare a comprehensive plan for the development of the power sector. The assumption which was adopted for the second phase of the Study -- that Tarbela Reservoir would be completed by 1975 -- was as important for the formulation of the power program as it was for the irrigation program. The



(R) IBRD-3288

VOLUME I
FIGURE 4

hydroelectric potential of Tarbela is so large relative to prospective power loads that a sensible action program for interim power development would need to anticipate the existence of Tarbela in 1975. The power characteristics of the Tarbela and the Mangla plants had to be determined for different assumptions as to flows, reservoir release patterns, number of generating units installed, etc. Special reservoir simulation studies were undertaken to indicate the implication for power of different modes of operation. Because the data on the irrigation program were subject to so much study and review, the power consultant had to make certain interim assumptions about tubewell pumping loads and reservoir operation and proceed on that basis to formulate a power program. Rather than use a fully integrated system analysis, the power consultant relied on judicious partial analyses related to his judgment of the overall character of the power system and the relative attractiveness of individual investments. Various alternatives were compared by hand. The long-term program for power was based on a set of detailed regional load forecasts. The load data and the related bulk supply program were prepared on a month-by-month basis for the full period, 1965-85.

5.32 In its review of the proposed power program the Bank Group's objectives were similar to those adopted in its review of agricultural and water proposals: to build up procedures which would enable it to broaden the range of alternatives and to test the economic efficiency of the consultants' proposals. In addition it was hoped to contribute to the process of developing techniques appropriate for updating over time the power program finally recommended. Using a computer, the Bank Group developed a simulation model of the electric power system of West Pakistan down to, but not including, the distribution stage. By providing a means for comparing the costs and operational characteristics of alternative proposals, this simulation technique played a central role in the formulation of the Bank Group's conclusions and recommendations; the power consultant's bulk supply proposals were checked with the aid of the simulation model, and some alterations were made on the basis of the Bank Group's analyses.

Joint Planning for Power and Irrigation

5.33 There are many points of overlap and interdependence between the power and irrigation sectors in West Pakistan, as indicated in the preceding chapters. Considerable effort was devoted throughout the Study to trying to ensure consistency in the Study and in the programs which resulted from it. One difficult problem was in the matter of costs and prices. It was easy to specify the cost concepts which were to be used: all economic comparisons between alternative investments were made in terms of the economic costs of the alternatives -- i.e. costs excluding transfer payments such as import duties, sales taxes and interest during construction -- while financial calculations, designed to indicate the total costs of the selected projects and programs, were carried out in terms of financial prices including these transfer payments. As in using economic prices for comparison of alternatives, the Bank Group also tried to approximate opportunity costs, representing the value of factors in alternative uses, in the case of farm budget calculations by pricing hired labor at current rural wage rates but assuming family labor to be available free. However, there were many uncertainties which had to be solved by judgment. In one sense, reasonable comparability among economic costs of engineering works could be ensured by using 1965 prices, on the assumption that increases in unit prices would affect all works compared in a similar way, but this was less reasonable for crop prices, the differential among which may well change over the years. 1965 farm prices were in fact taken for most crops, but where change seemed particularly likely -- in a downward direction for instance in the case of rice and in an upward direction in the case of meat -- special adjustments were made. Another problem, relating more particularly to the costs of engineering works, arose from the very varying amounts of knowledge and experience that exist regarding the different projects considered. Very large amounts of money have been spent, for instance, to firm up the costs of the Tarbela Project, and only a tiny fraction of that amount on most other surface storage projects. Or again, in the case of irrigation works, considerable experience has been accumulated regarding the costs of tubewells -- though there is still room for disagreement about them -- whereas there is practically no experience of large-scale canal remodeling. Difficulties of securing comparable costs were encountered all through the Study and they had to be handled by techniques such as taking price ranges, making contingency allowances of varying size and always coming back after making any comparison to reassessing its validity.

5.34 There were a number of technical interrelations between the agriculture and power sectors to be considered. Electricity for tubewell pumping will increasingly become an important part of the total power load and the projection of tubewell load growth was an important aspect of the irrigation program; its monthly pattern was derived partly with a view to the seasonal variations that will occur in the capability of the power system and it was also adjusted to allow for interruption at the time of daily system peak so as to fit it better with the overall pattern of power demand and system capacity. Another technical overlap concerned the repercussions of the recommended tubewell program for the pace of rural residential electrification; it was possible to make some broad projections in this regard.

5.35 Cognizance was taken of the fact that the agriculture and power sectors would to some extent be competing with one another and with other sectors for the same scarce resources. It was hard to be very specific about this on the macroeconomic side because no official provincial breakdown of the Perspective Plan for Pakistan (1965-85) which had been prepared by the Pakistan Planning Commission was available. However, as regards foreign exchange, some allowance was made for macroeconomic constraints by making certain comparisons at both current official exchange rates and various alternatives, most often a scarcity rate twice the current rate (i.e. PRs 9.52 instead of PRs 4.76 to the U.S. dollar). As regards capital, the interest rate of eight percent used in all economic comparisons was chosen as an approximation to the real opportunity cost of capital, i.e. the marginal productivity of capital in uses outside the sectors under study. In the selection of an appropriate interest rate the Bank

Group was conscious both of the need to give due recognition to the relative scarcity of capital in the Pakistan economy and of the importance of not biasing the project selection process unduly against the longer-lived alternatives such as storage reservoirs and hydroelectric plant which were relatively expensive in capital cost and relatively cheap in operating cost. The eight percent rate ultimately chosen is somewhat above the prevailing rate of interest on Government bonds in Pakistan and somewhat below typical rates of return on private investment. Use of the eight percent interest rate meant automatic exclusion from the program of projects yielding less than eight percent rate of return.

5.36 Besides finance and foreign exchange the agriculture and power sectors will also compete for the use of water stored behind the Mangla and Tarbela Dams and, as pointed out in Chapter IV, for use of the Province's natural gas reserves. Once Mangla is completed, and even more when Tarbela is completed, there will be room for choice between drawing down the reservoirs fully and thus releasing all the water stored from the kharif season for irrigation use in rabi and, on the other hand, retaining some water in the reservoirs throughout the year and thus increasing the power capability of the hydroelectric plants in the season when power supplies will be most short. To the extent that the reservoirs are drawn down more fully there will be a greater requirement for thermal generation capability -- and this will be largely based on natural gas, especially up to 1980. But use of more natural gas for power generation means that less will be available for manufacture of fertilizer for the agricultural sector.

5.37 The most critical meeting point between agriculture and power in the Study was the analysis of the justification of Tarbela itself. As the final, comprehensive phase of the Study was coming to an end, the coordinating consultant readdressed himself to this question and broadly confirmed the conclusion reached in the first phase of the Study regarding the rate of return to be anticipated from the project. The Bank Group also reappraised the Tarbela Dam in a number of studies, including a consideration of the project within the framework set by the agricultural projects recommended and an assessment, with the aid of the linear programming analysis of irrigation investment and the power system simulation model, of the loss that would be sustained if execution of the project were delayed ten years. All these studies concurred in indicating that Tarbela should be executed as scheduled.

VI. AGRICULTURAL IMPROVEMENTS AND IRRIGATION PROJECTS

6.01 This chapter discusses the program for the development of irrigation and agriculture presented in Volume II of the Bank Group's report. The program is based on the work of the Irrigation and Agricultural Consultants Association (IACA) but it also reflects the impact of views expressed by the Pakistan authorities during the course of the Study and of the Bank Group's own experience in Pakistan. The Bank Group has set forth projections of the higher levels of agricultural production that appear reasonable for the future. Throughout the next decades, but particularly for the period 1965-75, the Bank Group has been concerned with what is practically achievable within the constraints that are likely to be operative, rather than with the technical potential. It has been assumed that the development of irrigation and agriculture would receive the high priority in the allocation of resources, which its importance deserves, and that these would be efficiently and effectively deployed. Water development and agricultural development are essentially interdependent, and both receive the emphasis in the recommended program which the Bank Group considers appropriate under prevailing conditions. The level of agricultural production projected for 1975 would only be achieved as the result of a major effort of an emergency character and spectacular improvement in performance in all sectors. Its attainment, however, is designed to go far towards meeting West Pakistan's most pressing needs in food and exports of agriculturally based commodities.

6.02 The methods used in this part of the Study have been outlined in Chapter V. As noted in assessing the opportunities to stimulate agricultural development, the Bank Group studied data on a wide range of agricultural factors. These include crop yields, cropping patterns, cropping intensities, crop water requirements, the relationship between water and other agricultural inputs, land tenure, project organization and implementation, and the institutional base for agriculture in West Pakistan. It examined specific development projects, and reviewed the available information on water supplies from all sources, the requirements for increasing supplies from any of these sources, and the limit inherent in a complex plan where changes in supplies from one source affect the use which can be made of other sources. The more important findings and conclusions derived from these studies as they relate to agricultural improvements and irrigation projects are discussed in this chapter. A brief summary is presented first of developments as they relate to agricultural improvements.

6.03 The Province of West Pakistan covers a land area of some 200 million acres, of which about 70 million acres are considered potentially suitable for agricultural production. However, less than 40 million acres are presently cultivated. The Indus Plains include nearly 70 percent of the cultivated acreage, supply about 80 percent of the foodstuffs produced and contain a large majority of the population of the Province. The irrigated plains also offer the greatest scope for further agricultural development. For these reasons, this area has received primary emphasis throughout Volume II of the Bank Group's report.

Crops

6.04 The predominant importance of the canal-irrigated areas is illustrated in Table 18 in terms of the acreage under various major crops and the contribution of these crops to the Gross Production Value (GPV) of agricultural output. Production of three of the important crops grown -- rice, cotton and sugarcane -- is virtually confined to the canal-irrigated areas, and these account for nearly half the GPV of crops. Three-fourths of the GPV from wheat comes from these areas. Cotton is the most important cash crop and accounts for some 14 percent of the total cropped acreage in the irrigated areas; it is grown mainly in the southern Punjab, Bahawalpur and Northern Sind. Production of rice and sugarcane as cash crops is heavily concentrated in the irrigated areas of the northern Punjab and Peshawar.

Table 18

Cropped Acreage and GPV for Canal Irrigated and Other Areas (1965)
(Millions)

	Canal Irrigated		Remainder		West Pakistan	
	Area in acres	GPV PRs	Area In Acres	GPV PRs	Area In Acres	GPV PRs
Annual Food Crops						
Wheat	7.72	1,222.5	4.99	412.5	12.71	1,635.0
Millets	1.02	68.2	1.99	136.8	3.01	205.0
Maize	1.09	128.6	1.07	122.4	2.16	251.0
Others	3.08	412.9	3.12	288.1	6.20	701.0
Rice	3.52	589.0	-	-	3.52	589.0
Perennial Crops	1.62	1,112.0	-	-	1.62	1,112.0
Total Food Crops	18.05	3,533.2	11.17	959.8	29.22	4,493.0
Cotton	3.71	880.0	-	-	3.71	880.0
Fodder	4.99	-	1.20	-	6.19	-
Total Crops	26.75	4,413.2	12.37	959.8	39.12	5,373.0

Table18 also indicates that food crops account for about 75 percent of the total acreage currently cultivated, though somewhat less in the canal irrigated areas. Wheat, the staple food in most areas, alone accounted for nearly one-third of total acreage cropped.

Livestock

6.05 No less than 15 percent of the 39 million cropped acres are used for the production of fodders of various kinds, four-fifths of this area falling within the canal-irrigated plains. This indicates the importance of animals in West Pakistan's rural economy. This 15 percent under fodder crops understates the actual area devoted to livestock because crop residues provide about half the animal nutrient supply and large rainfed areas are also used primarily for grazing. Table 19 shows the estimated livestock population of West Pakistan in 1965.

Table 19

Livestock Population of West Pakistan, 1965
(in million heads)

Bullocks	7.4
Other work animals	2.4
Bovine cows	4.4
Bovine followers	3.5
Buffalo cows	5.4
Buffalo bulls and followers	3.1
Sheep	9.8
Goats	7.2
Total larger livestock	43.2
Poultry	10.0

A few of the larger farms in West Pakistan have begun to use tractors and other mechanized equipment, but the vast majority rely entirely on draught animals for cultivation, threshing and farm transport. Draught animals account for about one-quarter of the total animal population of 43.2 million head. While also producing meat most of the milk and meat in Pakistan come from the other 75 percent of the herd. Livestock products account for a very significant proportion -- estimated at some 35 percent -- of total agricultural output. Production of milk, meat, hides and skins, etc., is somewhat less heavily concentrated in the irrigated areas than production of field crops, since the non-irrigated areas provide extensive grazing land: farmers in the canal-commanded areas may be responsible for 70 percent of total output of livestock products though some of this occurs on the higher regions of the doabs not commanded by canals.

Farms and Farmers

6.06 One of the reasons why animal power will continue for long to be important in West Pakistan is that there is a very large number of small farms. The 1960 Pakistan Census of Agriculture shows that 49 percent of the farms are under five acres. However, there is wide variation over the Province. The average farm holding is 10.1 acres (with ancultivated area of 7.7 acres), but the range extends from an average of 5.5 acres in Peshawar Division to 35.9 acres in the largely unirrigated Kalat Division, west of the Indus. In general terms, farms are smaller in the more productive, irrigated areas of the Punjab and Peshawar Vale than elsewhere.

6.07 Despite the very large number of small farms, much of the farm area is in fact in relatively large farms. The 49 percent of farms under five acres account for only 10 percent of the culturable area, while 40 percent is in farms over 25 acres in size.

6.08 The pattern of land tenure also shows considerable variation over the Province. Owner-operated farms account for nearly half the acreage in the Punjab, but only about one-third in the Khairpur Division of the Sind. This reflects the fact that tenancy is more prevalent in the less developed parts of the Province, where large acreages are owned by absentee landowners. Land reform legislation has sought to deal with the problems posed by farms that are either excessively large or excessively small. The right to subdivide land below a minimum size designated as an "economic holding" has been limited, and the largest landowners (those with more than 500 acres of irrigated or 1,000 acres of unirrigated land) have been required to divest themselves of land in excess of the legal limits. Both kinds of measures have had some success in achieving their objectives, and the strategic position of the larger landlords may have been partially weakened in the process. Efforts to consolidate land holdings which are fragmented have proceeded slowly. It is difficult to relate the recent increase in production directly to the effects of land reform programs, in part, because land reform has had so little measurable impact on the size distribution of land holdings. On the other hand, land reform may be a factor in changing the attitudes of large landowners, and awakening a more active interest in improving the productivity of their lands through increased investments, including tubewells and mechanization of farm operations.

Fertilizer

6.09 One indication of the responsiveness of farmers to new inputs has been the very rapid increase in use of fertilizer in recent years. During the First Plan Period (1954/55 - 1959/60), fertilizer use grew only some 5,000 nutrient tons. Thereafter, the rise was more spectacular, as shown in the following table.

Table 20

Fertilizer Use During the Second Plan Period
(tons of nutrient)

Year	Nitrogen (N)	Phosphate (P_2O_5)	Total	Annual Increase (%)
1959/60	19,300	100	19,400	0.8
1960/61	31,100	400	31,500	62.7
1961/62	37,200	500	37,700	19.7
1962/63	42,900	1,400	44,300	17.5
1963/64	62,400	1,100	63,500	43.3
1964/65	84,000	2,000	86,000	35.4

6.10 This increase in fertilizer use was supported by a Government subsidy. The drop in growth of offtake in 1961-63 coincided with a decrease in the rate of subsidy. After reinstatement of full subsidy, consumption again grew rapidly. Shortages in supply probably limited use in the final year of the Second Plan to the quantities shown, for there have been pervasive reports of sales of fertilizers at black market prices since 1964/65. Though still small in absolute terms and largely confined to areas of higher standard farming, fertilizer has probably made an important contribution to the growth in production of cash crops, on which applications tended to be concentrated.

6.11 Even though water supplies are unreliable and below the optimum in many areas there would appear to be great scope for raising yields by increasing the use of fertilizer. Increased use of fertilizer will be the most important single factor in bringing about rapid agricultural growth in the near future. Various short-term projections of future fertilizer use have been made in the past and they tend to coincide at an absorption target of about 370,000 nutrient tons by 1969/70 or a rate of growth of well above 30 percent per annum over the next several years. This would imply a further acceleration over the already impressive experience during the Second Plan period. While the actual performance during the first year of the Third Plan (1965/66) does not show a major increase over 1964/65 the recent steps taken by the Government of West Pakistan which aim to have some 250,000 nutrient tons available during the current fiscal year would tend to support such an optimistic assessment. However, the problems of production and procurement as well as transportation and actual distribution should not be discounted nor should the influence of price supports be underestimated in an environment where the mass of farmers are still preoccupied with subsistence farming. Considering these difficulties, the major efforts being made to overcome them and the rate of growth of fertilizer usage achieved in the Second Plan, it would appear that the target for 1969/70 of about 350,000 nutrient tons, equivalent to about 1.6 million tons of fertilizer (ammonium sulphate equivalent), although much above that implied by IACA, as illustrated by Table 21 , is, nonetheless, reasonable for planning purposes.

Table 21

Projections of Fertilizer Consumption by IACA and Bank Group
('000 tons of nutrient)

	1964/65		1970		1975		1985
IACA:							
(a) Nitrogen	90		120		217		573
(b) Phosphate	-		55		103		335
Total	90		175		320		908
Rate of Increase (% p.a.)		14%		13%		11%	
Bank Group:							
(a) Nitrogen	90		250		470		620
(b) Phosphate	-		100		230		330
Total	90		350		700		950
Rate of Increase (% p.a.)		30%		15%		5%	

The rate of growth of fertilizer off-take may slow down somewhat during the Fourth Plan period but it should be feasible to maintain an average growth of 15 percent per annum, implying consumption of 700,000 tons of nutrients by 1975. This would again be double the IACA estimate. While a high degree of uncertainty is necessary inherent in all these projects, it would be possible for the West Pakistan authorities to reach these targets provided appropriate arrangements are made for supplies and distribution. After 1975, the growth in consumption would probably slow down.

6.12 Achievement of the Bank Group targets shown in Table 21 would mean reaching by the end of the Third Five Year Plan period somewhat beyond the coverage and rates of application envisaged by IACA for 1975. The rates of application for each crop shown in the following table have been developed from rates presently recommended by the Department of Agriculture. The projections imply that about half of the fertilizer usage would be for the wheat crop and another quarter for cotton. The projections of area covered and application per acre shown below reveal that the target chosen is ambitious and that its attainment will require determined efforts by all concerned.

Table 22

IACA's Projection of Fertilizer Coverage by 1975
(in percent of crop acreage covered; applications in lbs of nutrients)

	Punjab		Sind		Outside Areas	
	% of crop acreage covered	Application in lbs per cov'd. acre	% of crop acreage covered	Application in lbs per cov'd. acre	% of crop acreage covered	Application in lbs per cov'd. acre
Wheat - nitrogen	50	50	25	50	15	25
phosphates[a]	50	30	25	25	-	-
Cotton - nitrogen	60	40	40	40	-	-
phosphates	30	30	20	20	-	-
Fine Rice - nitrogen	50	30	-	-	-	-
phosphates	30	30	-	-	-	-
Sugarcane - nitrogen	70	60	50	60	-	-
phosphates	30	30	15	20	-	-
Kharif fodder-nitrogen	20	60	20	60	5	10
Rabi fodder-phosphates	20	50	-	-	-	-

a/ P_2O_5

Improved Seeds

6.13 The use of improved seed material has considerable potential. Probably only in the case of cotton has there been any widespread supply of improved varieties to farmers, and the significance of this improvement is open to doubt since controls on seed selection and protection against adulteration have not been very effective in all areas. Though it occurred too late to affect production during the Second Plan period, important progress has now been made in developing superior strains of crops, particularly wheat. Since 1959 West Pakistan, in collaboration with Mexican wheat breeding experts supported by the Ford Foundation, has embarked on an active wheat-improvement program. Several higher-yielding varieties have been developed and are in various stages of progress from the research stations to commercial multiplication. Presently, imported Mexican varieties (Penjamo and Lerma Rojo) are being multiplied while the locally produced Mexipak varieties are expected soon to reach the stage of distribution for commercial production.

6.14 The technical yield potential of the newly introduced wheat varieties is given by the wheat-breeding experts as about 45 maunds per acre compared with a current wheat yield in the better farming areas of 13 maunds. Harvesting data for 5,000 acres in the first year of commercial multiplication (1965/66 rabi season) show yields ranging between 26 and 34 maunds under actual farming conditions. Maximum yields exceeded 80 maunds, but the level of yields on some of the ADC seed farms did not even approach those presently achieved with indigenous varieties in the better farming areas of West Pakistan. A number of causes have been indicated: sub-optimum moisture conditions of the seed beds, excessive depth of sowing carried over from practices used with indigenous varieties, seed rates below those recommended for the new varieties, shortage of irrigation water and insufficient number of waterings, and deficient application of fertilizer. It is important to recognize that where there was failure not any one single factor was the cause but to some extent practically all major elements of efficient cultivation practices were lacking. The future success of the accelerated wheat-improvement program is thus not only dependent on the availability of adequate quantities of improved seeds but also on an overall improvement of crop husbandry practices.

6.15 The magnitude of total seed requirements for the major crops at the present time and as projected by IACA for the future is shown in Table 23.

Table 23

Seed Requirements for Major Crops
(Million maunds)

	1965	1975	1985	2000
Wheat	8.90	16.00	18.80	17.80
Cotton	0.90	1.60	2.60	4.00
Rice	0.70	0.80	0.80	0.90
	10.50	17.40	22.20	22.70

Actual distribution of improved seed by the Agricultural Department and the Agricultural Development Corporation in 1964/65 was 0.4 million maunds for wheat, 0.3 million maunds for cotton and 0.7 million maunds for rice. Thus improved seed covers only a small proportion of total requirements, except in the case of rice. Large quantities of improved seed will also be required for coarse grains and fodder.

6.16 The projection made by IACA and adopted by the Bank Group is 50 percent coverage of the wheat acreage with improved varieties by 1975 and 100 percent coverage by 1985. Improved wheat seed material of 18.8 million maunds (700,000 tons) will therefore be required by 1985 and about half this amount by 1975. Assuming that the seed is produced by the best farmers with an average yield of about 30 maunds per acre of seed material this would require that about 320,000 acres be devoted to improved seed production by 1975; in 1965/66 there were altogether under improved wheat varieties some 12,000 acres. Thus the task is substantial. The wheat breeding experts advising the Government of West Pakistan have predicted even more rapid progress is possible -- coverage of six million acres of irrigated land by 1969/70, implying a need for more than seven million maunds of improved seed material. At least 250,000 acres would be required to produce this quantity of seed. Use of these quantities of improved seed by 1969/70 would certainly be desirable, but it is doubtful whether it is achievable. The production, handling and distribution of such quantities of improved wheat seed would require a crash program for improved extension services, commercialization of multiplication and strict quality control over extensive areas, provision of adequate storage facilities to ensure retention of high germination rates, and an extensive and efficient distribution network.

6.17 As regards cotton IACA estimates that about 40 percent of the present acreage is planted with improved seed and that this could be raised to 100 percent by 1975. IACA found in their watercourse studies that typical potton plant populations were less than half the recommended 16,000 plants per acre. The low plant population appeared to be due partly to poor-quality seed and partly to low seed rates, emergence difficulties and post-emergency mortality. Thus, in conjunction with improving cotton seed quality IACA projects increasing seed rates and full plant populations; the seed requirements shown in Table 23 are calculated on the basis of recommended seed rates and plant densities.

6.18 For coarse rice important progress has been made with the development of high yielding dwarf varieties at the International Rice Research Institute in the Philippines. These varieties are being tested at Dokri Rice Research Station in West Pakistan with apparently good results. The possibilities of large-scale introduction are under consideration by the Agricultural Department which plans for a coverage with improved varieties of about one million acres by 1970, roughly equivalent to the target adopted here for 1975. By 1985 IACA would expect improved rice varieties to be in common use.

6.19 Wheat, cotton and rice together with sugarcane are the main crops for which IACA projects an improvement in the quality of seed used. In the case of sugarcane the choice of sets material need improvement as does the planting rate. At present only about half the recommended number of sets is being planted, and most of these are two-node sets while IACA considers three-node sets desirable. Hybrid and synthetic maize varieties have potential for West Pakistan, but they require considerable organizational and scientific support for maintenance breeding as well as large-scale planting in contiguous areas. In general IACA believes that progress in the use of improved seed will occur mainly with wheat and the three main cash crops, as mentioned above, because these are the ones on which farmers will concentrate attention. Use of improved seed will probably increase much more rapidly in the irrigated areas than outside them.

6.20 In its review of the IACA projections of the use of improved seed the Bank Group was very conscious of the fact that to measure progress in terms of the amount of improved seed employed could be quite misleading. In the past much of the so-called improved seed has been little if any better than farmers' own stocks. If improved seed is interpreted as meaning seed of high genetic quality, produced and distributed under controlled conditions providing a high degree of assurance that it would be true to type, free from adultrants and of high germination, then the Bank Group would feel that IACA's estimates are not unreasonable. The main point is that progress must be measured qualitatively as well as quantitatively and much depends upon the institutions responsible for production, multiplication and supervision of the distribution of improved seed material.

Plant Protection

6.21 In the past plant protection has been provided to farmers virtually free through the agricultural extension services, but the results have not been too satisfactory. It is estimated that at best some 12 percent of the cropped area has been receiving some form of plant protection, which may or may not have been effective, while as much as 15 percent of the potential yield of crops has been lost each year to pests. There is a shortage of properly trained personnel to carry out this service, treatments often are neither timely nor of proper dosage, insecticides have not been available in adequate quantities at the critical time, and the selection of areas for treatment appears to have been not always based on an objective assessment of the most pressing needs. Some of the problems have been on the side of the farmers too. The elimination of weeds serving as host plants for pests and destruction of crop residues immediately after harvesting is not practiced on a wide scale. Little attention is given to adjusting planting dates in accordance with pest-control needs.

6.22 IACA believes, and the Bank Group agrees, that plant protection measures are unlikely to improve much before the use of fertilizer and better husbandry have become more widespread and yields thus increased. Plant protection will then become recognized as increasingly important. But lack of knowledge on the part of the farmer and the extension service, the critical importance of applying the pesticide at the right time, the need that will arise for pesticides to be properly stored and transported in quantity and the problem of cost sharing between tenant and landlord will be serious constraints on the rate of progress. Therefore IACA has assumed a relatively small increase in the acreage sprayed by 1975, but more general use of chemical control in later years. Table 24 gives a rough assessment of the proportion of the acreage of different crops presently sprayed and IACA's projection of the increase in this proportion.

Table 24

IACA Projection of Plant Protection Coverage
(Percent of acreage under crop)

	1965	1975	1985
Rice Nurseries	20	45	65
Fine Rice	3	20	40
Coarse Rice	3	5	17.5
Cotton	5	20	40
Sugarcane	5	27.5	47.5
Fruit	25	25	45
Vegetables	10	15	35
Maize	3	7.5	27.5
Kharif fodder	-	5	17.5
Oilseeds	-	5	20
Wheat	-	-	10
Rabi fodder	-	-	-
Gram	-	-	-
Kharif pulses	-	-	10

Agricultural Implements and Mechanization

6.23 Existing farm implements are adapted to local conditions and mostly manufactured from local materials, but there is room for substantial improvement in them. Efforts are being made to develop improved hand tools and animal-drawn equipment at research centers and to promote their use with the aid of subsidies. However, in contrast to the rapid spread of private tubewells, the improvement in tools and simple equipment appears to be progressing rather slowly. Use of tractors and tractor-drawn equipment is expanding more rapidly but is still confined at present to a few larger farms; it is believed that in the whole of West Pakistan there are only about 6,000 tractors working on farms.

6.24 Mechanization will become more advantageous to farmers as cropping intensities increase. At high cropping intensities farming schedules will be tight and higher labor peaks arise, particularly in the overlap periods between seasons when some crops are still being harvested and the land is beginning to be prepared for sowing of others. Mechanized cultivation, which is apparently not generally more expensive than bullock farming, has the additional advantages of setting free land devoted to fodder. It also enables timely land preparation which contributes to better crop performance. However, there are a number of factors restraining the expansion of mechanization. The farm size problem and its associated financial implications have already been mentioned above. In addition, land fragmentation and the tenure and share-cropping system are likely to be a substantial barrier to rapid mechanization. The small size of individual fields enclosed by irrigation bunds would create physical problems for efficient use of machinery. Furthermore, even on larger farms the rapid adoption of mechanized farming would depend greatly on the existence of satisfactory service facilities including adequate supply of spare parts and mechanics. Research is still needed to select the right types of equipment and to develop equipment better suited to local conditions.

6.25 For the purpose of projection IACA has developed a "rate of mechanization" based on a hypothetical percentage of farm area fully mechanized. This would not be the case in practice since mechanization is a progressive process. Initially, mechanization would be partial, concentrating on specific activities such as cultivation and land preparation. In its approach IACA has taken this into account and has equated this with full mechanization on a reduced area. The following table shows the coverage and rate of mechanization by farm size groups as projected by IACA for reference years.

Table 25

IACA's Projected Rate of Mechanization
(Percent of farm area covered)

Farm Size Group	% of Total Farm Area in Group	1975 Percent Mechanization	1985 Percent Mechanization	2000 Percent Mechanization
Farms above 25 acres	40	20	50	85
Farms 5-25	50	4	10	30
Farms below 5 acres	10	-	5	10
Total Farm Area	100	10	25	50

To the above percentage coverage IACA has related complete mechanization units -- including a tractor with tilling and mowing equipment, seed drill and thresher, and a trailer and miscellaneous equipment -- costing about PRs 25,000 and capable of serving a cropped area of about 100 acres. The area assumed to be mechanized in Table 25 would require about 33,000, 83,000 and 165,000 such units for the respective reference years.

Livestock Development

6.26 Despite the great importance of the livestock sector in total agricultural production in West Pakistan the keeping of animals is haphazard and it plays a subsidiary role in the mixed farming system of the Province. The major part of the livestock population consists of scrub animals with poor genetical qualities. Many of the animals are underfed and depleted.

Indiscriminate breeding is widely practiced. The rural population appears to be fairly well supplied with milk and milk products, but effective distribution systems for making milk and milk products widely available in the towns are almost nonexistent.

6.27 The projections in Table 25 imply that animals will continue for a long time to be the main source of power on the farm. Even after a farmer has introduced some mechanical equipment -- usually for cultivation and threshing, at the early stages -- he still requires bullocks for operations such as cane crushing and transport, and so it is only when a fuller degree of mechanization has been reached that he can dispense with work animals. Apart from the continuing need for animals for work, more livestock will be required for meeting the demand for milk and meat, which is likely to grow rapidly as population and incomes grow. Moreover, as cropping intensities increase and work animals are called upon to do more work and as improved animal husbandry results in production of more milk and meat per animal, the intake of fodder per animal will be greater.

6.28 The size of the existing livestock herd in West Pakistan is uncertain, but IACA estimated the bench-mark data presented in Table 19 above and projected the growth of the herd. Draught animals are assumed to decline, in rough correspondence with the compensating growth of mechanization, from about 12 million now to about 6 million in 2000. Bullocks are the main component of the animal work force and will remain so. Table 26 illustrates the changes projected. The animal units (AU) used in the table are a common denominator equivalent in terms of total annual fodder consumption to one bullock. The table shows that the projected increase in the number of cattle and buffaloes raised for milk production more than offsets the decline in the number of working bullocks. Sheep and goats, important sources of meat in West Pakistan, also increase though somewhat less rapidly than cows and buffaloes.

6.29 The main producers of milk in West Pakistan at the present time are the 5.4 million buffalo cows, and, as the table shows, IACA projects continued growth of the number of such animals up to about 1985. However in later years the numbers of buffaloes would decline in accordance with IACA's recommendation to build up an improved herd of Zebu cows which would eventually become the main source of milk in the Province. The buffalo is at present a greatly superior producer of milk. However the heavy, late maturing buffalo requires more food intake for growth and maintenance than the less heavy and earlier maturing Zebu cow. Moreover the buffalo tends to be a seasonal breeder, resulting in long intercalving periods. There are promising dairy Zebu breeds in West Pakistan such as Sahiwal in Punjab and Red Sindi in Sind, and it is these which would be used as the base of the new milk herd. The very large expansion in the Zebu herd would be brought about by a massive program of artificial insemination of existing cows with semen from selected Sahiwal and Red Sindi bulls. IACA have drafted an outline of such a program, calling for a rapid expansion of the existing artificial insemination organization under the Directorate of Livestock Farms. IACA believes that the program should be started in the near future since it may take 10 years to achieve significant progress.

Table 26

Composition of Projected Livestock Population

	1965		1975		1985		2000	
	No. of Stock	Animal Units	No. of Stock	Animal Units	No. of Stock	Animal Units	No. of Stock	Animal Units
	- - - - - - - - (in millions) - - - - - -							
Work Animals								
Bullocks, adults	7.4	7.40	6.6	6.60	5.6	5.60	3.7	3.70
followers	1.8	1.40	2.3	1.77	2.0	1.54	1.4	1.08
Horses, camels etc.	2.4	1.20	2.1	1.05	1.8	0.90	1.0	0.50
	11.6	10.0	11.0	9.42	9.4	8.04	6.1	5.28
Milk/Meat Animals								
Bovines:								
Milk cow adults	4.4	3.32	3.8	3.11	3.0	2.52	2.0	1.78
Female followers	1.7	1.25	2.4	1.73	1.9	1.35	1.4	0.98
Milk Zebu & followers	-	-	-	-	0.7	0.58	7.6	6.76
Buffaloes:								
Bulls & followers	3.1	3.19	6.4	6.08	10.9	9.92	8.4	7.22
Cows	5.4	6.53	6.9	9.35	9.6	12.97	7.0	10.74
Browsing Animals:								
Sheep & Goats	17.0	2.77	20.1	3.16	24.7	3.82	27.2	4.15
Poultry								
Existing desi	10.0	0.13	10.0	0.13	10.0	0.11	10.0	0.10
Improved stock	-	-	2.4	0.06	7.1	0.24	20.3	0.68
Total		17.9		23.62		31.51		32.41
Grand Total		27.19		33.04		39.55		37.69

6.30 The projections in Table 26 imply an increase of nearly 40 percent in the total number of animal units between 1965 and 2000. To feed this larger animal population and to supply it with a gradually increasing feed intake over time, IACA has provided for expansion in the acreage of fodder crops. IACA measures animal feed in terms of Total Digestible Nutrients (TDN), which includes fodder, crop residues, and grazing. Part of the increase in feed requirements would therefore be met by crop residues from the increasing volume of crops raised for other purposes. Anticipated improvements in pasture management and control would also help to supply some of the additional TDN consumed by the larger herds.

Nevertheless, the acreage under fodder in the canal-commanded areas would have to increase from some 5.0 million acres now to 6.2 million acres in 1975 and 8.5 million acres by 2000. Total production of fodder (including that from areas outside the canal commands) would then double between 1965 and 2000. The consumption of TDN per animal unit would increase from an average of about 1,035 kilos at present to about 1,400 kilos by the year 2000. Included in this would be enough digestible protein to ensure a reasonably balanced diet for the livestock.

Improved Farming, Physical Inputs and Water

6.31 The discussions above inevitably emphasized physical targets for increase in the quantities of agricultural inputs and in the livestock herd. But mere increase in physical quantities by no means necessarily implies a commensurate increase in production of crops, milk and meat. Much depends on the quality of the inputs used, as pointed out for instance in the case of improved seed, and of the livestock herd developed; and much depends too on the quality of husbandry practices. Implicit in the Bank Group's projections of development is not only an increase in the physical quantities of inputs absorbed but also a steady improvement of quality -- seed more disease resistant and of higher germination rate, insecticides that are easier to apply and more effective, animals that produce more milk and meat per kilo of TDN consumed. Improvements in quality and effectiveness of use will depend partly on research -- and the Bank Group believes that much more attention should be given to this, especially to research with a practical orientation, as discussed in Chapter IX -- and partly on development of facilities for production and distribution which are capable of bringing to millions of farmers inputs of improved quality.

6.32 If these larger quantities of better-quality inputs are to be used to maximum effect, improvement of farming practices is essential. Indeed the Bank Group believes that there is scope for large increases in production simply by way of improvement in farming practices, but these improvements will probably come about largely as accompaniments to increased absorption of agricultural inputs and increased use of water. However it may come, it is clear that the basic need is for a much improved and expanded extension effort, capable of providing better advice and assistance to large numbers of farmers. Extension work will indeed be a very critical input, and the Bank Group discusses in Chapter IX below some of the measures that it believes are most urgently needed to improve the effectiveness of the extension service.

6.33 The Bank Group believes that adoption of more advanced and efficient farming techniques, including use of the modern physical aids to productivity, could lead to considerable increases in crop yields even with current water supplies, and it is for this reason that pride of place in this chapter has been given to discussion of the main measures required in this direction. In the past in West Pakistan, and still to some extent today, there has been a tendency to overstate the importance of further public water development as a means to secure increased agricultural production and to understate the importance of improved farming employing more and better inputs. The evidence is that typical water applications may now be in the neighborhood of 80 percent of the full delta irrigation level as defined in Chapter V. The Bank Group believes that this level of irrigation delta, even given the unreliability of supplies at certain critical times, is sufficient to support much greater use of other yield-improving inputs than presently obtains. Efforts to help farmers get better value from the water they now have are less spectacular than major construction works but in the Bank Group's opinion such efforts can contribute more in the immediate future to a broad improvement in farmers' productivity; and the importance of the people responsible for such efforts should be recognized.

6.34 Notwithstanding this opinion the Bank Group recommends that a major effort be made to increase and improve water supplies to farmers. Uncertain irrigation supplies are a serious deterrent to investment and enterprise by farmers at present. Unless this situation is corrected it will inhibit growth in the use of farm inputs. Water, moreover, is an accustomed input, and once it is available in adequate and reliable quantity there appears to be greater interest in other new means of increasing production. There are thus both technical and psychological complementarities between water and other inputs, as pointed out in Chapter III. Both additional irrigation water and increased use of other agricultural inputs will fill vital gaps in West Pakistan's current agricultural practice. Since few improvement measures can be taken in isolation, and maximum benefits are to be obtained only from a balanced combination of water and other inputs, it is important to avoid thinking of developmental inputs in mutually exclusive terms. Some measures may have to precede others, but there should be an integrated approach to development which calls upon all inputs to play their proper roles in reasonable balance at the appropriate time.

6.35 Thus the Bank Group considers that the projections of increasing absorption of non-water inputs, though presented independently in the first part of this chapter, are intimately interdependent with the water program presented in this chapter. The program as a whole applies to the period up to the year 2000, but the Bank Group has been particularly concerned with the initial period 1965-75. This is a critical time in Pakistan's development effort, and being the near future it is also the time for which plans can be more specific.

Irrigation Development -- Third Plan Period

6.36 There is an urgent need in West Pakistan for more reliable and greater supplies of irrigation water to enable farmers to extend their cropped acreage and increase their water applications per acre cultivated and to encourage them to absorb farm inputs in larger quantities. Because surface water cannot be increased quickly above existing levels there are only two important ways immediately feasible in which this need can be even partially met within the Third Plan period -- public tubewells and private tubewells.

6.37 As regards public tubewells WAPDA has under way a number of projects which add up to a construction program several times the size of what it has accomplished in the past; it is doubtful whether this program can in fact be fulfilled as scheduled and there is certainly very little scope for commencement of additional projects within the Third Plan period. There are four important ongoing public tubewell projects -- SCARP II in Chaj Doab, SCARP III in Thal Doab, SCARP IV in Upper Rechna Doab and the Khairpur groundwater development project. Some 955 wells had been completed in SCARP II by the end of 1966 but none in any of the other areas. Completion of all four projects will require installation of a further 7,183 wells. Table 27 shows approximately WAPDA's schedule for completion of these wells.

Table 27

Schedule of Implementation for the Ongoing Public Tubewell Projects
(No. of wells completed)

Project	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	Total
SCARP II	420	630	418	307	100	-	1,875
SCARP III	240	570	495	165	-	-	1,470
SCARP IV	110	500	780	790	745	345	3,270
Khairpur	80	200	288	-	-	-	568
Total	850	1,900	1,981	1,262	845	345	7,183

IACA have suggested deferment of 1,010 wells scheduled for SCARP IV because of extensive private tubewell development in the area which would be served by these wells. This would considerably reduce the peak levels of installation shown for the years 1967/68 and 1968/69 in the above table. Nevertheless, even with this adjustment, the program would still amount to about 5,850 wells in the last three and a half years of the Third Plan period or an average of about 1,670 wells per year. This target rate compares to an average performance between 1959 and 1966 of about 450 wells completed per year. The first year of the Third Plan period (1965/66) showed disappointing progress: about 1,000 wells were drilled but only about 140 were electrified and brought into operation. Financial and contractual arrangements still have to be made for about half the wells included in the above table. To bring 5,850 new public wells into effective operation before the end of the Third Plan would require increased financial allocations to WAPDA, removal of the constraints on electrification, establishment of proper inventory system and procurement schedules for electrical distribution equipment and supplies, and early establishment of management cadres capable of putting tubewell fields into operation immediately upon completion. For these various reasons the Bank Group considers it doubtful whether the ongoing program can be completed as scheduled unless it is given exceptional priority and the status of an emergency operation.

6.38 The measures needed to step up the rate of implementation of tubewell projects -- particularly those measures listed in the preceding paragraph -- should be taken as a matter of urgency. If implemented immediately the Bank Group believes that completion of about 2,000 wells per annum should become feasible towards the end of the Third Plan. Therefore the program presented here foresees completion by the end of the Third Plan of some 894 wells in projects additional to those included in WAPDA's ongoing program. Table 28 shows the Bank Group/IACA Action Program for the remainder of the Third Plan, including the additional projects, a revised WAPDA schedule for installation of the SCARP IV wells and various other minor changes from the WAPDA schedule of Table 27. All projects with the exception of SCARP III, Wagah and Shorkot-Kamalia would continue into the Fourth Plan period.

Table 28

Action Program for Public Groundwater Development During Third Plan
(No. of wells installed)

	1966/67	1967/68	1968/69	1969/70
SCARP II	420	590	615	580
SCARP III	270	520	465	215
SCARP IV	50	370	565	635
Khairpur	80	200	288	
Wagah			95	
Shorkot-Kamalia			100	326
Rohri North				140
Panjnad Abbasia				183
Total wells	820	1,680	2,128	2,079

Wagah is a small area (about 50,000 acres canal commanded) lying between the Bambanwala-Ravi-Bedian-Dipalpur Link, as remodeled under the Indus Basin Works, and the Indian border. It has in the past been served by the Upper Bari Doab Canal from the Ravi and so it will lose canal supplies when the Indus Treaty is fully implemented. Canal supplies in the BRBD Link are required for other areas and transfer of water from the Link into this area would anyway involve lift pumping and remodeling of the distributaries. The area is underlain by fresh groundwater and IACA estimates that the recharge to the aquifer from surface run-off and seepage from the adjacent link canal would be sufficient for tubewells alone to provide full-delta supplies for a cropping intensity of 150 percent.

6.39 The remaining three projects included in Table 28 are new projects which have been the subject of preliminary feasibility reports by IACA which have in turn been reviewed by the Bank Group. Tables 29 and

30 show some of the main technical characteristics of the areas in question and some details of the development proposed. The location of the projects is shown on Map 3 at the end of the chapter.

Table 29

New Third Plan Project Areas -- Technical Characteristics

	CCA per./nonper. a/ ('000 acres)	Water per Cropped Acre (a.f. per acre) Present	Required	Grounwater Quality and Depth (% CCA) Less than 1000 ppm less than 10 feet	more than 10 feet	Above 1000 ppm b/
Shorkot-Kamalia	214/80	2.2	2.8	71%	5%	24%
Panjnad-Abbasia	59/819	2.5	3.5	73%	9%	18%
Rohri North	598/-	2.6	3.4	37%	38%	25%

a/ Perennial/nonperennial.
b/ All groundwater of mixing quality, except for 13% of Shorkot-Kamalia area.

Table 30

New Third Plan Projects -- Proposed Development

	No. of Public Wells	Cropping Intensity Present	Proposed	Rate of Return to Project	Present Worth of Increase in Production (PRs mln) With Project	With Private Tubewells
Shorkot-Kamalia	426	92%	149%	21%	159	95
Panjnad-Abbasia	1,623	95%	148%	22%	596	288
Rohri North	1,580	95%	145%	16%	329	162

These projects were scheduled early in the proposed program of development largely because they are in a more advanced stage of preparation than most other projects. Nevertheless they are also projects upon whose priority there was a strong degree of unanimity among the results of the various analyses carried out by the Bank Group and its consultants described in Chapter V.

6.40 The Shorkot-Kamalia area lies at the southern tip of Rechna Doab and it includes areas of former river flood plain along the banks of both the Ravi and the Chenab. Part of the area has been irrigated since the 1890's by the Lower Chenab Canal, but much of it has only received perennial supplies in the last 30 years, chiefly under the small Haveli Project completed in 1939. WAPDA has prepared a public tubewell project, SCARP V, covering the whole of Lower Rechna Doab (some 1.5

million acres with 2,300 wells and scheduled to start in fiscal year 1967/68), which would complete the public tubewell coverage of Rechna Doab started with SCARP I and continued with SCARP IV. However Rechna Doab is one of the areas where private tubewells have spread most rapidly (there were an estimated 10,500 private wells in the area by 1965) and where chances seem to be good for further rapid growth. To take advantage of this opportunity of easing the burden on the public sector IACA suggested confining public tubewell development initially to the Shorkot-Kamalia portion of SCARP V. In this sector rapid growth of private tubewells is less likely to occur, farming being less advanced there; moreover there are very serious problems of soil salinity -- some 25 percent of the CCA is affected -- and of waterlogging -- more than 25 percent of the CCA has a water-table depth of less than five feet -- and private wells are unlikely to be able to cope adequately with these problems for a long time to come. Climatically this area is well suited to cotton, but yields are low compared to other areas due to waterlogging and salinity; rice, the other important cash crop in the area, is more tolerant of waterlogging, but yields are again low because climatic conditions are unsuitable. Public tubewell development will help to deal with these pressing problems, will enable substantial immediate increases in irrigation supplies since three-quarters of the area is underlain by fresh groundwater and will also provide sufficient water-table control so that additional rabi surface water deliveries, when they become available from Tarbela, can be absorbed without threat of further waterlogging. The tubewells required would all be installed within the Third Plan period.

6.41 Additional rabi surface supplies will particularly be needed in that part of the project area -- about one-quarter -- which is not underlain by fresh groundwater. To enable these additional quantities of surface water to be brought in, a small amount of canal remodeling will be required, and, though this is not scheduled in the program for execution until the early years of the Fourth Plan period it is discussed here because it was included in the cost base for calculation of the rate of return on the whole project shown in Table 30 above. The area for which enlarged canal capacity is required is mainly in the Haveli Canal Command. IACA estimate that an increase in capacity of about 30 percent will be adequate for the distributaries supplying the 11,000 acres underlain by groundwater of between 1,000 and 2,000 ppm TDS; the existing channels could be widened and deepened. But very much larger increases in canal capacity will be required in the 50,000 acres underlain by saline water or water that must be mixed with large quantities of surface water before application to the crops, and for these areas IACA recommends construction of entirely new channels paralleling the existing ones. The area underlain by water that is totally unusable for irrigation purposes is relatively small -- about 37,000 acres -- and IACA suggests that this would be an appropriate place for a pilot project in tile drainage. However the costs of this work have not been included in the cost base of the project because it would be largely in the nature of an experiment designed to test the feasibility of this type of drainage in the Punjab.

6.42 The Panjnad-Abbasia Project covers a much larger area than Shorkot-Kamalia and it would only be started within the Third Plan period, most of the tubewells not becoming operational before the early years of the Fourth Plan. The project area, which is adjacent to the confluence of the Indus with its Punjab tributaries, is one of the chief non-perennial areas originally developed as part of the Sutlej Valley Project. It typifies many of the advantages and disadvantages of that region. It has in the past suffered from severe water shortage because of unreliable river flows and a low priority for surface water allocations. Crop-water requirements are high relative to those elsewhere in the Punjab, because of the southern location of the project area, and Table 29 shows that current average irrigation supplies fall very seriously short of requirements. The shortage and unreliability of water supplies is reflected in the cropping pattern which has an unusually large component of drought-resistant coarse grains such as jowar and bajra. What water is available appears to be concentrated on the main crops -- cotton, for which the area is very well suited, and wheat -- and yields on these crops are comparable with yields obtained in the perennial areas of the Punjab. More than 80 percent of the project area is underlain by fresh groundwater, but private tubewells have so far grown slowly; there were estimated to be about 600 installed by 1965 or an average of only one well for nearly 1,500 acres of CCA. A small part of the project area is designated perennial and rabi surface supplies to that area may become somewhat more regular as a result of the completion of Mangla Dam, but otherwise the shortage and variability of irrigation deliveries will not be substantially altered by the Indus Basin Works. Apparently because of its location at the confluence of the rivers Panjnad-Abbasia suffers from a high water table -- groundwater within 10 feet of the surface in more than 80 percent of the area -- and severe waterlogging. The proportion of the land affected by soil salinity varies between about 20 percent and 60 percent in different parts of the project area. According to the Bank Group's calculations, public tubewells, supplemented by some additional rabi surface deliveries from Tarbela after the groundwater table has been brought under control by public wells, would enable full irrigation supplies to be provided for an intensity of 148 percent by 1985; private wells, on the other hand, as far as can be foreseen, would only be able to support an intensity of about 114 percent at that date. Hence, as indicated in Table 30, the increase in the net value of agricultural production with public wells is anticipated to be more than twice the increase attainable with private wells in present-worth terms.

6.43 To enable attainment of 150 percent cropping intensity over the whole of the project area canal remodeling would be required in about 100,000 acres underlain by groundwater of mixing quality. There are also extensive areas with saline groundwater and high water table adjacent to the project area where, IACA estimates, water supplies could be increased by canal remodeling sufficiently so as to support a cropping intensity at full delta irrigation of 150 percent intensity as compared to a present level of 82 percent. The economic analyses carried out by the Bank Group and its consultants suggested quite high priority for this work. However before additional surface water could be absorbed it would be necessary to provide for drainage of these high water table areas. IACA believes that the most economical form of drainage for the area would be tubewells discharging into channels which would dispose of the water in the neighboring Thar Desert. This scheme would need considerable investigation before it could be undertaken, but in conjunction with remodeled canals for the saline area and surface storage to provide the necessary rabi supplies it would enable large increases in irrigation supplies and agricultural output. Within a few years of commencement of public tubewell irrigation in the fresh groundwater zones in the area, it would also probably become important to provide drainage in the saline zones to prevent migration of saline water and consequent contamination of the fresh groundwater aquifer. Thus drainage and related canal remodeling for the saline zones in the Panjnad-Abbasia area are foreseen in the development program for the Fifth Plan (1975-80), and, as a start to them, canal remodeling for the mixing zone of Panjnad-Abbasia is proposed for the end of the Fourth Plan. Neither the costs nor the benefits of this work, however, are included in the Panjnad-Abbasia Tubewell Project presented.

6.44 Rohri North, the last area proposed for initiation of public tubewell development before the end of the Third Plan period, contrasts in many respects with the areas discussed above. It is one of the most promising areas of the Sind, located on the left bank of the Indus immediately south of the ongoing Khairpur tubewell project. The area is designated perennial and irrigation supplies, which are drawn from Sukkur Barrage, vary relatively little from year to year. Rohri Canal is in fact often run somewhat above its design capacity. However irrigation supplies are inadequate for the acreage now cropped; the canal was designed for a kharif cropping intensity of 27 percent, but the existing kharif intensity is about 36 percent. The area includes some of the most extensive areas of fresh groundwater in the Sind. Nevertheless private tubewells are very few and farming is generally backward. It is estimated that about 60 percent of the farm area or nearly three-quarters of the farms are operated by share-cropping tenants. The landowners generally live away from their lands, and apparently take little interest in their farms. The main cash crops are cotton in summer and oilseeds in winter, but relatively small acreages are devoted to them. However crop yields are rather above the very low averages representative of the Sind and IACA believes that the average cropping intensity could be increased from its current level of about 95 percent with underwatering to about 145 percent with full watering by installation of a public tubewell scheme and some slight additional surface supplies at times when canal capacity is not a constraint. Tubewells alone could provide sufficient water, in combination with current canal deliveries, to reach 150 percent intensity in almost all the fresh groundwater areas, but the average intensity would be held down by the mixing zones where intensities would be severely limited without canal remodeling and this, which would be exceptionally complicated because of the scale of the Rohri Canal, IACA does not recommend until the Fifth Plan period. Surface salinity is not a widespread problem in this area so that additional water supplies could be used immediately to grow more crops rather than for land reclamation. Waterlogging is also not a serious problem in most parts, although 40 percent of the area has groundwater within 10 feet of the surface so that the water-table control provided by the public tubewells will be valuable. Despite the generally favorable technical conditions for private tubewell development the prevailing situation in the project area is such that private wells are unlikely to spread rapidly. Nevertheless the Bank Group tested the proposed public project against an accelerated introduction of private tubewells (which were assumed to grow from about 100 in 1965 to about 2,200 in 1975). The public project appeared more attractive than the private project, producing twice as much in terms of present value of the increase in agricultural production. In practice, however, private tubewells might develop rapidly in certain confined areas -- for instance the blocks where groundwater is fresh and well below the surface, which cover nearly 40 percent of the project area -- and the Bank Group thinks that serious attention should be given to the possibility of encouraging private development there and concentrating the public effort initially in the hydrologically more complicated parts of the project area.

6.45 The Bank Group believes that a public tubewell program including the initiation of the three projects mentioned above is at the outside limits of what can be accomplished during the Third Plan period. This emphasizes the crucial need for continued rapid growth of private tubewells. The contribution from the public program alone will be inadequate to support the growth of agricultural production that West Pakistan must have to achieve a high overall growth rate in provincial output. While the performance of the public tubewell program has in the past fallen very far short of expectations despite the high priority it was accorded, private tubewell development with little Government support achieved an impressive rate of progress. As discussed in Chapter II private tubewells added more irrigation supplies during the Second Plan period than the public efforts as a whole. In view of the relative performances in the past, the need to ration the deployment of public resources, the urgency of improving agricultural growth, and the desirability of fostering private initiative amongst farmers, any lack of emphasis on continued private development at least for the time being would appear inconsistent with the needs of the situation.

6.46 IACA's overall projection of the total number of private tubewells that will be installed appears modest in the light of past experience. Their figures, adjusted in the light of information recently available regarding the situation that existed in 1965, would suggest that the number of private tubewells in existence would increase from about 34,000 in 1965 to about 55,500 in 1970. In their projection they made allowance for the fact that public wells will gradually be replacing private wells and that announcement of a forthcoming public tubewell project for an area will tend to slow down the rate of installation of new private wells there. In absolute terms the IACA figures imply that the average annual increase would drop from more than 5,000 wells during the Second Plan period to slightly more than 4,000 wells in the Third Plan. Recent preliminary estimates indicate that the total number of private wells installed in the northern zone alone between 1965 and 1966 exceeded 8,400 of which about 7,900 were apparently new wells while the remainder were replacements. While there may be a gradual slowing down of private tubewell development, and there is some indication that areas where private development has already been most active may be approaching a "saturation point", it is reasonable to expect that further extension can be brought about by public stimulation and encouragement, as envisaged in the Third Five Year Plan documents. Assuming that active support for private development is forthcoming and that any undue competition by public groundwater development is carefully avoided, the Bank Group sees no reason why an average annual rate of installation of about

6,500 wells, achieved at the end of the Second Plan period, should not be maintained during the Third Plan period. This would bring the total number of private wells in operation to 66,500 by 1970.

6.47 The need for such development is emphasized by the following table, which shows the maximum contributions to irrigation supplies in 1969/70 that can be expected from the public tubewell program, as rescheduled, and from the number of private wells projected by IACA and compares them with the amounts of groundwater shown by the sequential analysis to be required to meet irrigation requirements in that year under mean-year hydrological conditions.

Table 31

Groundwater Pumped During Third Five Year Plan Period if Action Program is Carried Out

	1965/66		1969/70	
No. of Tubewells in Operation	Canal Commanded Area	Outside Area	Canal Commanded Area	Outside Area
Public	2,900	-	9,600	-
Private	29,000	5,000	46,500	9,000
Estimated Annual Pumpage in MAF				
Public	2.7	-	10.2	-
Private	7.0	1.0	9.0	1.8
TOTAL	9.7	1.0	19.2	1.8
Private as percent of total	72%	100%	47%	100%
Requirement as calculated in the Sequential Analysis	9.6	-	21.7	-

It is anticipated that about 9,000 of the private wells projected by IACA for 1969/70 would be located outside the canal commands. The private wells within the canal commanded areas should deliver about 9.0 MAF. The number of public wells shown in Table 31 is the maximum that could be expected to be installed by 1970 if the recommended program were fully adhered to. It would appear, therefore, that continued private groundwater development on about the scale presently experienced is imperative in the short run if the essential growth in agricultural production is to be achieved. The Bank Group would strongly suggest that the Pakistan authorities implement policies conducive to rapid private tubewell development as a matter of urgency. The improvement of existing institutional support, in particular credit facilities, technical advice, and counsel for cooperative ownership and utilization, should be given high priority (see further Chapter IX). Financial resources required for such support would be small compared to the savings to the public sector that would accrue from avoidance of an over-extended public tubewell program and from the ability that the Province should develop to meet its own food requirements and forego imports.

6.48 There are two other major public projects in the water sector which are included in the Bank Group's program for commencement before the end of the Third Plan period. One is the Sukh Beas Drainage Scheme, for which IACA has prepared a project report on the basis of a proposal by the Government of Pakistan, and the other is the Left Bank Outfall Drain which has been proposed by LIP for the Sind but for which no project report is yet available. Both are large projects which will take many years to execute, especially the Left Bank Outfall, and it is important to start them early.

6.49 The purpose of the Sukh Beas Scheme is to permit reclamation of waterlogged lands and to prevent further waterlogging and flood damage caused by surface run-off in the upper and central parts of the Bari Doab. The main element of the project would be the canalization of the old bed of the Beas River, but a substantial part of the cost would be in the extension and remodeling of branch drains discharging into Sukh Beas. The course of the proposed 327-mile long drain runs from Kasur in Lahore District diagonally across Bari Doab to the Chenab River near Jalalpur Pirwala in Multan District. The catchment area is about 3.3 million acres bordering on the Dipalpur, Pakpattan and Mailsi canals on the east, and the Lower Bari Doab main canal on the west. The drain would have a discharge capacity of 462 cusecs at the head and 2,263 cusecs at the tail. Construction, including completion of field drains, is estimated to take nine years. IACA estimated the agricultural benefits of the project by comparing the flood damage which would occur with the provision of surface run-off drainage against the damage likely to occur without such provision. In this way IACA has established, on the basis of agricultural benefits alone, a rate of return of about 15 percent and a benefit/cost ratio of 1.8. The Bank Group considers the project to be of high priority. It would help protect crops from flood damage in one of the most productive areas of the Province and would support private as well as later public, tubewell development. To the extent that the reduction in prolonged flooding of large agricultural areas would reduce the recharge to the groundwater aquifer, the project would also contribute to the control of the water table in large parts of Bari Doab.

6.50 The Left Bank Outfall Drain, the first stage of a large drainage complex proposed by LIP for the Sind, would carry some surface run-off, particularly from areas south of Nawabshah (see Map 1 in Chapter I), but its main purpose would be to remove to the sea saline subsoil drainage water from the greater part of the Indus Left Bank south of Sukkur. It would have an overall length of 257 miles stretching from near Khairpur to the Rann of Kutch and would provide a maximum discharge of 15,000 cusecs. The cost has been estimated by the LIP consultants at PRs 610 million, exclusive of the branch and lateral drainage system. The massive scale of the works in this project, involving a construction period of some 16 years, necessitates an early start and because effluent disposal works would need to be available by the time drainage wells in saline groundwater areas come into operation, the Bank Group has concurred with the LIP consultants' proposals for construction to start in 1968. This would mean that a rapid program of studies and site investigations must now be undertaken.

Irrigation Development -- Fourth Plan Period

6.51 The principal objective of irrigation development in the Fourth Plan period, as during the Third Plan, must be to supply more water to the farmers in areas where it can be used to greatest immediate advantage and to deliver it to the land in a manner which is timely and suited to the crop calendar. Subsidiary to this objective, but not without importance, are two other considerations directly related to the fact that Tarbela is due to be completed at the end of the Fourth Plan. First, the drainage capacity of the land, especially in those areas which already have a high water table, needs improvement before additional supplies of irrigation water can safely be accepted on a long-term basis. Second, irrigation developments should be consistent with gradual movement towards the kind of integrated use of all water resources, which was described in Chapter IV and which will become increasingly important in later years when water resources are more fully used.

6.52 In public tubewell development during the Fourth Plan period the first job will be to complete the projects started before 1970. The top of Table 32 shows the four projects which, according to the recommended program, will be ongoing in 1970: SCARP II, SCARP IV, and two of the new projects discussed above in connection with the Third Plan -- Rohri North and Panjnad Abbasia. In these four projects alone there will be more than 4,800 wells to be completed during the Fourth Plan, on the present schedule. If these projects are assured of completion on schedule, then consideration would be given to further projects. If, in addition, private-well performance in the various areas appears likely to be as projected here and WAPDA seems able to commit itself firmly to completion of an average of 2,200 wells a year, then the Bank Group believes that the remainder of the schedule presented in Table 32 is worthy of serious consideration.

Table 32

Action Program for Public Groundwater Development During Fourth Plan
(Number of wells installed)

	1970/71	1971/72	1972/73	1973/74	1974/75
SCARP II	305				
SCARP IV	600	600	450		
Rohri North	360	360	360	360	
Panjnad Abbasia	540	500	400		
Dipalpur above BS Link	130	360	140		
Shujaabad	165	360	200		
Ravi Syphon Dipalpur Link		170	360	250	
Fordwah Sadiqia			150	360	155
Rohri South			230	360	360
Bahawal Qaim				210	360
Begari Sind				180	360
Dipalpur below BS Link				90	360
Sukkur Right Bank					180
Initiation of New Projects				180	540
	2,100	2,350	2,290	1,990	2,315

However, the Bank Group believes that further experience with private development may well justify some rephasing of this program. If new projects are to be ready for commencement at the beginning of the Fourth Plan detailed project preparation, which would normally take about two years before the start of construction work and therefore three years before the first wells come on stream, will have to start in the near future. The Bank Group's analysis indicates that highest priority in the preparation of Fourth Plan projects should be accorded to Rohri South, Fordwah Sadiqia and Bahawal Qaim. Decision on the Bari Doab projects -- Dipalpur, Shujaabad and Ravi Syphon-Dipalpur -- should be made in the light of further experience with private development. The Sukkur Right Bank and Begari Sind projects, both in the Lower Indus, would appear appropriate for execution late in the Fourth Plan. These projects are shown on Map 3 at the end of the chapter.

6.53 Fordwah Sadiqia and Bahawal Qaim projects are contiguous with one another as well as with Panjnad Abbasia and constitute a narrow strip of land, not more than about 20 miles wide, extending some 200 miles along the left bank of the Sutlej River. They represent parts of four canal commands originally developed under the Sutlej Valley Project. IACA defined the project areas to include those portions of these canal commands which, largely because of their proximity to the river, are underlain by usable groundwater. Like other parts of the Sutlej Valley Project these areas suffer from inadequate and unreliable canal deliveries. Conditions are quite suitable for private groundwater development but the installation of private wells has not attained a pace to compare with that in the neighboring Bari Doab. IACA estimated that in 1965 about 10 percent of the canal-irrigated area was receiving supplemental supplies from private tubewells. The standard of farming and average crop yields are also somewhat below those in Bari Doab. Though the area is very suitable for cotton, only about 7-8 percent of the canal-commanded acreage is devoted to cotton and average cotton yields are some 15-30 percent below the average attained in the main cotton growing areas of the Punjab. Drought-tolerant jowar and bajra are important kharif crops, especially in Bahawal Qaim. Coarse rice has become important in Fordwah Sadiqia because of the high water table -- within 10 feet of the surface over more than half the project area -- despite climatic conditions which are not very favorable. As a result of under-irrigation and high water tables there are areas of severe salinity; the problem is worse in Fordwah Sadiqia, where nearly 17 percent of the land is believed to be waterlogged waste and there are additional areas affected by soil salinity. Table 33 gives some details of the existing technical conditions and the proposed public tubewell development in the two areas.

Table 33

Proposed New Fourth Plan Project Areas -- Sutlej Left Bank

Technical Characteristics	CCA Per./nonper.[a/] ('000 acres)	Water per cropped acre (af/acre) Present	Water per cropped acre (af/acre) Required	Groundwater Quality & Depth (% CCA) Less than 1000 ppm: Less than 10 ft.	Less than 1000 ppm: More than 10 ft.	Above 1000 ppm
Fordwah-Sadiqia	61/298	2.0	3.0	32%	34%	34%
Bahawal Qaim	167/355	2.2	3.1	7%	57%	36%

Proposed Development	No. of Public Wells	Cropping Present	Intensity Proposed	Rate of Return to Project	Present Worth of Increase in Production (PRs mln.) With Project	With Private Tubewells
Fordwah-Sadiqia	665	81	145	30%	302	87
Bahawal Qaim	924	85	146	34%	431	117

a/ Perennial/nonperennial.

6.54 The contrast between the groundwater conditions in these two areas makes a difference to their development potential. Nearly two-thirds of each area are underlain by fresh groundwater, and the Bank Group believes that the number of private tubewells installed in each area might, in the absence of public development, increase some 300 percent by 1975 and 400 percent by 1985. In neither case would private tubewells be able to pump more than about half of annual recharge. Whereas this would make it imprudent to deliver any more surface water, when it becomes available from Tarbela, to Fordwah Sadiqia with its already high water table it would matter much less in the case of Bahawal Qaim where the water table is below 10 feet over more than 90 percent of the area. According to IACA's judgment, substantial quantities of Tarbela water could safely be delivered to Bahawal Qaim. In that case, with private tubewell development, Bahawal Qaim might be raised to a full delta cropping intensity averaging 125 percent by 1985, but Fordwah Sadiqia could only be raised to about 96 percent by that time. Public tubewell development, on the other hand, would raise both areas to cropping intensities in the neighborhood of 145 percent average, but in Bahawal Qaim it would also leave available for use elsewhere most of the Tarbela water. The various economic analyses reflected these technical differences. All concurred in showing high priority for the Fordwah Sadiqia project. But the benefits of the Bahawal Qaim project were found to be sensitive to the assumptions made regarding the feasibility of altering surface water allocations and regarding the value of surface water released from the project area. In the proposed program the project is scheduled for completion at a time when the overall availability of surface water would be a less severe constraint; so that the rate of return given in Table 33, which includes the benefits from the saving in surface water, is to some extent an overstatement. The Bank Group therefore concluded that Fordwah Sadiqia was a priority project for early execution and that while Bahawal Qaim was also fully worthy of inclusion in the program it should be scheduled one year later.

6.55 In the Lower Indus area the recommended program includes three tubewell projects for initiation during the Fourth Plan period -- one, Rohri South, of relatively high priority and proposed for commencement early in the Plan, and two, Begari Sind and Sukkur Right Bank, of somewhat lower priority and presently scheduled later in the period. The table below gives some details regarding these project areas and the development proposed.

Table 34

Proposed New Fourth Plan Project Areas -- Lower Indus

Technical Characteristics	CCA Per./nonper.[a] ('000 acres)	Water per cropped acre (af/acre) Present	Water per cropped acre (af/acre) Required	Groundwater Quality & Depth (% CCA): Less than 1000 ppm[b] Less than 10 ft.	Groundwater Quality & Depth (% CCA): Less than 1000 ppm[b] More than 10 ft.	Above 1000 ppm
Rohri South	528/-	2.6	3.5	4%	72%	24%
Begari Sind	-/349	2.4	3.2	90%	10%	-
Sukkur Right Bank	232/41	3.1	3.2	58%	1%	41%

Proposed Development	No. of Public Wells	Cropping Intensity Present	Cropping Intensity Proposed	Rate of Return to Project	Present Worth of Increase in Production (PRs mln.) With Project	Present Worth of Increase in Production (PRs mln.) With Private Tubewells
Rohri South	1,500	83	132	23%	342	118
Begari Sind	880	80	150	14%	180	41
Sukkur Right Bank	820	111	150	16%	178	52

a/ Perennial/nonperennial.
b/ Less than 1,200 ppm in case of Begari Sind.

The Rohri South project area, over 500,000 acres canal-commanded area, covers the lower half of the existing Rohri Canal Command on the left bank of the Indus and extends from the site of the proposed Sehwan Barrage to Hyderabad. It shares many of the same problems as Rohri North which was discussed above in connection with the Third Plan: very heavy dependence on share cropping, prevalence of absentee landlords, canal supplies that are fairly reliable since they come from Sukkur but very inadequate in total quantity, and almost complete lack of private tubewell development. Rohri South actually fares somewhat worse than Rohri North for canal supplies, partly as a natural consequence of being at the tail of the Rohri Canal and partly due to problems of siltation and canal regime. The water shortage restrains the rabi intensity which is lower than that in the North and it causes water applications in kharif to be below the optimum. Crop water requirements in the area are relatively high because of its southerly location. Nevertheless the area has some advantages. Problems of waterlogging and salinity are minimal, being confined to barely two percent of the area. Three-quarters of the irrigated land is underlain by fresh groundwater and the remainder by water between 1,000 and 2,000 ppm that can be mixed with surface supplies. Rohri South has the reputation of being the best cotton area in the Sind and nearly a quarter of the land is sown to cotton each year; yields, at about 2.8 maunds of lint per acre, are not high but they compare favorably with other parts of the Sind. Oilseeds, mainly for export to East Pakistan, and wheat are the main rabi crops and yields on these crops too are relatively high. It is clear that the main irrigation need in this area is simply for increased supplies of water. Water supplies can be greatly increased merely by installing tubewells, but this is one of the areas where even in the fresh groundwater zones tubewells alone will not provide sufficient water for 150 percent intensity at full delta. Canal remodeling will be needed and is planned in connection with the Sehwan-Manchar Project in the 1980's. In the meantime the proposed public tubewell project could raise the project area to 132 percent intensity. Maximum effort should be made in the years before it starts (it could start in 1970) to get private enterprise to carry part of the burden by installing wells in the very extensive areas which are technically ideally suited for private well development. Should private development succeed, then the Bank Group would suggest to redesign and limit the public project to the areas less well suited for private development.

6.56 Begari Sind and Sukkur Right Bank areas, both on the right bank of the Indus and adjoining one another at the city of Sukkur, contrast in many respects with Rohri South. From a technical point of view they belong to a slightly later stage of development: the main need in these areas is for drainage, though more reliable water supplies could also help, and in both areas there are very extensive areas which are heavily salt affected and will need a major reclamation effort. Both areas include the usable groundwater portions of the canal commands in this area. Most of Sukkur Right Bank is commanded from Sukkur, while Begari Sind area has only been transferred from reliance on inundation canals much more recently, with the completion of Gudu Barrage in 1962. Coarse rice is the most important single crop in both areas, especially in Sukkur Right Bank where it occupies about 95 percent of the acreage cultivated in kharif. The standard of rice husbandry is relatively good. Average rice yields are among the highest in the Province, but they do vary greatly among farms, mainly due to the uncertainty of water supply and shortage of labor at the critically important transplanting stage. In Begari Sind the shortage of water under inundation canal conditions for meeting the highly peaked requirements of rice was minimized in the past in some of the area by planting cotton which requires about the same total quantity of water but spread over a much longer period. Nevertheless cotton yields are very low, partly because of the predominantly high water table conditions. As the water table is lowered and better seed, better plant protection and more fertilizer come to be used, IACA has indicated that cotton will probably become a relatively more attractive crop and so they project a large increase in the acreage devoted to cotton and a reduction in the acreage devoted to coarse rice. However, substantial increases in cropping intensity will only come about with reclamation -- some 35 percent of Sukkur Right Bank and 45 percent of Begari Sind are totally unused at present, mainly because of severe soil salinity and much of the land that is cultivated is affected by yield reducing salinity. Eventually it will be possible, without any canal remodeling, to make the nonperennial portions of the project areas perennial and to raise the annual cropping intensity to 150 percent, but the process will inevitably be slow and so the returns to these public tubewell projects are rather low compared to some others recommended. Private tubewells, on the other hand, appear incapable of providing adequate water-table control and the increase of production attainable with them would likely be only a fraction of what could be reached with public development. Water-table control is needed here more urgently than almost anywhere else, and whether or not this can begin to be provided during the Fourth Plan will depend greatly on the rate at which WAPDA can speed up its execution of tubewell projects and on the extent to which private enterprise can take over the development of easier areas for groundwater development.

6.57 There are four project areas in the Bari Doab which have been identified for possible development during the Fourth Plan period. They include some two million acres of canal-commanded area or about one-third of the total in the Doab, but they have been selected in such a way as to cover almost two-thirds of the area in the Doab having groundwater within 10 feet of the surface. The most northern of the project areas, Ravi Syphon Dipalpur Link Command, within the boundaries of which lies the city of Lahore, is one of the oldest areas of canal irrigation in the Province, having been supplied in the past mainly from the Upper Bari Doab Canal (called the Central Bari Doab Canal in Pakistan since Partition) with headworks at Madhopur on the Ravi; it is a perennial area. As the name of the area implies, the canal which commands it represents the last stretch of the Bombanwaba-Ravi-Bedian-Dipalpur Link and after 1970 it will draw all surface water supplies from the Chenab through this Link. Most of the remainder of the area identified for possible development in the Fourth Plan period is nonperennial and, apart from some 250,000 acres supplied from Sidhnai Barrage, it is almost entirely Sutlej Valley Project area on the right bank of the Sutlej, which after 1970 will also depend entirely on the links for surface water supplies. The table below gives some details of the four areas and of the public development projects studied.

Table 35

Possible New Fourth Plan Project Areas -- Bari Doab

Technical Characteristics	CCA Per./nonper.[a] ('000 acres)	Water per cropped acre (af/acre) Present	Water per cropped acre (af/acre) Required	Groundwater Quality & Depth (% CCA) Less than 1000 ppm: Less than 10 ft.	Less than 1000 ppm: More than 10 ft.	Above 1000 ppm
Dipalpur above BS	-/372	2.1	2.6	54%	38%	8%
Shujaabad	33/346	2.4	3.2	65%	15%	20%
RSD Link	595/-	1.5	2.3	10%	33%	57%
Dipalpur below BS	-/611	2.2	2.6	8%	51%	41%

a/ Perennial/nonperennial.

Table 35 (continued)

Possible New Fourth Plan Project Areas -- Bari Doab (continued)

Public Development	No. of Public Wells	Cropping Present	Intensity Proposed	Rate of Return to Project	Present Worth of Increase in Production (PRs mln.) With Project	With Private Tubewells
Dipalpur above BS	630	74	150	25%	150	150
Shujaabad	725	95	149	31%	259	178
RSD Link	780	113	150	25%	301	301
Dipalpur below BS	850	83	150	36%	192	192

Except in the Ravi Syphon Dipalpur Link Command, with its perennial canal supplies, existing cropping intensities are low compared with the Bari Doab average of 102 percent. Nevertheless in all these areas very substantial private tubewell development has taken place, so that by 1965 there was an average of one private well to about 400 or 500 acres and private wells together with Persian wheels are estimated to have been supplying between one-quarter and one-third of total water supplies -- and a much higher proportion of course in the rabi season. Between 20 and 25 percent of the land in each area is receiving supplemental supplies from private tubewells. One-half to two-thirds of the rabi cropped acreage is devoted to wheat. Fodder to support the large livestock population of the Doab is important in both seasons in all the project areas, but especially in Ravi Syphon Dipalpur Link and Shujaabad because of their proximity to the major cities of Lahore and Multan, respectively, where fodder is required for Tonga horses, etc. Rice, mainly of low quality, and cotton are the two other important kharif crops, but as waterlogging and salinity are removed, the different canal commands will probably distinguish themselves more clearly, those in the North increasing their cotton acreage and devoting more land to fine rice which is much more profitable than coarse rice but susceptible to soil salinity and those in the South concentrating to an even greater extent than they do now on cotton in kharif.

6.58 There is every prospect that private tubewells will continue to develop rapidly in the Bari Doab to support these increased cropping intensities and to provide water for the absorption of more fertilizer and other inputs. The Bank Group believes that, even in these somewhat more difficult areas which have been delineated as possible projects, private tubewells might spread, given proper stimulus, in the zones underlain by usable groundwater rapidly enough to reach an average density of one well for about every 120 acres by 1975. This would represent a considerably more rapid rate of development of private wells than envisaged by IACA. The Bank Group also believes that private tubewells at this density would be able to pump annual recharge in all the project areas except Shujaabad. And even in Shujaabad the private wells might be able to provide sufficient water table control to permit absorption, as in the other areas, of the same amount of additional surface water, mainly in rabi, as could be absorbed with public groundwater development. The result would be that average cropping intensities could be raised, entirely by private groundwater exploitation, to about the same level as could be reached with public groundwater development, except in the case of Shujaabad where the smaller contribution to be anticipated from private groundwater development would limit the full delta cropping intensity to about 126 percent. Since yield growth would not be expected to differ much with public or private groundwater development provided sufficient effort was made to support the growth of private tubewells with an expanded agricultural extension service, credit, and improved supply of fertilizer, better seed, etc., the increase in production should be of the same order of magnitude with private tubewell growth at this rapid rate as with a public tubewell project, as implied by Table 35.

6.59 The real prospects for this kind of private development will become clearer towards the end of the Third Plan. It will likely differ somewhat among canal commands, and even if the prospects turn out most favorable there will still remain a large amount of irrigation work to be undertaken by the public sector in the Bari Doab during the Fourth Plan. The main construction work on the Sukh Beas Drainage Scheme, introduced above in discussion of the Third Plan, will take place during the Fourth Plan. Attainment of a 150 percent cropping intensity in Ravi Syphon Dipalpur Link Command, whether with public or with private tubewells, will depend on canal remodeling in some 330,000 acres underlain by groundwater which is either too saline to be used on the crops or requires mixing. Canal capacity is severely limited in this canal command, being one of the old perennial areas, and all analyses have agreed in giving especially high priority to canal remodeling in the mixing zones although the restraining effects of lack of canal capacity on growth of cropping intensity would be much less severe there than in the unusable groundwater zones.

6.60 There are also considerable variations among the technical characteristics of the different project areas and these will call for varying degrees of public assistance in the improvement of irrigation, whether or not the full public projects outlined are undertaken. The area which most of the technical and economic analyses showed to be least in need of a public tubewell scheme out of the four was Dipalpur below the Balloki-Suleimanke Link. Some 60 percent of the area is underlain by fresh groundwater and the remainder by usable groundwater. Canal capacity is already sufficient to provide enough water, in conjunction with tubewell supplies, to reach an effective average cropping intensity of 150 percent. Soil salinity is confined to very small areas. The water table is less than 10 feet from the surface in about 28 percent of the area, which is considerably less than in the other proposed projects. IACA recognized that it might be preferable to postpone public development of this project. However, they proposed that the portion of the project area with a high water table might be brought under public development earlier, and the Bank Group recognizes that early public development might be required in order to secure proper mixing in the 40 percent of the area underlain by groundwater between 1,000 and 3,000 ppm, which also contains most of the land with high water table. Dipalpur above the Balloki-Suleimanke Link is more seriously affected by high water table -- within 10 feet of the surface over some 55 percent of the area and perhaps as much as 70,000 acres effectively waterlogged -- but almost the entire area is underlain by fresh groundwater which can be directly used. There the greater problem, solution to which will certainly require public assistance is reclamation of salt-affected land; a large portion of the project area is affected by salinity and while simple addition to water supplies will help to deal with this, about 125,000 acres will require major reclamation efforts if the projected cropping intensities are to be reached. In the Ravi Syphon Dipalpur Link, to the west, soil salinity is much less widespread but 45 percent of the area is underlain by groundwater of mixing quality and 12 percent by groundwater in excess of 3,000 ppm; the consequent need for canal remodeling was already referred to, and at a later stage, probably soon after 1975, drainage by shallow tubewells or by tile drains will be required. Shujaabad was the only one of the four areas which did not appear capable of reaching the same cropping intensity and increase in output with accelerated private development as with public groundwater development, but the differences were not very large. Being situated at the confluence of the Ravi and Chenab, the project area suffers severely from high water table -- within 10 feet of the surface over about three-quarters of the area and about 100,000 acres effectively waterlogged. In about 20 percent of the area groundwater would require mixing. Nevertheless private development has been rapid and there would appear to be considerable opportunities for its extension. Therefore the Bank Group concluded that while the prevalence of high water table and the extensive areas affected by salinity might be dealt with most effectively by a public project, with its more efficient drainage capability, nevertheless this, like the other areas selected in the Bari Doab, was an area which it might be prudent to omit from the public tubewell program if that program had to be cut back.

6.61 The public tubewell projects recommended above and the surrounding discussions of the projects and of private tubewell development in the same areas are the outcome of the basinwide survey and the various technical and economic analyses -- both basinwide and project specific -- described in Chapter V above. The basinwide economic analyses, using standardized data for each potential project area, did suggest that high priority for public groundwater development attached to certain areas not included in the final recommended program. There was a number of reasons for exclusion of these areas -- such as lack of data or doubt about the validity of the data used, uncertainty as to the feasibility of the development recommended by the economic analysis, and the fact that the economic analyses sometimes used areal units which were impractical to develop alone or were rather large so that they included some areas of relatively low priority along with others of very high priority. The various economic analyses agreed in giving high priority, for instance, to the small Peshawar Canal Commands -- largely due to the high-value crops which are widely grown there. Development in these areas was deferred in the recommended program until after 1975 because of lack of knowledge about aquifer conditions in the area and because what evidence is available suggests that well drilling is difficult there. The economic analyses also tended to show quite high priority for public tubewell development in the canal commands in the Thal and Indus Right Bank area -- Thal, D.G. Khan and D.I. Khan (Paharpur). For these areas, too, data are severely lacking and what data were available were of dubious quality. Moreover the canal systems in these areas are still under development and, as pointed out in Chapter II, natural conditions are not very favorable to irrigated agriculture. Extensive land leveling is required in Thal before efficient use of surface water supplies will become possible, and the sandy soils have poor water-retention qualities. Infrastructure, such as communications and markets, are only now under development, and the areas are thinly populated. Some of the analyses suggested priority for much wider areas in Lower Rechna Doab and Lower Bari Doab than have been included in the final program; large portions of these areas were excluded not because they have poor potential but precisely because they have such good potential that extensive groundwater exploitation will likely be undertaken by private enterprise. The small southerly portions of these areas where rapid private development seem less likely -- Shorkot-Kamalia in Rechna and Shujaabad in Bari Doab -- were tentatively included in the recommended program, but with reservations in the case of Shujaabad as discussed above.

6.62 The tubewell projects constitute the most critical part of the recommended public investment program for irrigation development during the Fourth Plan period and account for some 50 percent of the cost, but there are also developments proposed in canal remodeling and in drainage. The canal remodeling is primarily for the purpose of supplying the additional quantities of surface water required in several areas where mixing is required and partly to increase supplies in some saline areas contiguous with the project where tile drainage would be introduced simultaneously. Some of the projects proposed in these fields have been discussed earlier in connection with the tubewell projects: canal remodeling in Panjnad Abbasia, Ravi Syphon-Dipalpur Link and Shorkot Kamalia and tile drainage in Shorkot Kamalia. The surface drainage schemes, Sukh Beas and Lower Indus Left Bank, on which considerable expenditures would be incurred in the Fourth Plan period, were also discussed earlier in connection with the Third Plan. Both of these projects are proposed for starting as soon as possible, say, 1968. There would also be a number of other minor canal and drainage works which are ongoing. None of the specific proposals in canal remodeling and tile drainage listed in the table below could be underway until about 1969 and therefore have been included for execution during the Fourth Plan period.

Table 36

Specific Project Proposals -- Canal Remodeling & Tile Drainage

Canal Remodeling	('000 acres)	Tile Drainage	('000 acres)
Khairpur East & West	454	Shorkot Kamalia	40
Panjnad Abbasia	100	Lower Bari Doab	70
Ravi Syphon Dipalpur Link	330	Tando Bago	90
Lower Bari Doab	70	Khairpur East	120
Shorkot Kamalia (Haveli)	60	Kalri Baghar	30
	1,014		350

6.63 Both canal remodeling and tile drainage are recommended for Khairpur as an extension of the ongoing public tubewell project there. The various economic analyses undertaken showed higher priority for canal remodeling elsewhere, but practical considerations recommend execution of this work. After the Khairpur Project was started it was found that much of the groundwater was less saline than had been anticipated so that it could be used for irrigation provided it was mixed with surface water. IACA agreed with the LIP consultants that Khairpur, with a project team and facilities already in existence there, would be a good place for a first attempt at the difficult task of large-scale canal remodeling in the Sind. The program also includes tile drainage accompanying canal remodeling in a small area -- some 70,000 acres -- at the head reach of the Lower Bari Doab Canal. This project is intended primarily as a pilot project in tile drainage in the Punjab. The area proposed lies on the left bank of the Lower Bari Doab Canal and is a saline groundwater zone with shallow water table. The effluent would be disposed of into the Lower Bari Doab Canal. The other two areas listed for tile drainage are in two Ghulam Mohammed Barrage commands in the Sind and the projects proposed are essentially pilot projects in this type of drainage, which may later become very important in the extensive saline groundwater zones of the Sind.

6.64 The recommended program for the Fourth Plan period also includes a small allocation of PRs 75 million for flood protection works. IACA's analysis suggested that there was no justification for major works designed solely to provide protection from floods. Nevertheless they recognized the need for some works, especially as development proceeds and the damage that can be done by floods consequently becomes more severe. The specific projects undertaken will be guided by the work of the West Pakistan Flood Commission which is preparing a flood control plan for the Province. The Bank Group also foresees the possibility of continued rapid growth of private tubewells in several areas. The main new private tubewell investments during the Fourth Plan are expected to occur in the portions of Bari and Rechna Doabs not included in the public program and in the Indus Right Bank and Lower Indus regions. Considerable replacement investment might also be required in areas already covered by private tubewells and not brought within the public program. In areas where public tubewell programs are carried out, private tubewells probably would not be replaced as they wear out. Therefore, according to the Bank Group estimates, the total number of private tubewells in existence in 1975 might on balance be no larger than the number existing in 1970.

6.65 The following table illustrates the change in the number of public and private wells and in their contribution to total water supply between 1970 and 1975, assuming implementation of all proposed public tubewell projects on schedule.

Table 37

Groundwater Pumping During Fourth Five Year Plan Period if Action Program is Carried Out

	1969/70		1974/75	
	Canal Commanded Area	Outside Area	Canal Commanded Area	Outside Area
No. of Tubewells in Operation				
Public	9,600	-	20,700	-
Private	46,500	9,000	38,500	14,000
Estimated Annual Pumpage in MAF				
Public	10.2	-	21.7	-
Private	9.0	1.8	8.5	2.8
Total	19.2	1.8	30.2	2.8
Private as percent of Total	47%	100%	28%	100%
Requirement as calculated in the Sequential Analysis	21.7	-	31.0	-

The last line of the above table gives the amount of groundwater which the sequential analysis of the proposed program showed to be required to meet projected requirements, and it indicates that the proposed program can provide sufficient water. Public and private wells together would be pumping an amount of groundwater close to what IACA projected as annual recharge in usable groundwater zones by 1975 -- 34 MAF. The more than 20,000 public tubewells in operation would cover nearly 12 million acres of canal commanded area, or more than 40 percent of the total, and nearly 70 percent of the usable groundwater zones. The 38,500 private wells within the canal commands might cover at least another 3.5 million acres, so that more than 90 percent of the usable groundwater area would be receiving additional irrigation supplies from tubewells.

Irrigation Development -- Fifth Plan Period

6.66 The completion of Tarbela in 1975/76, with its storage and regulation capabilities, following the extensive public and private tubewell developments proposed for the Third and Fourth Plan periods, would create a situation in which irrigation supplies could be matched to the water requirements of crops to a much greater extent than has been possible in the past or will be possible before 1975. Irrigation supplies should then become adequate to meet the needs of an increasing cropped acreage at full delta, including the conversion to full perennial cropping of nonperennial areas where canal capacities, recharge to the aquifer or groundwater quality are inadequate to permit this to be done by groundwater development alone. Public and private tubewells would by 1975 have begun to reduce the water table in extensive areas where sustained application of increased surface supplies would otherwise cause a danger of waterlogging. Tarbela water would also play an important part in raising cropping intensities in the 12 designated tubewell project areas to the full 130-150 percent attainable without canal remodeling. It would be particularly important in the zones with groundwater of mixing quality. According to IACA projections all the tubewell project areas, barring Sukkur Right Bank, would absorb Tarbela water though the amount absorbed initially in 1975/76, when additional drainage pumping was still required and intensities were still below the ultimate attainable, would be less than what would be required later.

6.67 Specific projects have not been studied for the period after 1975, but some general lines of priority activity, insofar as they can be foreseen, have been identified. First priority would attach to completion of the public tubewell projects initiated in the Fourth Plan period. In addition public tubewell development would be carried further, especially in some of the usable groundwater zones that were not considered to be of sufficiently high priority for inclusion in the program for the first ten years. In addition, installation of tubewells for drainage purposes in saline zones might start on a large scale. Canal remodeling would become a much more important part of irrigation development activity with the increased supplies in the critical overlap months that would be available both from Tarbela and as a result of substitution of groundwater for surface water in some of the tubewell project areas with fresh groundwater. Figure 6 illustrates the main lines of activity in different areas suggested for this later period.

6.68 According to the schedule of execution for the proposed public tubewell projects there would remain some 2,300 wells to be completed in the first two years of the Fifth Plan period. The table below shows the number of wells involved in each area.

Table 38

Completion of Proposed Tubewell Projects in Fifth Plan Period
(Number of wells completed)

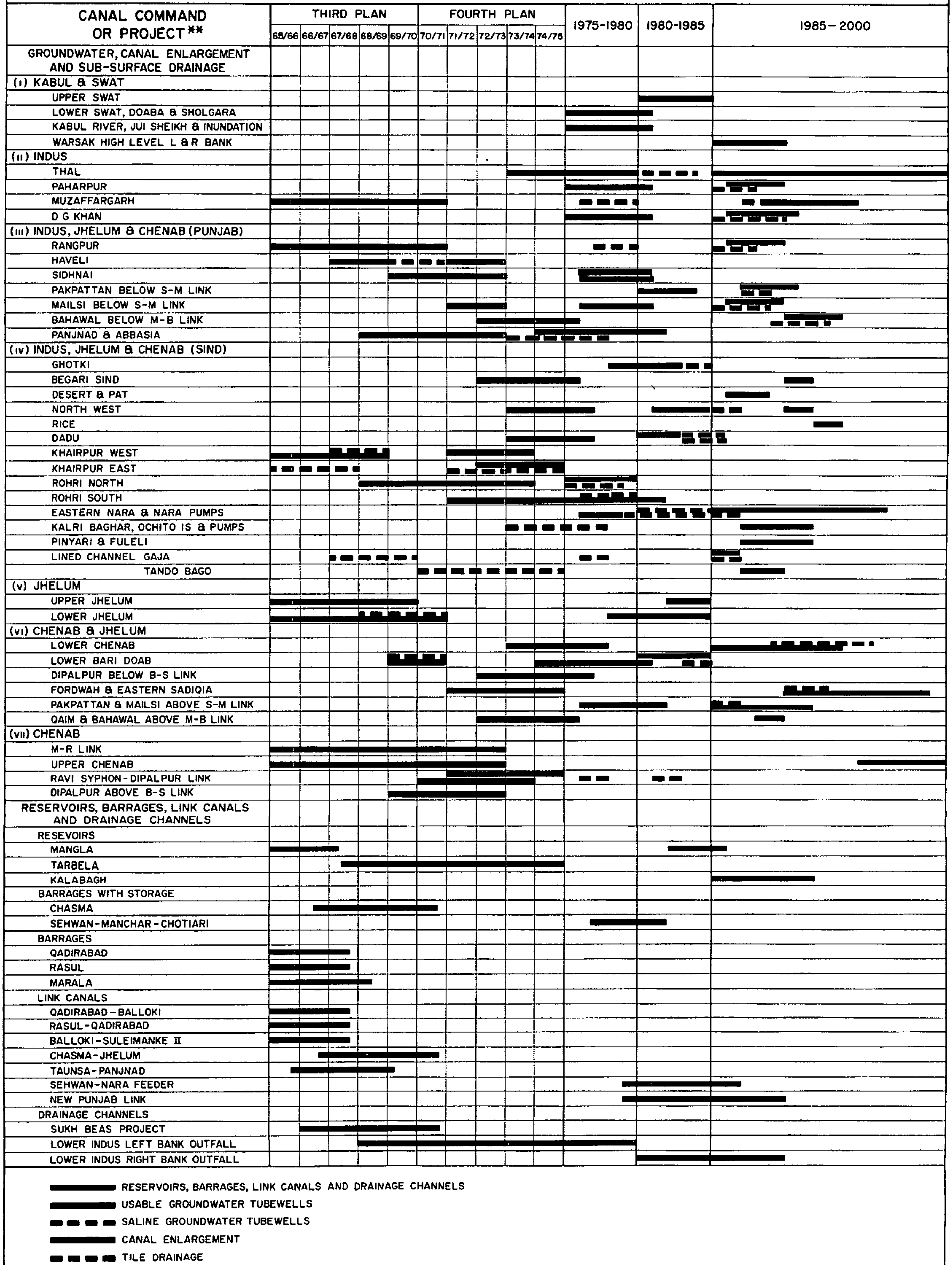
	1975/76	1976/77
Rohri South	360	190
Bahawal Qaim	354	
Begari Sind	340	
Dipalpur below BS Link	360	40
Sukkur Right Bank	360	280
	1,774	510

With the final completion of these tubewells some 5.8 million acres of canal commanded area would have been brought under public tubewell development by the projects specifically identified in the course of the Study. Of the total 5.8 million acres, some 4.1 million acres would be in fresh groundwater zones, 1.5 million acres in zones underlain by groundwater of mixing quality and 0.1 million acres in saline zones. In some 50 percent of the area covered by the projects groundwater would be pumped initially from a depth of less than 10 feet, indicating the concentration of the projects in areas with usable groundwater and high water table. The total pumping capacity installed in the projects would amount to about 37,000 cusecs, designed to extract about 12.6 MAF at full development; full agricultural development would generally be reached within about ten years of completion of well electrification but somewhat later in areas with very low initial cropping intensities or heavy reclamation needs.

6.69 Besides the 2,800 wells required to complete Fourth Plan projects, an additional 13,000 public wells might be installed during the Fifth Plan period according to the IACA projections. Some 4,000 of these would be in saline groundwater areas, particularly in the Rohri Canal Command and in the Thal and Indus Right Bank area. It is in this period also that drainage wells would be provided for the saline zones in the Panjnad Abbasia and Ravi Syphon Dipalpur Link areas that were discussed above for initial development of the usable groundwater zones in the Third and Fourth Plan periods. IACA proposed that about 9,000 wells in new projects in usable groundwater zones might also be introduced in the Fifth Plan period. These wells fall into two rather different categories. Some would be in areas such as Thal, D.G. Khan and D.I. Khan canal commands, where three-quarters of the area is underlain by usable groundwater but agricultural prospects are somewhat less bright than in the longer established farming areas and there is much infrastructure to be built in the meantime. Some of the Peshawar commands are also proposed for development in this period. But a large portion of the wells proposed for this period would be installed in the areas such as Lower Bari and Lower Rechna Doabs that had before been left for private development. On the IACA schedule there would by the end of the Fifth Plan in 1980 be only a few small areas with usable groundwater not developed by public wells -- notably Upper Swat, Warsak and parts of Pakpattan and Ghotki. This schedule reflects IACA's belief that public wells are generally more efficient than private wells, and that the complexities of integrating water supplies, water-table control, and drainage require public operation in the long term. The Bank Group believes these arguments are weighty but it also thinks private wells might become sufficiently dense and well-organized in some areas to provide reasonable water-table control and some degree of integration with the overall irrigation system, so that preservation of private exploitation could be worthwhile. The Bank Group recommends that this question should be left open for resolution after more experience has been gained about the full capabilities of private groundwater development, and so it concludes that some of the proposed 9,000 public wells in new projects may not be required in the Fifth Plan period.

6.70 Enlargement of canals serving about two million acres is foreseen for the Fifth Plan. Some of this would be in areas of saline groundwater but most would be in areas where the increased canal supplies could be used in conjunction with groundwater. Apart from the small amounts of canal remodeling proposed in connection with tubewell projects discussed above, IACA, in accordance with the economic analyses, attributes highest priority for major canal remodeling in the Punjab to Panjnad-Abbasia. Without canal enlargement large parts of the mixing zones in this area would be constrained to about 120 percent cropping intensity. Therefore continuation of canal remodeling in this area and extension of the work into the adjacent saline zones would be an important part of the Fifth

REVISED* IACA PROGRAM FOR IRRIGATION DEVELOPMENT



*MINOR REVISIONS MAINLY IN 1965/75 PERIOD - SEE CHAPTER IV **CANAL COMMANDS ARE GROUPED BY RIVER SOURCES

IBRD-3284

Plan period development. Another important area for canal remodeling in this period is some 500,000 acres in Sidhnai which were not included in the Shujaabad Project proposed for the Fourth Plan; here canal remodeling would be undertaken simultaneously with the installation of irrigation tubewells. Another priority area, where the canals were also originally designed to provide perennial surface supplies, is Rohri South where, as pointed out in connection with the tubewell project proposed for the area for initiation in the Fourth Plan, groundwater development alone would enable attainment of a full delta cropping intensity of only about 130 percent.

Irrigation Development -- Sixth Plan Period

6.71 With virtually all areas of usable groundwater covered by tubewells by 1980 and high cropping intensities already attained in many of these areas, attention would then swing increasingly towards areas underlain by groundwater too saline for irrigation use. Installation of drainage tubewells would continue at a rapid pace (5,000 wells in the Sixth Plan period), canals serving some three million acres would be enlarged, the Left Bank Outfall Drain which was proposed above for initiation in 1968 would be completed and work would commence on the other large-scale drainage project proposed by the LIP consultants -- the Right Bank Outfall Drain. In addition, the Sehwan-Manchar Project (see Chapter VII) would be completed in the Sind and a new link canal would be built across the Punjab to provide sufficient water for remodeled canals in zones of saline and mixing quality groundwater in the eastern Punjab.

6.72 The canal remodeling in Rohri South and the installation of drainage wells and tile drains there during the Fifth Plan would come to fruition with the completion of the first stage of the Sehwan Barrage in 1980. This completion date is considerably later than that proposed by the LIP consultants because IACA found that substantial development could be achieved in the Rohri Command, given the availability of Tarbela water, simply by the installation of tubewells in the usable groundwater zones, as proposed for the Fourth Plan period. Moreover, canal remodeling in the saline zones of Rohri necessitates the installation of drainage tubewells, and the basinwide studies suggested that the capacity to install wells could first be used to greater advantage in usable groundwater zones, as proposed in the programs for the Third and Fourth Plans. By 1980, however, the necessary expansion of canal capacity would have been executed and, in conjunction with Sehwan Barrage, a new feeder from Sehwan to the Rohri Canal would have been built to bring water to the enlarged canal. By 1982 the storage potential of the Sehwan Barrage and the neighboring Lake Manchar would have been developed. During the Sixth Plan period drainage wells and tile drains would be installed in Nara further to the east and after 1985 the feeder would be extended from Rohri to Nara.

6.73 The other main developments in the Sind in the Sixth Plan period would be the major drains mentioned above, canal remodeling and either tubewell or tile drainage in the saline zones of the Sukkur Right Bank canal commands, and public tubewell development in Ghotki. The Lower Indus Left Bank Outfall Drain was discussed in connection with the Third Plan; the Right Bank Drain, which would be built between 1980 and 1990, would serve the Gudu and Sukkur Right Bank areas and drain their effluent into the Indus downstream of Sehwan Barrage. The Ghotki area, something of an exception in the Sind, was omitted from the program for public development in earlier years because it is underlain by usable groundwater with a depth to water table in excess of 10 feet and it was felt that there were good prospects of private tubewell growth in the area. However, the water table appears to have been rising quickly mainly as the result of too much surface water and this position may need reexamination.

6.74 Development in the Punjab in the years following 1980 would be closely related to construction of the new trans-Punjab link which IACA recommends for initiation around 1980. Without such a new link the possibility of increased canal deliveries in the Punjab and hence the feasibility of development in the extensive saline and mixing zones in the eastern Punjab would be severely restricted. IACA proposed construction of a new canal with a capacity of about 1.5 MAF/month on an alignment across the Punjab running from the tail reach of the Chasma-Jhelum Link, crossing the Chenab in the vicinity of Chiniot, and leading ultimately into the Sutlej. Besides providing increased surface supplies for the eastern Punjab, such a link would add to the flexibility of the irrigation system by bringing much land that had previously been commanded only from the Jhelum/Chenab also under the command of the Indus. As the construction of this link proceeds so it will be possible to provide increased canal supplies further eastward. Because of the importance of this link, the Bank Group would stress the need for preparatory work, especially of possible alignments. IACA also recommends canal remodeling in the Sixth Plan period in saline and mixing zones in Chaj and Lower Bari Doabs. Remodeling in the Sutlej commands would come later as the link was extended there.

Irrigation Development after 1985

6.75 Apart from the introduction of public tubewells in Warsak High Level canal commands development foreseen after 1985 takes the form entirely of canal remodeling and of drainage tubewells and tile drains for saline zones. Canals serving some 10 million acres would be remodeled between 1985 and 2000, bringing the total area which would be provided with enlarged canal capacity between now and 2000 to some 16 million acres. Apart from some important areas, such as Sidhnai and Rohri which have already been discussed, where enlarged canal capacity is required in addition to irrigation tubewells to provide sufficient water for a 150 percent cropping intensity, most of the areas proposed for canal remodeling have groundwater in excess of 1,000 ppm. The canal remodeling program proposed -- which would increase the aggregate canal withdrawal capacity by some 40 percent to about 19 MAF/month -- is the minimum believed necessary to achieve cropping intensities of about 150 percent in perennial areas and 95 percent in those few areas likely to remain nonperennial (or an average of 145 percent for the development CCA of 29.4 million acres). Remodeling on this scale coupled with surface storage sufficient to meet the higher of the two sets of requirements projected by IACA (see Chapter VII) would by the year 2000 result in the complete diversion of mean year river flows into the irrigation system. Any water that enters the sea in a year of mean inflow would be essentially derived from saline drainage effluent discharged either through the river channels or through the Left Bank Outfall Drain.

6.76 Thus the proposed canal remodeling program does not include provision for the enlargement of canals supplying fresh groundwater zones that would be necessary if the underground storage potential of these zones were to be developed. This type of development, mentioned in Chapter IV as an alternative to surface storage, was investigated by IACA. They concluded that it might be adopted in the long term but they did not include it in the program. Since the fresh groundwater areas are mainly confined to the Punjab, development of underground storage of any scale would necessitate major link canal construction additional to that proposed above for the Fifth Plan. It would also entail some difficult hydraulic problems in operating the enlarged canal system because of the wide variations in canal flow that would be involved.

The Growth of Irrigation Supplies

6.77 IACA projected the irrigation water requirements implied by its program for agricultural development rising from estimated mean-year water supplies in 1965 of 68 MAF at watercourse head to 94 MAF in 1975, 117 MAF in 1985, and 135 MAF in 2000. The program outlined in the preceding pages would meet this growth of requirements with increased supplies of surface water and groundwater in the proportions indicated in the table below.

Table 39

Relative Use of Surface and Groundwater Measured at Watercourse Head

Reference Year	Surface Water		Groundwater		Total
	MAF	Percentage	MAF	Percentage	MAF
1965	58	85	10	15	68
1970 a/	56	75	19	25	75
1975	63	68	31	32	94
1985	77	66	40	34	117
2000	91	67	44	33	135

a/ Estimate for 1970 derived from sequential analysis with some adjustment for surpluses occurring during rabi period and effect of adopted pumping pattern (including pumping needed for lowering of water table in project areas) on surface water use.

This tabulation shows that the proportional contribution from groundwater is expected to be more than doubled over the first ten years. Thereafter the ratio would remain fairly constant because under balanced recharge pumping, the permissible pumping would become proportional to the surface supplies. After 1975 up to full development the increment in canal supplies follows the pattern of demand created by canal enlargement and includes the amounts that would be available from surface storage reservoirs (see Chapter VII). The contribution of private tubewells to the total groundwater abstraction in the canal commanded areas is currently about 50 percent but, although rising in absolute terms from 5 to 8 MAF in the decade 1965-75, the percentage contribution would fall to about 25 percent in 1975 and lower in following years as public wells supersede private ones. Figure 5 compares projected growth of surface water usage with mean flows.

6.78 The following table illustrates that the distribution of water supplies between Peshawar, the Punjab and the Sind would remain fairly constant over time, with the Punjab areas taking a slightly increasing share in the early period.

Table 40

Watercourse Deliveries to Main Sectors of Indus Basin
(MAF/Year)

Reference Year	Vale of Peshawar MAF	Vale of Peshawar Percent	Punjab MAF	Punjab Percent	Sind MAF	Sind Percent	Total (rounded) MAF
1965	1.7	2.5	40	59.5	26	38	68
1975	1.9	2	61	65	31	33	94
1985	2.8	2.5	75	64	39	33.5	117
2000	2.8	2	85	63	47	35	135

Groundwater which in 1965 accounted for nearly 25 percent of irrigation supplies in the Punjab and a negligible quantity elsewhere would from about 1975 onward account for over 40 percent of total irrigation supplies in the Punjab but only some 12 percent in the Sind.

Expected Results of Development

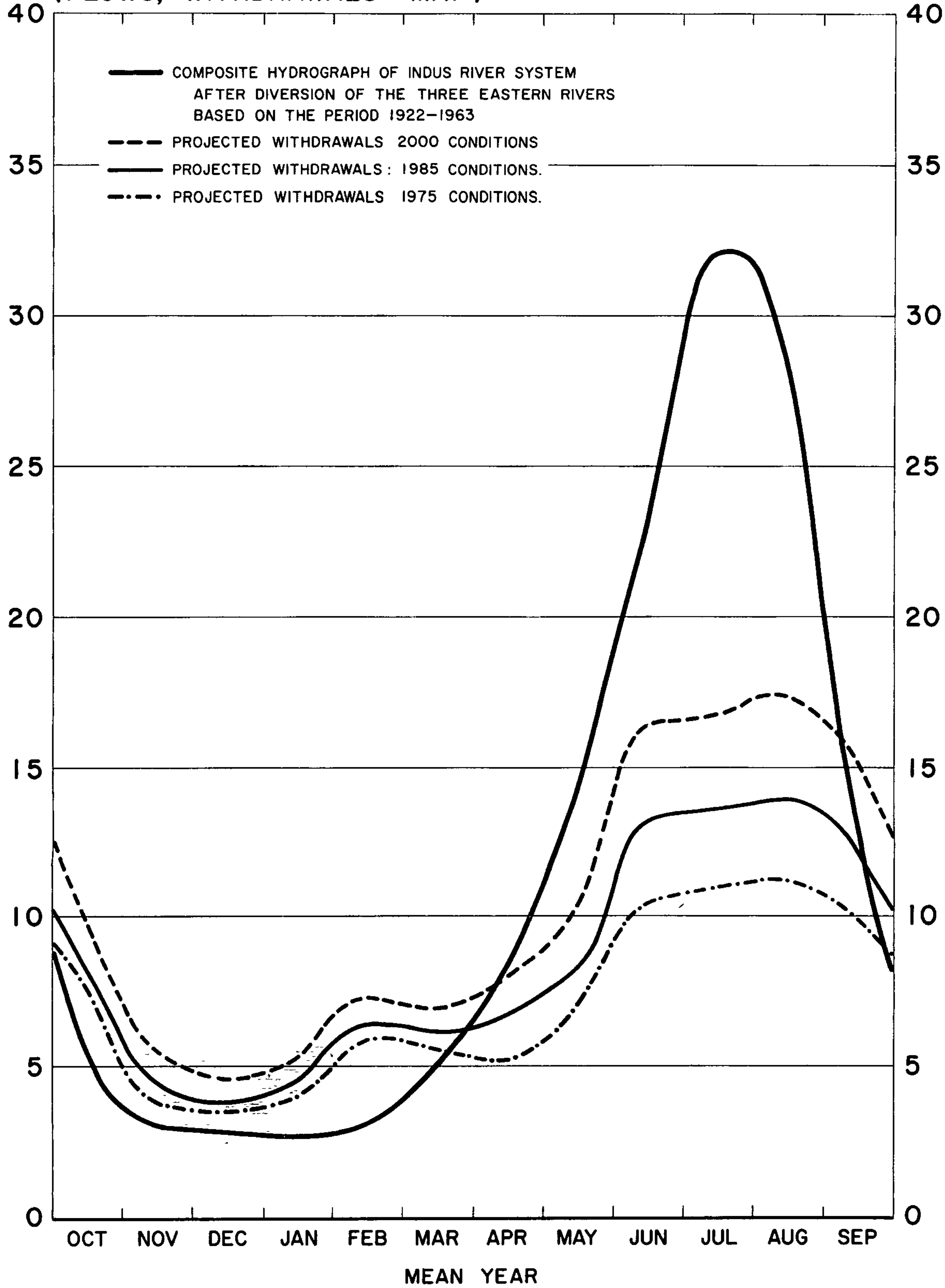
6.79 On the basis of the general strategy and programs discussed heretofore, it is possible to construct estimates of agricultural production at different reference years between 1965 and 2000. Projections of this kind must be regarded as indicative at best, dealing as they do with a rural sector where subsistence farming is still an important element and where the bench-mark data are of varying degrees of accuracy. Estimates of future levels of agricultural production are particularly difficult for West Pakistan, with its large territory and its great variation in farm sizes, tenure arrangements, climatic conditions, and degrees of irrigation development.

6.80 In order to relate projected growth of agricultural production to the proposed Water Development Program, at least for the period of the Action Program, the production data for different regions were aggregated into four major types of area as follows:

(i) Ongoing project areas -- CCA within the Indus Basin where groundwater development projects have received sanction under Government planning procedures and are already scheduled for implementation (5.5 million acres CCA).

PROJECTED USAGE OF AVAILABLE SURFACE WATER IN THE INDUS RIVER BASIN OF WEST PAKISTAN

(FLOWS, WITHDRAWALS – MAF)



(2R) IBRD – 3223

(ii) IACA project areas -- CCA within the Indus Basin covered by the groundwater projects recommended in the Action Program (5.8 million acres CCA).

(iii) Deferred project areas -- CCA within the Indus Basin not scheduled for public groundwater development projects before 1975 (18.4 million acres CCA).

(iv) Outside areas -- noncommanded areas. This includes non-commanded land interspersed with the CCA within the canal system (12.4 million acres).

6.81 The Bank Group's estimate of the agricultural production likely to result if the Action Program were implemented as scheduled, and if the longer term water resource development program were also carried out is summarized in Table 41. The table shows the impact of the program on the growth of cropped acreage, yields and gross value of agricultural output in the different areas and in all areas combined. The bottom block of the table shows that the Gross Production Value (GPV) of agricultural production is projected to grow at an annual rate of 5.2 percent for all West Pakistan during the periods 1965-75 and 1975-85. Slower growth rates for the 15 years, 1985-2000, would reduce the annual rate for the entire period, 1965 to 2000, to 4.5 percent per annum. The upper portions of the table show that the average growth rate in total output for the 1965-75 period results from a combination of 1.6 percent per annum growth in cropped acreage (primarily concentrated in the canal commanded areas) and 3.5 percent per annum growth in yields. For the 1975-85 period, cropped acreage would grow 1.3 percent per annum and yields 3.9 percent. Total GPV for all West Pakistan is projected to grow nearly fivefold over the period 1965-2000, on a basis of cropped acreage that increases by slightly less than 50 percent. The relatively substantial increase in acreage during the earlier years reflects the immediate effect of an increase in water supply, whereas the large increase in productivity, measured by the increase in GPV per acre, particularly reflects the expanding use of agricultural inputs combined with more adequate watering of crops.

6.82 The development of water supplies indicated in Table 39 shows an increase of deliveries to the watercourse head amounting to 38 percent over the decade 1965-75, 25 percent during 1975-85, and 15 percent during 1985-2000. These figures reflect the concentration on public and private tubewells before 1975 and a continuation of groundwater development to 1985 at the same time that Tarbela water becomes available. Opportunities for such a rapid growth in water supplies would largely be exploited by 1985. It is therefore this period, 1965-85, when the impact of these developments would be most widely felt throughout the CCA and the highest rates of growth in output would take place.

6.83 The Bank Group considers it reasonable to expect that the earliest effects of water resource development would occur in the ongoing project areas. Cropping intensities would rise as new supplies of irrigation water are spread over a larger cropped acreage than before. Growth in agricultural

TABLE 41

PROJECTION OF GROWTH OF AGRICULTURAL PRODUCTION a/

		1965		1975		1985		2000	Average Growth Rate (1965-2000)
Acreage (in million acres)									
	CCA	Cropped Acreage							
On-going Project Areas	5.53	5.03	(4.1)	7.51	(1.0)	8.29	(0)	8.29	1.4%
IACA Project Areas	5.76	5.27	(2.7)	6.89	(2.0)	8.40	(0)	8.42	1.4%
Deferred Project Areas	18.35	18.05	(1.3)	20.39	(1.6)	23.85	(0.9)	27.53	1.2%
Subtotal - Canal Area	29.64	28.35	(2.1)	34.79	(1.5)	40.54	(0.6)	44.24	1.3%
Outside Areas	-	12.37	(0.6)	13.05	(0.6)	13.76	(0.3)	14.45	0.4%
Total	-	40.72	(1.6)	47.84	(1.3)	54.30	(0.5)	58.68	1.0%
Yield (in terms of Rupees of GPV per acre cropped)									
On-going Project Areas		261	(3.7)	375	(4.0)	551	(2.2)	760	3.1%
IACA Project Areas		227	(2.8)	299	(4.6)	469	(3.3)	760	3.5%
Deferred Project Areas		236	(3.4)	330	(3.5)	469	(3.3)	760	3.4%
All Canal Area		239	(3.4)	334	(3.9)	486	(3.0)	760	3.4%
Outside Areas		156	(3.3)	216	(3.5)	305	(3.2)	493	3.4%
All Areas		214	(3.5)	302	(3.9)	440	(3.0)	695	3.4%
Total Gross Production Value (Rs. billions)									
On-going Project Areas		1.30	(8.0)	2.82	(5.0)	4.57	(2.2)	6.30	4.6%
IACA Project Areas		1.19	(5.6)	2.06	(6.7)	3.94	(3.3)	6.40	4.9%
Deferred Project Areas		4.27	(4.7)	6.74	(5.2)	11.19	(4.2)	20.92	4.7%
Subtotal - Canal Area		6.77	(5.5)	11.62	(5.4)	19.70	(3.6)	33.62	4.7%
Outside Areas		1.93	(3.9)	2.81	(4.1)	4.19	(3.6)	7.15	3.8%
GRAND TOTAL		8.70	(5.2)	14.43	(5.2)	23.90	(3.6)	40.77	4.5%

a/ Figures in brackets represent average growth rates in the respective periods in percent per annum.

production, reflecting both acreage and yield increases, is estimated at eight percent per annum in these areas during 1965-75.

6.84 The construction of the IACA tubewell projects should be largely completed during the period 1965-75. The period of most rapid growth for these areas, however, is expected to come in the decade 1975-85 at a time when increased surface water supplies would also be available from Tarbela. Increases in both cropping intensity and yields would begin about midway between 1965 and 1975. Output would increase about 5.6 percent per annum in the 1965-75 decade and 6.7 percent during 1975-85.

6.85 The deferred project areas constitute the largest single category used in these projections and also contain the areas most dependent in the years before Tarbela is completed on private tubewell installations. The Bank Group has estimated that there were 15,600 private wells in these areas in 1965, and that each well commanded an area of 100 acres at a cropping intensity of 125 percent. This would be a CCA of 1.56 million acres and a cropped acreage of 1.95 million acres. Since the full CCA of the deferred project areas is 18.35 million acres, there would still be 16.79 million acres CCA not served by private tubewells. This remainder includes some of the best irrigated land in the Province and has at present approximately an average cropping intensity of 96 percent.

6.86 The Bank Group estimates that private wells in the deferred project areas would increase from 15,600 in 1965 to 37,500 in 1975, and by then would command a CCA of approximately 3.0 million acres and a cropped area of 4.2 million acres (140 percent intensity). The remaining CCA of 15.35 million acres (18.35 million acres less 3.0 million acres) could only increase in cropping intensity slightly to 105 percent by 1975, or a cropped acreage of 16.19 million acres. The contribution of private tubewells would be replaced after 1975 by further public groundwater development and by additional surface water, and the deferred project areas could then achieve an average cropping intensity of 130 percent by 1985, rising to 150 percent during the period 1985-2000. On the basis of this development in the deferred project areas output would grow by 4.7 percent per annum up to 1975 and by 5.2 percent between 1975 and 1985.

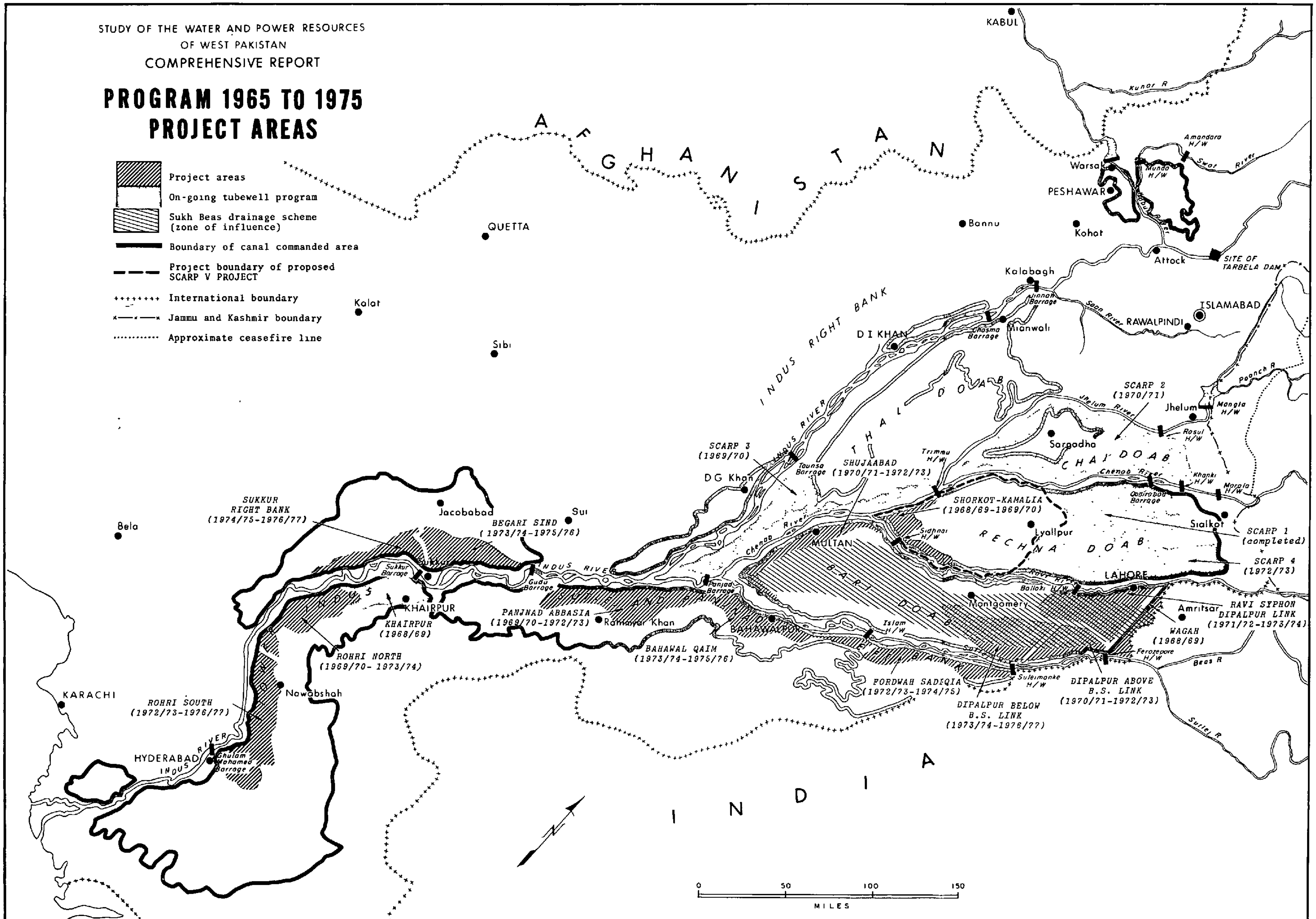
6.87 A relatively small amount of water development is projected outside the CCA, although considerable private tubewell activity is expected to take place in the outside areas, with the number of wells increasing from 5,000 in 1965 to 25,000 by 1985. This category is quite large (12.4 million acres) and the impact of this number of private tubewells would not be very great in terms of increased cropped acreage. Moreover, these areas are, by definition, outside the canal commanded portions of the Basin and would not benefit from the increased water supplies resulting from Tarbela or the construction of other storage facilities and canal remodeling. Growth in agricultural production would be somewhat lower in these areas, increasing at a rate of around 4 percent per annum between 1965 and 1985.

6.88 The Bank Group projections in all areas show lower rates of growth after 1985 than before that date, but this is not an implication that it considers a continuation of high rates of growth is impossible. It does mean that foreseeable growth after 1985, with techniques and inputs now known, would depend largely on improvements in yields alone, and these may be increasingly difficult to obtain once the levels projected for 1985 have been reached. On the other hand, advances in agricultural technology during the intervening years could open vast opportunities for increased production which are not now contemplated.

6.89 The cropping patterns used for planning purposes and underlying these global projections of the increase in agricultural production were derived partly on the basis of forecasts of demand for agricultural products and also on the basis of a number of other factors, as discussed in Chapter V. The main focus was on what farmers might actually be expected to achieve. Some of the assumed shifts in cropping pattern were described above, for the sake of example, in reference to the project areas that were studied in detail. In general terms, over the next twenty to thirty years in the Basin as a whole, fine rice was expected to become more important than coarse rice, and the acreage in jowar/bajra, gram and rabi pulses was expected to decline. The acreage in oilseeds was projected to grow only slightly larger than that sown in 1965, while wheat acreage would rise during the first decade but would be constant and then declining in later years when considerably higher yields would be obtained. There would be substantial acreage increases (in addition to that in fine rice, mentioned above) in cotton, fodder and green manure; the increase for these three crops alone would be 11.1 million cropped acres. In broad terms the contemplated changes can be summed up as constituting a relative shift from grain production for domestic consumption toward export crops and livestock support.

6.90 Comparison of the percentage change in acreage and increases in physical production of important crops and livestock products is another indicator of the relative emphasis given to the growth of different kinds of agricultural output. Among crops, cotton would have the largest percentage increase in acreage and production. Wheat, which would have a high growth in acreage in the first decade and a decreasing acreage in the period 1985 to 2000, was expected to have the smallest percentage increase of physical production among the major crops. The rate of growth in wheat production is, in fact, only slightly greater than the projected rate of population growth.

6.91 The expected contributions from livestock production are substantial. The size of the production herds has been placed at levels biologically consistent with estimates of available total digestible nutrients (TDN), which includes fodder production, crop residues, and an allowance for grazing. The quantities of TDN consumed per animal were assumed to increase over time because animal husbandry practice would be gradually improving. There would also be change in the kinds of cattle to be raised for milk and meat production. Buffaloes provide a major part of the milk production up to 1985, and the herd size increases up to that date, but it declines in the years after 1985 when there would be an increase in the number of dairy cattle from Zebu breeds such as the Sahiwal and Red Sindi. The herd increase projected depends on a very widespread


STUDY OF THE WATER AND POWER RESOURCES
OF WEST PAKISTAN
COMPREHENSIVE REPORT
PROGRAM 1965 TO 1975
PROJECT AREAS
Project areas
On-going tubewell program
Sukh Beas drainage scheme (zone of influence)
Boundary of canal commanded area
Project boundary of proposed SCARP V PROJECT
International boundary
Jammu and Kashmir boundary
Approximate ceasefire line
AFGHANISTAN
INDIA
KABUL
Warsak
PESHAWAR
Kohat
Bannu
Attock
SITE OF TARBELA DAM
Amandara H/W
Munda H/W
Swat River
Kunar R
QUETTA
Kalat
Sibi
Kalabagh
Jinnah Barrage
Chasma Barrage
Mianwali
ISLAMABAD
RAWALPINDI
Soan River
D I KHAN
INDUS RIGHT BANK
INDUS RIVER
THAL DOAB
SCARP 2 (1970/71)
Jhelum
Mangla H/W
Poonch R
Jhelum River
Rasul H/W
Sargodha
CHAJ DOAB
SCARP 3 (1969/70)
Taunsa Barrage
DG Khan
SHUJAABAD (1970/71-1972/73)
Trimmu H/W
Chenab River
Khanki H/W
Marala H/W
Qadirabad Barrage
SHORKOT-KAMALIA (1968/69-1969/70)
Sialkot
SCARP 1 (completed)
Lyallpur
RECHNA DOAB
SCARP 4 (1972/73)
LAHORE
Sidhnai H/W
MULTAN
BARI DOAB
Montgomery
Balloki H/W
Ravi R
RAVI SYPHON DIPALPUR LINK (1971/72-1973/74)
Amritsar
WAGAH (1968/69)
SUKKUR RIGHT BANK (1974/75-1976/77)
Jacobabad
BEGARI SIND (1973/74-1975/76)
Sui
Bela
Sukkur Barrage
Sukkur
Gudu Barrage
INDUS RIVER
Panjnad Barrage
KHAIRPUR
KHAIRPUR (1968/69)
PANJNAD ABBASIA (1969/70-1972/73)
Rahimyar Khan
BAHAWALPUR
Islam H/W
BAHAWAL QAIM (1973/74-1975/76)
ROHRI NORTH (1969/70-1973/74)
FORDWAH SADIQIA (1972/73-1974/75)
Suleimanke H/W
DIPALPUR BELOW B.S. LINK (1973/74-1976/77)
Ferozepore H/W
DIPALPUR ABOVE B.S. LINK (1970/71-1972/73)
Beas R
Sutlej R
KARACHI
ROHRI SOUTH (1972/73-1976/77)
Nawabshah
HYDERABAD
Ghulam Mohamed Barrage
INDUS RIVER
0 50 100 150
MILES

and effective artificial insemination program, as mentioned above. The Bank Group has followed the conversion rates of its consultants in deriving estimates of milk and meat production at future reference years and applying these to estimates of herd buildup gives production estimates for livestock production which show an annual growth rate of five percent for the period 1965-2000. Although the Bank Group has used these estimates, it retains reservations about them on several counts. Basic data on West Pakistan livestock, required as bench marks, are admittedly of uncertain quality, but they have been used in the absence of any alternative that appeared more reliable. The livestock projections make allowance for the biological constraints governing production and reproduction, but they also depend implicitly on improvements in herd management and selective breeding practices. These latter may ultimately impose more critical constraints on livestock growth than the availability of TDN. The livestock estimates thus appear technically feasible, but they may be subject to downward adjustment in light of the importance of managerial factors.

6.92 Projections of demand for agricultural products are necessarily very uncertain -- as illustrated by wide differences between two separate estimates of the elasticity of domestic demand for agricultural products discussed in Chapter X. Thus it is important that there be sufficient flexibility in the programs for irrigation and agriculture to permit the changes in cropping patterns needed to meet changes in demand. Comparisons were made between projected production by crops and estimates of demand for each crop and, as would be expected, they did not show a balance for each commodity, further illustrating the need for flexibility. These comparisons are discussed in general terms in Chapter X, which considers the broader implications of the 5.2 percent per annum growth in GPV of agriculture and 4.5 percent per annum growth in value added in agriculture implied by the projections in this chapter. As regards specific crops, there would in general be a fair degree of flexibility within the proposed water program for shifts in acreage toward wheat -- such as might take place in response to the recent increase in price of wheat and in view of the availability of the new high-yielding varieties. For instance, rather large fodder acreages have been projected on the production side -- even larger than required to support the ambitious livestock program mentioned in the preceding paragraph -- and some of this acreage could be shifted to wheat. Oilseeds, gram and pulses are also, like fodder, crops which are grown in both seasons and the amount of acreage devoted to them rather than to wheat in rabi would in practice depend largely on the relative yields and prices obtaining for the crops in the future. Cotton acreage, on the other hand, could not normally be transferred to wheat, within the limits of projected water availabilities, because although it is true that, with present varieties, they overlap in time in the fields and compete for the same acreage, there would be no provision within the irrigation program to meet the water requirements of wheat in other rabi months; however, cotton acreage could be transferred to other kharif food crops such as coarse grains or oilseeds, though this would be less likely in view of the very important position that cotton holds among Pakistan's exports. Shifts in the opposite direction -- out of foodgrains into cotton -- would clearly be easier because of the readier availability of water in the kharif season. Thus it would appear that there is considerable scope within the irrigation program proposed for shifts at the margin to meet demands for agricultural products of differing composition.

VII. SURFACE WATER STORAGE

Introduction

7.01 The chapter discusses the findings of the Study with regard to surface water storage needs and the manner in which they can best be met. The Bank Group's analyses and recommendations are based on the work of both IACA and Chas. T. Main International. The surface storage program proposed in this chapter has been drawn up within the overall framework of the irrigation program presented in Chapter VI above.

7.02 From the early 1970's, when the Indus Waters Treaty of 1960 will be fully implemented, the flows of four main rivers will remain available to Pakistan -- the Indus, Kabul, Jhelum and Chenab. They have a combined average annual discharge of some 142 MAF.

Table 42

Mean Year Discharges of Principal Rivers

	MAF	% of Total
Indus above Attock	66	47
Kabul above Attock	27	19
Total Indus at Attock	93	66
Jhelum at Mangla	23	16
Chenab at Marala	26	18
	142	100

Nearly half of the average annual discharge is in the Indus itself and the remainder is divided roughly equally between the other three rivers. Small additional contributions will be made from several minor tributaries and in some years part of the surplus flood flows in the Ravi and Sutlej will be likely to pass downstream. These flows, being heavily dependent on the size of the monsoon, will fluctuate greatly from year to year.

Current Storage Development

7.03 Mangla Dam, with its initial live storage capacity of about five MAF, provides the first sizable amount of surface water storage capacity to be built in West Pakistan. Barrages and weirs have been built on the main rivers over the course of the last century, as described in Chapter II, but they have been able to store only insignificant amounts of water. The first dam to be built with storage capacity was Warsak, completed in 1960. The project was designed primarily for power purposes with a storage capacity of only 23,500 acre feet which is rapidly being reduced by deposition of sediment; it is estimated that the reservoir will shortly reach a minimum residual capacity of about 10,000 acre feet, useful for peaking purposes on the power units but insignificant from the agricultural point of view.

7.04 With the completion of Mangla Dam it will be possible to store a portion of the flood flows on the Jhelum in the summer of 1967. The reservoir at Mangla is formed by the 11,000 foot long Mangla Dam, a smaller dam at Jari, and long dikes, all of zoned earth embankment type. The reservoir will have an initial gross storage capacity of 5.9 MAF and a live storage capacity of about 5.3 MAF at drawdown level of 1040 feet or 4.9 MAF at drawdown level 1075 feet. About 0.4 MAF of the live storage is in the Jari Arm beyond the Mirpur Saddle, but a trench has been excavated through the Saddle to enable about 0.3 MAF of this water to be diverted into the main reservoir and released through the power plant. Five diversion tunnels of 30-feet diameter were constructed through a ridge at the left abutment in order to divert water from the dam area during its construction. Four tunnels have been lined with steel penstocks of 26-foot inside diameter for their full lengths and they will be the initial means of releasing water for irrigation purposes and power generation. The fifth tunnel is plugged with a steel bulkhead, but steel linings can be installed and the tunnel plug removed if and when it is required for irrigation purposes or for power generation.

7.05 Live storage of about 0.5 MAF on the Indus main stem will be added in 1971 at Chasma Barrage, some 35 miles downstream of Kalabagh; construction began in the middle of 1967. The main purpose of the barrage is to divert water from the Indus to the Jhelum River, as part of the Indus Basin Works, through the Chasma-Jhelum link canal. The barrage was originally designed with a headpond elevation of 640 feet, but it was found that by raising the barrage structure some six feet and extending bunds on either side, live storage of about 0.5 MAF could be provided (between elevations 642 and 649 feet) at relatively low cost of about $32 million. This storage capacity is expected to be permanent since sediment collecting above elevation 642 would be flushed out during subsequent flood seasons.

Future Storage Developments

7.06 Although a large number of potential storage sites can be identified on the rivers of West Pakistan -- Chas. T. Main has identified upwards of 100 of them -- the Province does not in fact present opportunities for cheap storage development, as far as is now known. Technological progress may change this situation and economic development with concomitant improvement of the transportation infrastructure will help significantly to reduce the costs of dam construction at some potentially good sites, such as in the Upper Indus. Apart from this problem of accessibility there are several other factors, discussed in Chapter IV, which account for the high cost of providing storage in West Pakistan: the difficulty of finding sites which combine the right topographic features for formation of a large reservoir with bedrock formations capable of carrying heavy structures; the high concentration of annual flows within a few months in the summer and the extreme year-to-year variability of some of the rivers resulting in the need for provision of very large spillway capacity; the heavy silt loads of the major rivers and particularly of the Indus and the Kabul, meaning that, as far as can now be foreseen, storage capacity provided in a reservoir will be sharply reduced in a relatively short period. The result of these factors is that surface storage is a rather expensive means of making water available to the farmers in the months that they need it.

7.07 Planning of surface storage in an integrated irrigation system with two cropping seasons, as in West Pakistan, involves a careful consideration of the potential for irrigation development in each of the two seasons. Absorption of irrigation water in the kharif season of high natural flows is currently limited mainly by canal capacity and the shortage of water during the early planting period. But as canal enlargement and tubewell pumping proceed, more surface water will be able to be absorbed in that season, and less will be available for storage. Demand for surface water in the rabi season of low river flows is presently greatly in excess of supply, but tubewells will be able to meet a large part of this demand. In devising their program for the development of irrigation IACA carried out an integrated analysis, as discussed in Chapter V. In their analysis, future rabi watercourse requirements were met as far as possible from the groundwater available from the proposed tubewell fields plus natural river flows. IACA's studies indicated that groundwater pumping, when feasible, was generally a much cheaper way of meeting rabi irrigation requirements than provision of surface storage. But there was a limit to the speed with which tubewell development would proceed and, in some areas with somewhat more saline groundwater, surface water supplied from reservoirs would be essential to meet growing irrigation requirements. The demand for surface storage at any particular stage of development was thus estimated as the residual of total irrigation requirements, in each of the rabi months, that could not be met from groundwater and natural flows.

Flows Available for Storage

7.08 The amount of surface water available for storage depends on river flows during kharif and on the amount of water required for immediate delivery to the watercourses in that season. Kharif requirements of surface supplies for irrigation in turn depend mainly on the cropping patterns and intensities attained in different areas (with their different crop-water requirements), and the extent to which water can be supplied from tubewells in that season. IACA projected cropping patterns and intensities for kharif and rabi seasons taking into account the current situation in different areas, likely trends in demand for kharif and rabi crops and in yields of such crops, and the various alternative means available for increasing water supplies to meet the water requirements of higher intensity cropping. Table 43 shows the projected average intensities and kharif-rabi ratios for the development CCA (29.4 million acres), as defined by IACA.

Table 43

Projected Cropping Intensities and Kharif-Rabi Ratios

Present	Average Annual Cropping Intensity (%)	General Kharif-Rabi Ratio
1965	97	1: 1.09
1975	112	1: 1.20
1985	125	1: 1.16
2000	145	1: 0.94

The amount of irrigation supplies to be provided from the groundwater aquifer was projected by IACA on the basis of the canal command studies described in Chapter V, which integrated groundwater and surface water supply over the months on the assumption that balanced recharge would be pumped in the course of a mean-flow year. Kharif pumping in usable groundwater zones was minimized, with a view to concentrating usage of recharge to the aquifer in the rabi months when river flows are low; but in some cases and in some months kharif pumping was needed to balance recharge over the course of the year or because watercourse requirements exceeded canal capacity.

7.09 Tables 44 and 45 show IACA's projections of the amounts of surface water that would be available in 1985 and at the stage of "full development" in the reference year 2000 for surface storage on the Jhelum and on the Indus. The sharp decrease in the storable surplus after 1985 reflects the increase in the kharif-rabi ratio and the increase in kharif intensities from about 58 percent to 75 percent between 1985 and 2000 (see Table43) as a result of the large canal remodeling program envisaged for that period.

Table 44

Mean Year Storable Surplus Based on IACA's Projected Program: Jhelum River at Mangla
(MAF)

Month	Mean Flow At Mangla a/	1985 Irrigation Requirements b/	1985 Storable Surplus	Full Development Irrigation Requirements b/	Full Development Storable Surplus
May	3.6	0.8	2.8	2.1	1.5
June	3.7	0.7	3.0	1.8	1.9
July	3.8	0.6	3.2	1.1	2.7
Aug	3.0	0.8	2.2	1.6	1.4
Sept	1.6	1.0	0.6	2.0	Storage Release
Total	15.7	3.9	11.8	8.6	7.5

a/ 41-year period, 1922-63.
b/ After full allowance is made for use of flows from the Chenab River.

Table 45

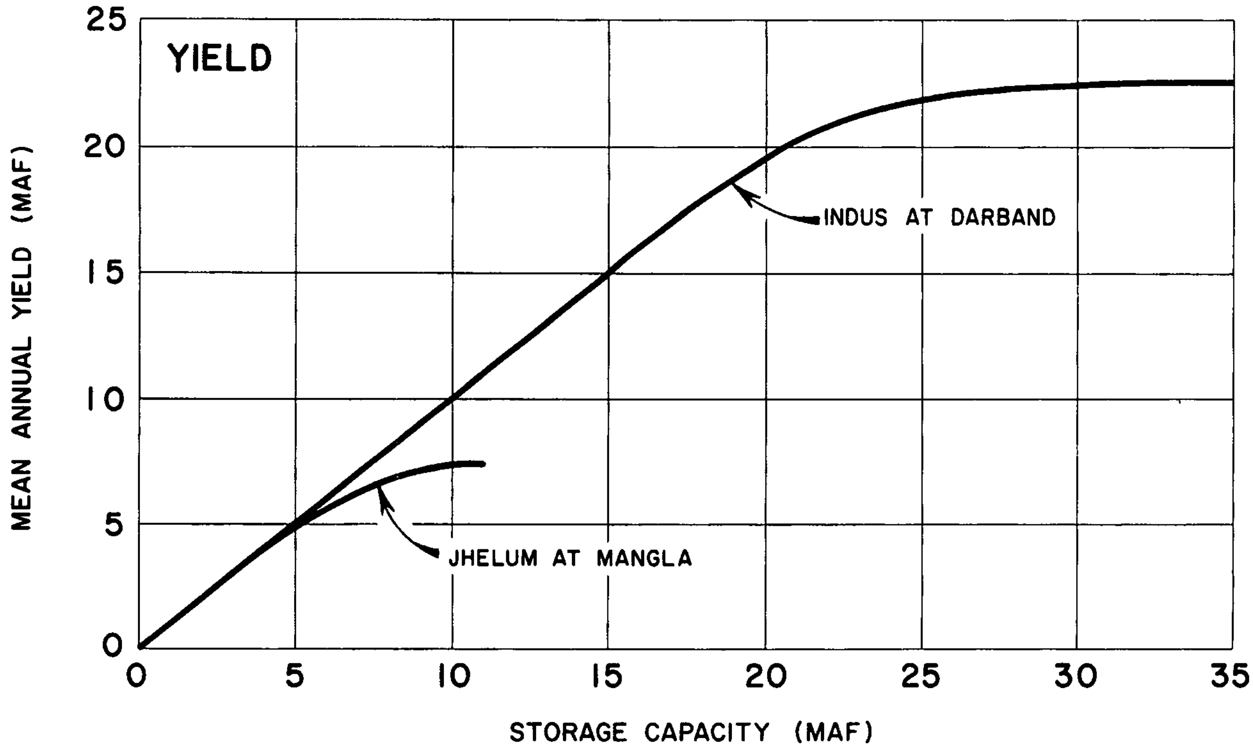
Mean Year Storable Surplus Based on IACA's Projected Program: Indus River at Tarbela (MAF)

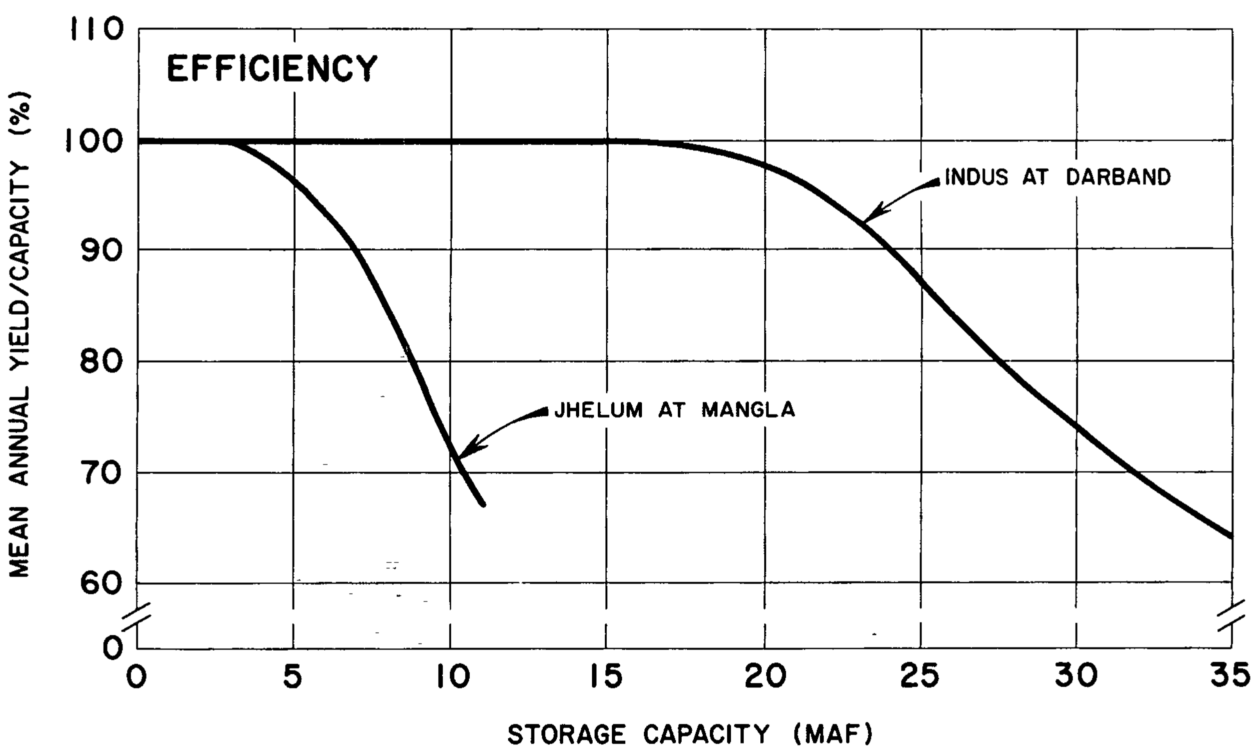
Month	Mean Flow At Mangla a/	1985 Irrigation Requirements b/	1985 Storable Surplus	Full Development Irrigation Requirements b/	Full Development Storable Surplus
May	4.4	3.1	1.3	6.0	Storage Release
June	10.2	5.0	5.2	9.4	0.8
July	16.8	1.5	15.3	5.7	11.1
Aug.	16.0	2.4	13.6	6.1	9.9
Sept.	6.8	4.5	2.3	6.6	0.2
Total	54.2	16.5	37.7	33.8	22.0

a/ 41-year period, 1922-63.
b/ After full allowance is made for use of flows from the Kabul River.

7.10 The situation in the projected year 2000 conditions when the plans made by IACA would reach full realization is shown in Table 46 and Figure 7. These show IACA's estimates of the amounts of water that could be stored, under mean year flow conditions, with reservoirs of different sizes on the Indus and the Jhelum. The figures are derived from an analysis of the monthly discharge records of the two rivers over the impounding season for the 41-year period, 1922-63, and take account of the required mean irrigation releases implied in IACA's program during these months at the ultimate stage of development. The figures show that, when kharif irrigation requirements have reached the stage projected by IACA after completion of their full program of canal remodeling, and on the assumption that kharif requirements will receive priority each year, it will be possible to fill a reservoir on the Jhelum only to the extent of two MAF in every year; whereas it will still be possible to fill reservoirs with total live storage capacities in excess of 15 MAF every year on the Indus. The efficiency of storage capacity, measured as a ratio of mean annual storage yield to storage capacity available, falls off rapidly on the Jhelum River at figures above six MAF, whereas it remains around 100 percent up to nearly 20 MAF on the Indus at Darband.

AVERAGE ANNUAL YIELD AND EFFICIENCY OF STORAGE CAPACITY ON THE INDUS AND JHELUM RIVERS*





* Based on the period 1922–1963, assuming year 2000 conditions, impounding period June through August for the Indus and May through August for the Jhelum

(2R)IBRD–3224

Table 46

Average Annual Yield and Efficiency of Storage Capacity on the Indus and Jhelum Rivers at the Ultimate Stage of Development a/

Storage Capacity (MAF)	Average Annual Yield (MAF)		Efficiency of Storage Capacity (Percent)	
	Indus at Darband	Jhelum at Mangla	Indus at Darband	Jhelum at Mangla
1	1.0	1.0	100	100
2	2.0	2.0	100	100
3	3.0	2.9	100	97
4	4.0	3.8	100	95
5	5.0	4.6	100	92
6	6.0	5.4	100	90
7	7.0	5.9	100	84
8	8.0	6.4	100	80
9	9.0	6.6	100	73
10	10.0	6.7	100	67
15	15.0	b/	100	b/
20	19.5	b/	98	b/
25	21.8	b/	87	b/
30	22.5	b/	75	b/
35	22.6	b/	64	b/

a/ Assuming the year 2000 mean year irrigation requirements as estimated by IACA continue to be met during the impounding season.
b/ Not physically feasible to provide capacity of this size on the Jhelum.

Surface Storage Requirements

7.11 As regards the future storage requirements IACA estimated that they would grow from roughly four MAF in 1970 to about 9.3 MAF in 1975 and approximately 21.5-26.5 MAF in 2000. Because of the tightly integrated nature of the irrigation system and of the plan which IACA prepared for it these projections of requirements are sensitive to the size and location of whatever tubewell program is carried out and to any significant changes in the pattern of irrigation requirements (e.g. due to the development of new strains of crops, with different growing seasons). The estimates, which are shown in Table 47, are based on the assumptions that the full IACA program will be carried out and that cropping patterns and crop water requirements develop as projected. The uncertainties built into these estimates of storage demand cannot be overlooked. For example, if the remodeling of canals in fresh groundwater areas and the use of subsurface storage proves infeasible storage demand in the year 2000 would not be 21.5 MAF but 26.5 MAF. Under the IACA program for 1965-75, the use of groundwater is projected to increase by 200 percent, from 10 MAF in

1965 to 30 MAF in 1975; the use of surface water at the watercourse by some 10 percent, from 58 MAF to 63 MAF. There would be further increases in the second decade and still more by the year 2000. Even so, the river system will still, according to IACA, supply 67 percent of the total crop requirements at the stage of ultimate development. At present 85 percent of water used on crops comes from surface water.

Table 47

IACA's Estimate of the Demand for Storage on the Indus & Jhelum Rivers: 1975, 1985, 2000
(MAF)

	1975			1985			2000		
	Indus	Jhelum	Total	Indus	Jhelum	Total	Indus	Jhelum	Total
Mean	5.0	4.3	9.3	8.8	4.5	13.3	15.5 a/ 19.0 b/	6.0 a/ 7.5 b/	21.5 a/ 26.5 b/
Median	5.7	5.4	11.1	9.7	5.6	15.3	-	-	-
3 years in 4	6.9	6.0	12.9	12.1	6.2	18.3	-	-	-

a/ Assuming canal enlargement in fresh groundwater areas.
b/ Assuming IACA's program of canal enlargement (see Chapter VI).

7.12 The estimates relevant for planning surface storage development are primarily those for the mean year, because the plans for groundwater development include sufficient tubewell capacity to make up for deficiencies in natural water supplies (from rainfall and canal deliveries) during the rabi season in all except years of very low flow. Indeed, during the next 20-30 years, when the tubewell projects will still be in a development phase and ultimately achievable cropping intensities will not have been reached, there should generally be sufficient tubewell capacity installed to meet irrigation requirements even in years of worst hydrological conditions. This assumption that the groundwater aquifer could be used to meet shortfalls in low-flow years meant that it was unnecessary to provide reserve capacity in the storage reservoirs and so it served to minimize the requirement for surface storage capacity. It is estimated that, had the surface storage system been designed to meet all residual requirements three years in four -- instead of those in a mean year -- surface storage needs would have increased by 30-50 percent. Thus the IACA approach leads to the most sparing use of the more expensive source of additional water.

Recommended Program of Surface Storage Development

7.13 The recommended program of surface storage development was drawn up to meet the low ultimate requirements of 21.5 MAF on the Jhelum and Indus combined -- corresponding to the assumption that canal-remodeling will be feasible in fresh groundwater areas so that these areas can be made independent of surface supplies in the rabi season. This assumption relates only to the post-1985 period because, as Table 47 showed, the two sets of requirements are identical before that date. The component projects of the program, which are discussed more fully in the following pages, are listed in Table 48. Figure 8 compares the projects recommended for construction in the 1967-85 period with the projected demand for stored water.

Table 48

Recommended Storage Program

Project	In-Service Water Year	Initial Live Storage Volume (MAF)
Mangla a/	1968	5.22 c/
Chasma a/	1972	0.51
Tarbela	1975	8.60
Sehwan-Manchar b/	1982	1.80
Raised Mangla	1986	3.55 d/
Chotiari b/	1990	0.90
Kalabagh (with power)	1992	6.40
Swat	2002	2.00
Low Gariala	2011	4.60
Skardu	After 2020	8.00

a/ Ongoing projects.
b/ Timing geared to irrigation planning for the Sind.
c/ Volume recoverable through main outlet works and power plant, assuming cut through Mirpur Saddle to release 0.28 MAF from Jari Arm.
d/ Raised to maximum height now contemplated.

First Stage Storage on the Indus

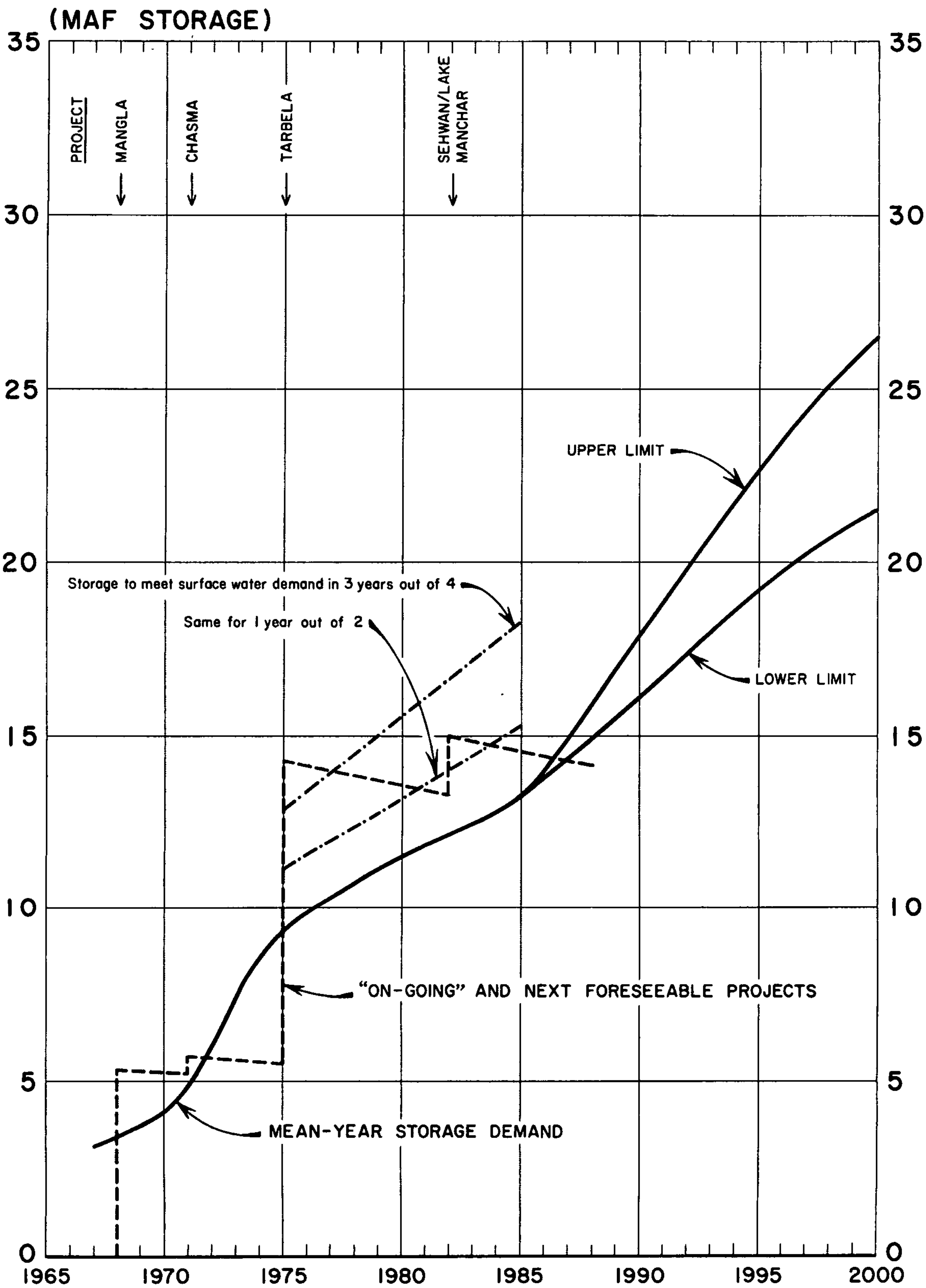
7.14 It is readily apparent from the figures presented in preceding tables that the projected mean year surface storage requirements up to 1985 could not be met by any project other than one on the Indus. Mean year storage requirements in 1985 were projected in Table 47 at a total of 13.3 MAF. Storable surpluses in 1985 were projected in Tables 44 and 45 at 11.8 MAF on the Jhelum and 37.7 MAF on the Indus. However, quite apart from the size of the storable surplus on the Jhelum it is questionable whether it would be feasible to provide more than about 8.5 MAF on that river -- and even more questionable whether it would be economical to concentrate so much storage there in view of the rapidly falling efficiency of storage beyond six MAF on the Jhelum anticipated at full development and indicated in Table 46 and Figure 7. In practice it might be possible to reduce the demand for surface storage in 1975-85 by additional overpumping of the groundwater aquifer, and this possibility is discussed below, but there would also be considerable operational difficulties in trying to meet rabi requirements of the whole basin with regulation on the Jhelum only. Therefore the problem of selecting a project for meeting the projected irrigation requirements of 1985 was essentially a matter of choosing the most suitable site for first-stage development on the Indus.

Tarbela and Kalabagh

7.15 There are two projects which were considered contenders for first-stage storage on the Indus, given the relatively large storage capacity that would be needed to meet the projected requirements -- Kalabagh and Tarbela (see Map 4 at the end of the Chapter). Various sizes of reservoir might be constructed at either site, but the first phase of the Study, revolving around the Tarbela Project itself, had suggested that not only was a large-scale reservoir justified but advantage lay with Tarbela and it was around that assumption of the availability of such large storage that the irrigation program drawn up in the second phase of the Study had been built. Tarbela, towards the lower end of the 300 mile-long main Indus Gorge, would have at its maximum feasible size an initial gross storage of the order of 11.1 MAF and, with a drawdown level of 1332 feet, live storage of about 8.6 MAF. The largest dam believed feasible at Kalabagh, a site some 150 miles downstream of Tarbela at the end of a 100-mile series of gorges below Attock, would have gross storage of the order of 8 MAF. It might be feasible to construct there a structure capable of sluicing through silt -- though that would be at the sacrifice of any firm power capability -- and then the reservoir would have live storage of about 8 MAF which would be reduced by siltation only quite slowly. Without sluicing and with a hydro-electric installation, Kalabagh would have initial live storage capacity of the order of 6.4 MAF.

7.16 A facet of development that cannot be neglected when very large-scale engineering works are required to meet early needs is the degree of investigation to which the projects in question have been subjected. Kalabagh and Tarbela contrast with one another strongly in this respect. The Kalabagh site was proposed in 1956 by consultants to the Government as being suitable for an earth and rockfill dam with an abutment overflow spillway. At that stage of the analysis, limited subsurface investigations were carried out, including 15 drill holes, 150 to 300 feet in depth, and 55 test pits. Foundation rocks at the proposed dam site were found to be sandstones and shales, overlain by up to 60 feet or more of alluvium in the river channel. Since 1956, further reports have been prepared by WAPDA and its consultants, but no additional exploratory work has been undertaken. The general location of the Tarbela site was established in 1954. In 1959 WAPDA made a contract with TAMS (Tippetts-Abbett-McCarthy-Stratton of New York) for final site selection and engineering. Three locations for a dam were considered in initial studies covering a 20-mile stretch of river. In May 1961 TAMS recommended adoption of the Bara site and this was accepted. By January 1962 investigations and designs were sufficiently advanced for the preparation of a project planning report covering the preliminary phases. At this stage many of the features of the scheme were of a tentative nature and subject to further exploratory work on site. Towards the end of the year, in November 1962, a supplement to the project planning report was issued. This supplement, while still based on the adoption of the Bara site, showed considerable changes in concept of the dam, both in alignment and in design. The report further brought out that a number of additional points required investigation on site before the designs could

IACA'S ESTIMATE OF THE TOTAL MEAN-YEAR DEMAND FOR STORED WATER ON THE JHELUM AND INDUS RIVERS



(2R) IBRD-3225B

be finalized. Planning work over the three years 1960-62 had cost nearly $10 million and over the following three years about the same amount again was spent on further engineering investigations and drafting of designs. The estimated cost of exploratory work, detailed design, model tests and preparation of tender documents over the period from November 1965 to the end of 1967 is estimated at about $9 million. Thus nearly $30 million and eight years will soon have been spent in preparatory work on the project.

7.17 The Tarbela Project, as now planned, will be the largest water storage and hydroelectric project in Pakistan; and if it is executed according to the present schedule, it will probably also be the largest single contract ever to have been let in the world. The centerpiece of the project is a major earth and rockfill dam rising 485 feet above river bed level with a crest length of about 9,000 feet and an impervious clay blanket extending some 5,000 feet upstream. This dam will be flanked by two auxiliary embankments on the left abutment. All told, the three embankments will contain 179,000,000 cubic yards of fill materials. With a crest elevation of 1,565 feet, the embankments are designed to impound 11.1 MAF of water to a normal operating level of 1,550 feet. The project is designed so that the reservoir could be drawn down to 1,300 feet, which would provide an initial live storage of 9.3 MAF.

7.18 Two spillways with a combined discharge capacity of 1,670,000 cusecs are to be provided at the left abutment to handle a flood inflow of 2,127,000 cusecs, with a rise of 6.8 feet in the water level of the reservoir above the normal operating elevation. The service and auxiliary spillways are designed for seven and nine radial gates, respectively, each 50 feet by 58 feet in size. Four concrete-lined tunnels, each 45 feet in diameter at the upstream end, in the right abutment would be used to divert the flow of the river during construction and subsequently as power intakes and/or for irrigation releases. The designs envisage that a power plant will be installed ultimately with 12 generating units each rated at 175,000 kw.

7.19 The cost of all these basic structures excluding power facilities is estimated at $625 million in 1965 prices and excluding Pakistan duties, taxes and interest during construction, items which are not germane to economic comparison among projects on the basis of the present worth of their total costs. Table 49 shows a breakdown of these 1965 economic costs of Tarbela. This is the cost estimate arrived at in the first phase of the Study and given in the Bank Group's 1965 report on Tarbela. It is believed to be still the best available, although some individual items may be subject to minor change.

Table 49

Estimated Economic Cost of Tarbela
(Million US$ equivalent)

Reservoir Works	Total	Foreign Exchange
Precontract costs	16.5	4.7
Net contract costs	414.4	284.0
Contingencies (20%)	86.2	57.7
Engineering and Administration	36.2	30.0
Insurance and Miscellaneous	9.0	9.0
Performance Bond	4.0	4.0
Land Requisition and Resettlement	59.0	-
	625.3	389.4

7.20 Plans for a dam at Kalabagh are obviously in a much less advanced stage and a number of very different concepts are still under consideration. Chas. T. Main considered several different possibilities and used the meager data available to prepare rough preliminary designs for each. They concluded that the best construction, from a number of viewpoints, would be a central earth and rockfill dam, flanked by a concrete buttressed sluice/spillway structure on the right bank. The project as envisaged could have a live storage capacity of 6.4 MAF with 1,125 mw of power or 8 MAF if the reservoir were completely drawn down each year. The concrete structure would consist of some 25 low level sluiceways built between buttresses. A massive concrete weir in the right diversion channel would form the base of the structure and provide support for the buttresses. The cost of the structure would be about $540 million and construction time is estimated at seven years.

7.21 The fact that the Kalabagh Project is in so much earlier a stage of preparation than Tarbela has important implications for analysis. The amount of time required to carry out further site investigations, model tests and design work to bring the Tarbela Project from the stage of initial identification to readiness for construction was indicated above. Most of this work has yet to be done on Kalabagh. Consequently, Chas. T. Main estimated that if Tarbela could be completed by 1975, Kalabagh which would take about the same amount of time to build could not be completed before 1979. The early stage of preparation at which the Kalabagh Project now stands relative to Tarbela also means that the cost estimates are subject to a much wider margin of error. Some allowance was made for this, by using 20 percent contingencies on contract and precontract costs for Tarbela and 30 percent contingencies on the comparable cost items for Kalabagh. Still it is difficult to attribute an equal degree of validity to the resultant cost estimates. An indication of the magnitude of changes to which the cost estimates for major dams may be subject can be gained from a brief look at the history of Tarbela cost estimates. The dam on the Indus envisaged in the Indus Waters

Treaty of 1960 was then believed to cost about $194 million; the total amount of fill required would be about 94,000,000 cubic yards and the dam would create a reservoir with initial gross storage of about 5.1 MAF. The dam now proposed for Tarbela is much larger; it would involve nearly twice as much fill and it would create a little more than twice as much gross storage capacity. This would suggest that the cost estimate should not be more than about twice what it was in 1960; in fact the cost estimate has gone up by an additional $250 million, it has more than trebled. It should also be noted that the cost of a dam at Kalabagh depends heavily on the type of structure finally chosen, and the type of structure which is feasible in turn depends particularly on foundation conditions at the site, which remain a matter of considerable uncertainty. Chas. T. Main estimated that the Kalabagh Project might cost as much as $734 million if a conventional Mangla-type spillway proved the only structure feasible. Thus while the Bank Group feels that the estimate of $540 million for a sluicing structure at Kalabagh is the best that can now be prepared it agrees with Chas. T. Main that the feasibility of the sluicing concept could not be established without considerably more investigation and study and that the cost estimates must be considered subject to a wide margin of uncertainty.

7.22 The siltation problem is a major factor in the comparison between the Kalabagh and Tarbela Projects. It was an important consideration in the minds of those who had originally rejected the Kalabagh Project as an alternative to Tarbela. Kalabagh is downstream of the confluence of the heavily silt laden Kabul River with the Indus. As a result the sediment load of the river there is on the order of 540 million tons a year or some 20 percent more than at Tarbela. Thus the reservoir created by a large earthfill dam there, comparable to the dam proposed for Tarbela, would fall in live storage capacity to about one MAF within some 25-30 years after construction.

7.23 The reservoir at Tarbela, being somewhat larger and having a lower estimated silt inflow, would be reduced to a residual permanent live storage of about one MAF over a somewhat longer period -- about 50 years. Average annual sediment transport of the Indus at Tarbela is estimated at about 440 million tons, equivalent to about 0.25 MAF compacted volume; the rate of depletion of storage capacity has been calculated on the assumption that initially about half of the annual sediment load will be deposited in the live storage area, the remainder being passed through the dams or over the spillway or else accumulating below minimum reservoir drawdown level. It is estimated that about 90 percent of the total annual sediment load is carried by the river during the period of peak flood flows between the middle of June and the middle of August.

7.24 As a possible solution to the siltation problem Chas. T. Main suggested for Kalabagh the sluicing structure mentioned above -- a type of design which would not be feasible at Tarbela primarily because of the combination of unconsolidated foundation material and very great width of the river there. Chas. T. Main's proposal for Kalabagh included an earth and rockfill dam across the river and a concrete sluicing structure on the right bank. Under this scheme Kalabagh Reservoir would be drawn down completely in May of each year and, in years of mean flow, all the Indus water would be allowed to pass through the low-level sluices essentially unrestricted until near the end of July. Impounding would be achieved in late July and August. With this schedule, more than 60 percent of the annual total of sediment would be passed through the dam during June and July. During seasons of particularly high flow, with the reservoir empty, some of the sediment previously retained in the river channel might be scoured out. Assuming that a solution could be found to the operational problem involved in deciding when to close the sluices in order to be sure of filling the reservoir each year under varying conditions of river flow, Chas. T. Main estimated that the live storage capacity of the reservoir would be depleted by only about 25,000 acre-feet a year for 100 years and that it would then reach a permanent minimum of 5.2 MAF.

7.25 The chief disadvantage that attaches to "sluicing Kalabagh", aside from the requirement of a concrete structure, is that passage of maximum sediment would involve elimination of power generation during three or four months in the year. Around the sluicing period the reservoir level would be below that required for turbine operation. It is questionable whether it would be worthwhile installing power facilities at all when they would be out of operation for more than one-quarter of the year.

7.26 The Bank Group considered the Tarbela and Kalabagh Projects in light of these various considerations and of its conclusion that the order of magnitude of the consultants' projections of requirements for power and for storage capacity on the Indus seemed reasonable. Kalabagh as a conventional structure without sluicing was clearly not very attractive because of its lower live storage and lower power potential than Tarbela and the extremely short life of the main body of storage volume. Kalabagh with sluicing would have nearly the same initial live storage as Tarbela and the storage volume would last very much longer; it might also be somewhat cheaper than Tarbela. However the longer life would be gained at the sacrifice of all firm power capability whereas Tarbela's shorter storage life would be compensated to some extent by the fact that the project would provide more than one-quarter of the total electric energy required by West Pakistan between 1975 and 1985 and very substantial amounts thereafter. It would not in fact be possible to build Kalabagh sufficiently early to meet the requirement for storage on the Indus as quickly as Tarbela could. However, if the project were to have substantial technical advantages over Tarbela or to be significantly cheaper it might be worth accepting lack of storage on the Indus for an additional four years. The Bank Group could have recommended in favor of delay to provide opportunity for further investigations and studies to firm up the Kalabagh Project. This would have been to gamble on the chance that further investigation at Kalabagh would show that the net advantages of a project there, in terms of lower cost and longer-lived storage, would sufficiently outweigh the disadvantages, in terms of lack of firm power to make it worthwhile accepting the certain loss of four years' live storage. The present worth in 1965 of the saving in construction costs that would result from completing Kalabagh in 1979 rather than Tarbela in 1975, on the most optimistic assumption regarding the costs of Kalabagh, would be $125 million. The loss of four years' live storage (1975-78) can be estimated at about $85 million in present worth terms on the basis of an average value at watercourse head of PRs 80 per acre foot of stored water provided to meet the IACA irrigation requirements. The power benefits of Tarbela between the years 1975 and 1985 alone are estimated at about $100 million in present worth terms and most, if not all, of this would be lost if Kalabagh with sluicing were built in 1979. Experience with the cost estimates on Tarbela and the real lack of evidence for deciding whether or not a sluicing structure is feasible means that a sizable risk factor must be attached to the potential saving on cost of $125 million and also to the larger amount of storage that Kalabagh would provide in later years; moreover this potentially larger amount of storage is not in fact very important because it would occur after the time when a second storage project was built on the Indus, which would almost necessarily be upstream of Kalabagh and would therefore protect it to a considerable extent from siltation. Opting for these uncertain benefits would mean suffering certain losses of power and irrigation benefits in the order of at least $150 million. Therefore the Bank Group concluded that Tarbela appeared still to be the better project for first stage storage on the Indus.

The Benefits of Tarbela

7.27 Because of the expense and importance of large-scale surface storage development on the Indus within the overall irrigation and power program which was the outcome of the Indus Special Study it was necessary to try to define the benefits which attach specifically to such development; because of the closely integrated nature of the water supply system and of the different parts of the recommended program it was also difficult to do this. The Bank Group and its consultants carried out several separate evaluations of these benefits.

7.28 The economic efficiency of the Tarbela project has of necessity to be seen in terms of its functional contribution within an integrated system which is about to undergo radical change. Following the implementation of the Indus Treaty Works the traditional natural flow diversion system will in the next phase be converted into a system based on river regulation and the integration of surface and groundwater. In the course of this transformation the value of surface water storage will be enhanced by the presence of tubewell fields and conversely the provision of main-stem storage will greatly improve the efficiency of tubewell development. Within the recommended program ground and surface water supplies have been integrated so as to meet water requirements in accordance with the time schedules of assumed cropping patterns from different sources of supplies. The integrated water supply schedule would satisfy crop water requirements on time, provide for mixing, avoid acceleration of waterlogging and be compatible with the recommended power program in terms of amount and timing of groundwater pumping and of releases of water through the hydroelectric plants. Under the planned water supply schedule Tarbela releases would take place between November and April, but a small reserve would be held over into May because Indus flows are particularly variable in that month. The operating pattern upon which IACA finally resolved for planning purposes is shown in Table 50 below.

Table 50

Tarbela Release Pattern

Reservoir Filling		Reservoir Release			
Month	Percent of Total	Month	Percent of Total	Month	Percent of Total
June	45	October	nil	February	26
July	55	November	8	March	19
August	nil	December	11	April	10
September	nil	January	21	May	5
	100				100

7.29 This pattern was drawn up on the basis of lower than average river flows in the rabi season, in such a way as to minimize the risk of water shortages and of exceptionally heavy groundwater pumping loads in the later part of the season. In practice the release pattern will probably be varied from year to year, but this basic pattern is adequate for planning purposes. Nearly 70 percent of storage at Tarbela would, on this pattern, be released during January, February and March.

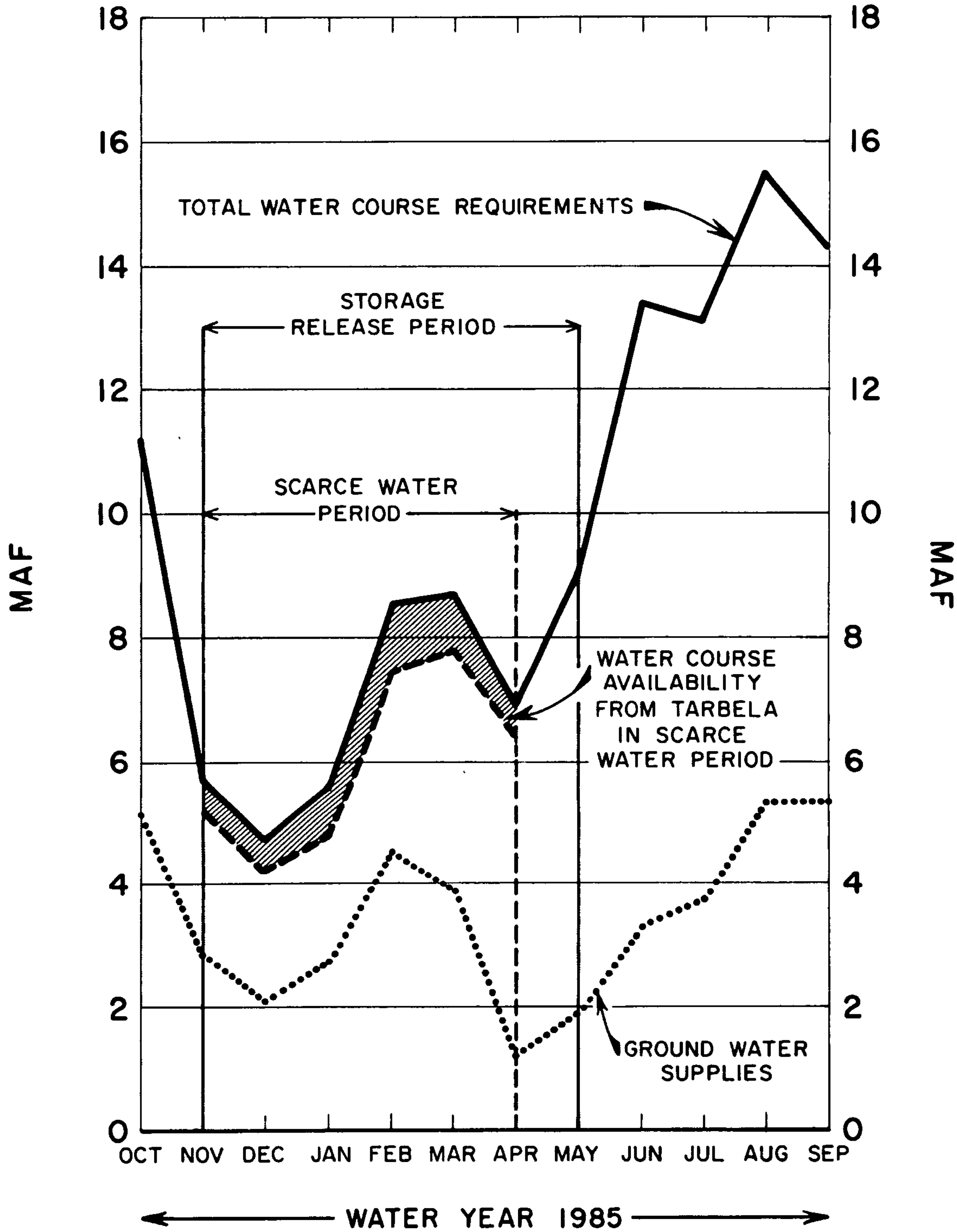
7.30 Figure 9 and Table 51 give an impression of the relative roles of surface and groundwater in the proposed program in meeting irrigation requirements over the course of the year. The year 1985 under mean year hydrological conditions has been chosen for illustrative purposes and the specific contribution of Tarbela has been indicated.

7.31 The live storage capacity of Tarbela in 1985, after 10 years of siltation, would be about 7.5 MAF, but actual watercourse deliveries from Tarbela storage would be only about 4.3 MAF because of conveyance losses. However the higher than natural river flows in the rabi season and the resultant additional conveyance losses would add to the recharge to the aquifer and, to the extent that it occurred in areas of fresh groundwater -- and most of the areas close to the river are fresh groundwater areas -- a part of it could be recovered by tubewells. IACA estimated this recoverable recharge in 1985 at 1.4 MAF.

TARBELA PROJECT

WATER COURSE REQUIREMENTS AND SUPPLIES BY SOURCES

(SYSTEM SUMMARY- 1985 CONDITIONS)



(R)IBRD-3434

Table 51

Monthly Distribution of Watercourse Supplies by Sources
(Mean Year Flows -- 1985 Condition)

Month	Surface Water MAF	Surface Water Percent per Month	Tarbela MAF	Tarbela Percent per Month	Groundwater MAF	Groundwater Percent per Month	Total MAF	Total Percent per Month
October	6.1	54.5	-	0.0	5.1	45.5	11.2	9.6
November	2.3	41.1	0.4	7.1	2.9	51.8	5.6	4.8
December	2.1	44.7	0.5	10.6	2.1	44.7	4.7	4.0
January	2.0	35.7	0.9	16.1	2.7	48.2	5.6	4.8
February	3.0	34.9	1.1	12.8	4.5	52.3	8.6	7.4
March	3.9	44.8	0.9	10.4	3.9	44.8	8.7	7.5
April	5.1	73.9	0.5	7.3	1.3	18.8	6.9	5.9
May	7.1	78.9	-	0.0	1.9	21.1	9.0	7.7
June	10.0	74.6	-	0.0	3.4	25.4	13.4	11.5
July	9.3	71.5	-	0.0	3.7	28.5	13.0	11.2
August	10.2	65.8	-	0.0	5.3	34.2	15.5	13.3
September	9.0	62.9	-	0.0	5.3	37.1	14.3	12.3
	70.1		4.3		42.1		116.5	100.0

7.32 Taking account of these contributions to irrigation supplies and of changes in them over the years, the Bank Group and IACA evaluated the agricultural benefits of Tarbela and added them to the power benefits in order to derive an overall rate of return. IACA valued Tarbela's direct irrigation contribution during the scarce water period, November through April, at an average value per acre-foot derived by dividing total water availability in that period (including natural flow and groundwater deliveries) into total estimated value of rabi crops; this was done for each year to 2015, allowing for gradually increasing absorption of Tarbela water in the early period according to their schedule of storage requirements and gradually decreasing contribution from Tarbela in later years as live storage is depleted. Estimates were equally made of the value of recoverable recharge, on the basis of an average unit value for irrigation water over the whole year (since recharge might be recovered in kharif as well as in rabi) and a deduction for the cost of pumping such recharge. Power benefits were taken by IACA to be as estimated by Stone & Webster in the first phase of the Study on the basis of comparison between the present worth of the costs of generating programs including and excluding Tarbela up to 2015. The present worth in 1965 of the total costs of the Tarbela Project, including operation and maintenance costs, were estimated at PRs 1,959 million. The results of IACA's computations are presented below in Table 11 and compared with the results of calculations by the Bank Group.

7.33 The Bank Group introduced a number of modifications to IACA's evaluation. In particular it derived a time series of average values of additions to present rabi water supplies on the basis of its analysis of the 6 million acres of project areas selected by IACA and designated in the program for commencement of public groundwater development within the next 10 years; all but one of the 12 project areas identified would absorb some Tarbela water. The time series indicates rising average values as the water is used to greater advantage by farmers in combination with more agricultural inputs. The Bank Group applied these average values of incremental water to total water available from Tarbela in each year, rather than to that portion of Tarbela water which happened to fall within IACA's estimated storage requirements. The Bank Group took the view that once Tarbela was completed, all the water which it stores would be used though initially to rather low advantage. Recoverable recharge, in the amounts estimated by IACA, was valued at the same unit value of incremental water supplies less an allowance for costs of pumping. For purposes of this evaluation the Bank Group added to the irrigation benefits derived on the basis of the project areas allowances for net power benefits, first the value used by IACA (about PRs 365 million in present worth terms) and second a value calculated by the Bank Group (about PRs 600 million in present worth terms) on the basis of studies described in Volume IV and annexes with fuel costed at current financial prices.

7.34 Table 52 summarizes the results of these calculations of the benefits of Tarbela, and the Bank Group is satisfied that, to the extent that the functional contribution of Tarbela in the overall program is measurable, the benefits of the project may fairly be considered to lie within the range from 9.2 percent to 13.3 percent.

Table 52

Results of Tarbela Evaluation Under Varying Assumptions

	Consultant's Evaluation	Consultant's Evaluation Modified	Bank Group Evaluation[a/] I	Bank Group Evaluation[a/] II
Net Present Worth of Benefits at 8% (PRs million)	3,770	3,353	1,994	2,241
Power Benefits as % of Total	10.0	10.7	18.3	27.3
Benefit/Cost Ratio (at 8%)	1.9	1.8	1.1	1.2
Rate of Return (percent)	13.3	12.5	8.4	9.2

a/ In the Bank Group's evaluation Analysis I is based on the use of IACA's estimate of power benefits while Analysis II includes the power benefits assessed by the Bank Group.

7.35 Besides estimating the absolute rate of return on the Tarbela Project the Bank Group also attempted to check the proposed timing of the project by considering what would be the effects of a 10-year delay in construction. With the linear programming technique for analysis of various types of irrigation investment in different areas it was possible to evaluate the difference in cost and project composition between a water development program which did not include Tarbela until 1985 and the IACA program including Tarbela in 1975. The hypothetical delayed Tarbela alternative was built around an early completion of Raised Mangla (1975) and Sehwan-Manchar (1980) plus a public tubewell program which was changed to permit overpumping as a substitute for some of the rabi surface water supplies that were to be provided from Tarbela. The alternative also allowed for means of meeting the main power load forecast used in the rest of the Bank Group's studies through the construction of additional thermal plant using natural gas as fuel.

7.36 Comparison of the costs of the two programs, both designed to produce the same net amounts of power and of agricultural output, indicates that the sacrifice involved in delaying construction of Tarbela 10 years would be in the neighborhood of PRs 230 million ($50 million equivalent) in present-worth terms when a shadow rate of twice the current exchange rate is used for valuing foreign exchange expenditures. At the current exchange rate, the costs of delay would be about PRs 490 million ($100 million equivalent) in present-worth terms. The validity of this comparison rests on the assumption that if Tarbela were delayed then the hypothetical program, equally if not more complex than the one built around Tarbela, could in fact be implemented. The Bank Group believes that the alternative program is valid for purposes of economic evaluation of Tarbela but it also believes that the program formulated around the early completion of Tarbela has a degree of security that cannot be matched by such a hypothetical alternative. Just because the Tarbela Project has been so thoroughly investigated there is a fair degree of certainty that once construction is started its contribution to power and irrigation supplies will indeed become available eight to nine years later. In contrast the use of public tubewell projects for extensive overpumping in order to substitute for surface water supplies, on which the alternative partially depends, would represent a new and yet untested form of operation of the irrigation system. The very scale of the Tarbela Project does also provide a margin of safety -- for meeting any unanticipated growth in power demand, for instance, or for providing additional irrigation supplies in the first few years after its construction when computed requirements of stored water are below the capacity of the reservoir.

7.37 In physical terms, the Bank Group emphasizes that the Tarbela Project will make a major contribution to the projected increase of rabi crop production in the Indus plains by regulating the natural river flows and by supplying additional water. Of the total future increase in rabi water delivered to the farmer, both from ground and surface sources, Tarbela will by 1985 contribute almost a quarter. As for electric energy, the 12,000 million kwh of power which Tarbela will be capable of generating annually would be absorbed relatively quickly into the system; and in a situation where the present known gas reserves are not so very ample for meeting all the calls that will be made upon them, Tarbela will provide a badly needed supplement to potential hydro and thermal power development.

The Silt Problem on the Indus

7.38 The silt load of the Indus was discussed in general terms above in the context of the choice between Kalabagh and Tarbela. All the calculations of Tarbela benefits have been based on the assumption that live storage volume will be depleted at the average annual rates of 0.12 MAF for the first 20 years of the projects and 0.17 MAF for the following 30 years, corresponding to average silt load of the Indus at Tarbela of 440 million tons. These rates of depletion imply that live storage would decline as indicated in the table below.

Table 53

Quantities of Stored Water Available for Irrigation Release at Tarbela (MAF)

Storage Release Period	Available Storage	Storage Release Period	Available Storage
1975/76	8.48	1999/2000	5.35
1979/80	8.00	2004/2005	4.50
1984/85	7.40	2009/2010	3.65
1989/90	6.80	2024/2025	1.10

In the context of the proposed program of surface storage development reductions in the availability from Tarbela are compensated by successive additions of other projects. If any means could be found of reducing the accumulation of silt in the reservoir it would clearly make possible very large savings in investment expenditures. The obvious means of reducing the rate of depletion of the reservoir -- dredging -- is infeasible because of the sheer magnitude of the problem; it may be of some use for keeping channels open (e.g. to the Siran Arm) but it is believed to be no general solution. Extremely little is known about the silt load of the Indus -- its origin, time of occurrence, nature, etc. -- and very little work has been devoted to trying to find a solution; obviously the problem is becoming very important for it will gradually eliminate much of the value of a $625 million investment. A thorough survey of the silt problem and of means to overcome it is urgently needed.

7.39 The rate of siltation, particularly for short spans of years, could be even greater than assumed here. The average rate assumed was calculated on the basis of only a few years' collection of empirical data. Most of the silt load is borne by the summer flood flows but the recorded data suggest that silt loads are very variable and tend to increase more than proportionately with the higher floods. The variations may be caused in part by erratic geomorphic processes resulting from heavy rainfall, landslides and avalanches. Should there be a succession of years in which these geomorphic processes were particularly active, the usable volume of the reservoir could be depleted at a faster rate than assumed. Another uncertainty relates to bed load, assumed in this Study at five percent of suspended sediment load; any errors resulting from this assumption are probably small compared with those related to the vagaries of nature but no reliable methods exist for measuring bed load and opinions differ about its importance on the Indus.

Financial Requirements for Tarbela

7.40 The Tarbela cost of $625 million quoted in the preceding discussions and used in the Bank Group's economic analyses covers only the reservoir works and excludes the cost of power facilities and financial charges such as duties, income, excise and sales taxes, interest during construction, provision for inflation, financial contingencies, etc. The detailed buildup of the economic costs is shown in Volume III, Annex 1, Figures 8 and 9. Table 54 shows the economic costs of the reservoir works at Tarbela in slightly different order from the way they were presented in Table 49 and relates them to a total financial figure of about $900 million for the reservoir works plus the civil works and mechanical and electrical equipment for the first eight power units. The figures are the same as those used in the Bank Group's report of February 1965 on the Tarbela Project. The Bank Group considers that the figure for total financial requirements remains a reasonable estimate. Table 55 presents the estimated financial requirements of $816 million for the project's start without power units, but including the powerhouse structure for the first four units. Two other minor changes have been incorporated in Table 55. The allowance for precontract costs has been raised in the light of current knowledge; since some of the works covered were previously covered under the contract costs some slight compensating reduction might be warranted in the latter but the amounts involved are too small and too uncertain to justify the change. A small item has also been included in Table 55 for the cost of supervision of the project based on the experience of carrying out the Indus Basin Works. Table 55 brings out the fact that the estimated value of the civil engineering contract is about $530 million, inclusive of civil works for the first four power units.

Second Stage Storage on the Indus

7.41 According to the IACA projections of stored water requirements a second major storage project on the Indus will not be required until about 1990, and the tentative program given in Table 48 does not bring in the second major project on the Indus until 1992. This is partly because two smaller projects in the Lower Indus area, Sehwan and Manchar, which are discussed below would be introduced around 1980 in connection with canal development there. Need could arise for major second-stage storage on the Indus somewhat earlier than projected, particularly if the canal remodeling program is carried less far than suggested by IACA. But even if a second major storage project is not required before about 1990 it is important to formulate views about which project that might be -- in order to give direction to investigation efforts and to ensure

Table 54

TARBELA PROJECT

Estimated Financial Requirements
(including first eight generating units)

(US$ million equivalent)

		Expenditures		Receipts
		Total	Foreign Exchange	
1.	Precontract Costs			
	From January 1, 1965	16.5	4.7	-
2.	Civil Construction:			
	(a) Dam and Reservoir	414.4	284.0	-
	(b) Power facilities	55.1 b/	35.7 b/	-
	(c) Income tax a/	61.0 c/	-	61.0
	(d) Excise and sales taxes a/	24.4 c/	-	24.4
	(e) Performance Bond	3.3 d/	3.3	-
	(f) Insurance and miscellaneous	7.5 e/	7.5	-
	Estimated bid value	565.7	330.5	
3.	Subtotal	582.2	335.2	
4.	Engineering Contingencies (20%)	116.4	67.0	17.1
5.	Subtotal	698.6	402.2	
6.	Mechanical and Electrical Plant	35.6 b/	31.7 b/	-
7.	Contingencies on line 6 (10%)	3.6	3.2	
8.	Subtotal	737.8	437.1	
9.	Import Duties a/	48.0 c/		48.0
10.	Engineering and Administration:			
	(a) Dam and Reservoir	36.2	30.0	-
	(b) Power facilities	8.4	7.0	-
11.	Subtotal	830.4	474.1	150.5
12.	Land and Resettlement	59.0	-	-
13.	Subtotal	889.4	474.1	150.5
14.	Allowance for Inflation a/			
	(a) 1.5% p.a. on Foreign Exchange Costs	39.8	39.8	-
	(b) 2.0% p.a. on Local Currency Costs	43.4	-	-
15.	Subtotal	972.6	513.9	
16.	Financial Contingency a/			
	(a) 5% on expenditure through 1968	14.9	9.2	-
	(b) 10% thereafter	54.0	28.7	-
17.	Subtotal	1,041.5	551.8	
18.	Expenditures between			
	November 30, 1962 & January 1, 1965 f/	5.8	2.1	-
19.	Subtotal	1,047.3 g/	553.9 g/	150.5
20.	Less Receipts	150.5	-	
21.	TOTAL	896.8	553.9	

NOTES:

a/ These items have been included in the cost estimates set out above to arrive at an estimate of the financial requirements. They are excluded from the figures in Table 21 of Volume III because they are not pertinent to an economic evaluation.
b/ First eight units only. Excludes all transmission and distribution.
c/ Based on figures prepared by Coopers & Lybrand.
d/ The cost of this item is given as US$4.0 million in Table 21 but is a bid item. It has therefore been reduced to US$3.3 million so that when contingencies are added back (20%) the total becomes US$4 million.
e/ This figure has been reduced from US$9.0 million to US$7.5 million for the same reason as in d/ above.
f/ In Table 21 all costs incurred prior to January 1, 1965, have been disregarded. Those incurred prior to November 30, 1962, have been met from the Indus Basin Development Fund.
g/ Makes no provision for interest during construction.

Table 55

TARBELA PROJECT

Estimated Financial Requirements
(excluding all mechanical and electrical power plant)

(US$ million equivalent)

		Expenditures		Receipts
		Total	Foreign Exchange	
1.	Precontract Costs			
	From October 1, 1965	34.8	13.0	-
2.	Civil Construction:			
	(a) Dam and Reservoir	414.4	284.0	-
	(b) Power facilities	27.6 b/	17.9 b/	-
	(c) Income tax a/	59.0 c/	-	59.0
	(d) Excise and sales taxes a/	21.0 c/	-	21.0
	(e) Performance Bond	3.3 d/	3.3	-
	(f) Insurance and miscellaneous	7.5	7.5 e/	-
	Estimated bid value	532.8	312.7	
3.	Subtotal	567.6	325.7	
4.	Engineering Contingencies	106.2	59.6	16.0
5.	Subtotal	673.8	385.3	
6.	Import Duties a/	36.0 c/		36.0
7.	Engineering and Administration	36.5	30.1	-
8.	Subtotal	746.3	415.4	132.0
9.	Land and Resettlement	59.0	-	-
10.	Subtotal	805.3	415.4	132.0
11.	Allowance for Inflation a/	73.2	34.1	-
12.	Subtotal	878.5	449.5	
13.	Financial Contingency a/	60.2	32.3	-
14.	Subtotal	938.7	481.8	
15.	Supervision	9.0	7.7	-
16.	Subtotal	947.7 f/	489.5 f/	132.0
17.	Less Receipts	132.0	-	
18.	TOTAL	815.7	489.5	

NOTES:

a/ These items have been included in the cost estimates set out above to arrive at an estimate of the financial requirements. They are excluded from the figures in Table 21 of Volume III because they are not pertinent to an economic evaluation.
b/ Civil engineering work only for first four power units.
c/ Based on figures prepared by Coopers & Lybrand for February 1965 report.
d/ The cost of this item is given as US$4.0 million in Table 21 of Volume III but is a bid item. It has therefore been reduced to US$3.3 million so that when contingencies are added back (20%) the total becomes US$4 million.
e/ This figure has been reduced from US$9.0 million to US$7.5 million for the same reason as in d/ above.
f/ Makes no provision for interest during construction.

that sufficient information is available by the time that the need arises to make a decision. It was apparent in the discussion of Tarbela and Kalabagh that only barely enough data were available for reaching a wise choice.

7.42 Further storage development on the Indus will be intimately affected by the prior existence of Tarbela and it will be important to investigate each potential storage site not only for its own direct advantages and disadvantages but also from the point of view of its effect upon and interrelation with Tarbela. One series of potential projects -- at sites on the left-bank tributaries of the Indus downstream of Tarbela -- will in fact only be feasible because of the prior existence of Tarbela; Indus water would be diverted from Tarbela, in the late flood season after Tarbela had been filled, down long diversion canals discharging at these sites. Projects at other sites on the Indus main stem upstream of Tarbela would likely have a great effect on the rate of siltation at Tarbela, while projects downstream would be to some extent protected from siltation by Tarbela.

Sehwan-Manchar Project

7.43 Sehwan-Manchar, scheduled in the recommended program for completion in 1982, is an example of a scheme whose potential will be closely affected by the existence of Tarbela. Being located in the Lower Indus where evaporation is much higher than in the North, and consisting of shallow basins with broad water surface, it would make only a small contribution to rabi water supply if it had to be operated independently of groundwater development or of other storage on the Indus; for that would mean that its water had to be spun out over the whole rabi season. If on the other hand it could be operated in conjunction with Tarbela, its water could all be released early in rabi, minimizing loss to evaporation and permitting retention of more water in Tarbela in the early winter so that power capability would remain higher there.

7.44 The Sehwan-Manchar scheme is in fact the most important single irrigation work proposed by the LIP consultants. It is designed to increase water supplies to some of the best agricultural land in the Sind at the lower ends of Rohri and Nara Canals on the left bank of the Indus. The scheme takes advantage of the existence of Manchar Lake some four miles away from the river on the right bank. A 3,500-foot long barrage would be built across the Indus near Sehwan to impound water to a maximum level of 125 feet SPD. The barrage would thus be able to store effectively about 0.8 MAF, which would be released into a new 36,000 cusec feeder canal to the southern parts of the existing Rohri and Nara commands. An inlet channel from the Indus, upstream of the barrage, to Lake Manchar would be built and the containing bund at the Lake would be raised to permit retention of water there up to the same level as at Sehwan. Lake Manchar would then have effective storage capacity of about 1.0 MAF and it would be filled partly from the Indus and possibly partly from the Lower Indus Right Bank Outfall Drain also proposed by LIP. The water would be released through an enlarged Manchar Outfall back into the river above the barrage and diverted into the left-bank feeder leading to Lower Rohri and Nara.

7.45 The Sehwan-Manchar Project could thus provide total storage of about 1.8 MAF and it is estimated that it would cost between $177 and $221 million. As such it would provide relatively expensive storage, but it might also eliminate the need for remodeling the upper portions of the long Nara and Rohri canals from Sukkur, so that the net cost of storage would be quite low. The scheduling of the project depends on the scheduling of related irrigation works in the Sind. Under the integrated program proposed construction would start in 1975, and so it is important to start the necessary preliminary investigations at an early date, particularly regarding evaporation and siltation.

7.46 A small possible additional development of the same project, actually scheduled in the recommended program for 1990, would be storage at Chotiari Lake, located on the eastern fringe of Nara canal command. The lake would be converted into a reservoir by construction of a 14-mile long bund. Live capacity would be 1.1 MAF and the storage available at canal head would be about 0.9 MAF. The reservoir could be filled either from an extension of the left-bank feeder mentioned above or from the existing Nara Canal. Cost of the Chotiari Scheme is estimated in the range $12-15 million.

Four Major Alternatives

7.47 For large scale storage development on the Indus after Tarbela there appear to be four main alternatives, as far as can now be foreseen -- Kalabagh, Side Valley Storage, Upper Indus sites and the Thal Offstream storage scheme. Kalabagh was discussed in connection with the choice of Tarbela. A few details of the other three alternatives will be presented here.

Side Valley Storage

7.48 The possibility of diverting water from Tarbela to storage in either the Soan or the Haro river valleys on the left side of the Indus has for some time been seen as an additional attraction of the Tarbela site. It has been suggested that storage capacity of the order of 30 MAF might be built on these rivers, to be filled almost entirely by diverted Indus flows. Four potential side valley storage projects were studied by Chas. T. Main -- Gariala and Sanjwal-Akhori on the Haro and Dhok Pathan and Dhok Abbaki on the Soan (see Map 4 at the end of the chapter).

7.49 Chas. T. Main concluded that the Gariala site was definitely preferable to the Sanjwal-Akhori site for major storage on the Haro, since a much larger reservoir could be built there, with larger power capability, and the unit cost of storage would be lower. The dam proposed for Gariala by Chas. T. Main would be about 375 feet high and would have a crest length of 40,000 feet. It would contain about 189 million cubic yards of embankment materials, or somewhat more than required for Tarbela. The dam could be constructed all at once or in two stages: a first stage with a live capacity of 4.6 MAF, a second stage adding 3.4

MAF. Of the full capacity of 8 MAF, a modest 0.4 MAF would be derived from the Haro River in a mean year with the rest being diverted from the Tarbela Reservoir, after the floods had brought the water elevation there to about 1550 feet, via a five-mile canal with a capacity of 76,000 cusecs. A power installation at Gariala would only be able to generate part of the year. However, one of the advantages of Gariala would be a long life of useful storage; some 5.4 MAF of capacity would still be available after 100 years of service. No subsurface explorations or detailed mapping have been carried out at the site. The consultant had to base his work on topographic maps, air photographs and one generalized, unsurveyed geological cross-section of the dam site. Chas. T. Main estimated the cost of the single-stage project at about \$650 million. The Bank Group estimates that if conditions were somewhat less favorable than assumed, then the costs could rise to the order of \$975 million,

7.50 Dhok Pathan and Dhok Abbaki are sites close together on the Soan River, thought to be capable of supporting similar dams. The projects would be mutually exclusive. Dhok Pathan would probably be the better site for storage of water diverted by gravity from Tarbela, whereas Dhok Abbaki, seven miles downstream, might be preferable as a pumped storage project in connection with a reservoir at Kalabagh. The dam envisaged by the consultant for Dhok Pathan would be an earth and rockfill structure some 275 feet high with a crest length of about 12,000 feet, containing 38 million cubic yards of fill. The reservoir would provide a usable live storage capacity of about 7.5 MAF. Water would be conveyed from Tarbela to the reservoir by a costly 70-mile conveyance system requiring canals with a combined capacity of 76,000 cusecs and auxiliary structures, such as syphons, aqueducts and culverts. A subsidiary dam and reservoir would have to be built at the point where the canals crossed the Haro. Maintenance costs on the long conveyance system would be high because it would only be used for some three months in the year. Engineering and geological data are extremely scant but Chas. T. Main made a rough estimate of costs, as for Gariala, which totaled \$1,130 million. The Dhok Abbaki scheme, in connection with Kalabagh, would provide about the same storage capacity and it would be cheaper in terms of direct construction cost -- about \$635 million according to Chas. T. Main's estimate -- because the long conveyance system from Tarbela would not be needed. The Soan River channel would merely need to be deepened to convey water from Kalabagh to the foot of the dam, whence it would be pumped into the reservoir. The pump turbine units would be reversible, with a capacity of about 2,000 mw on the pumping cycle and 1,900 mw on the generation cycle. To meet the large pumping load the power system would need substantial additional generating capacity which would add significantly to the true cost of the project.

7.51 The best of these sites for side valley storage would therefore appear to be Gariala, though it is possible that Dhok Abbaki might become attractive at a later date after completion of Kalabagh. Gariala would be substantially cheaper than Dhok Pathan but it would still apparently cost at least as much as Tarbela. One of the main difficulties with these side valley schemes, which adds substantially to the cost, is the very large canal capacity or, in the case of Dhok Abbaki, pumping capacity needed to bring water from the Indus; the large capacity is needed because of the relatively short period, about two months, that would be available for filling the reservoirs, between the time when Tarbela was filled and the end of the flood season. Maintenance of the canals and the power plants, if installed, would be expensive because of little use, and it would be possible to generate power for only about eight months in the year as the reservoirs were being drawn down. One additional disadvantage of Gariala specifically is that it would inundate the town of Campbellpore.

Upper Indus Sites

7.52 The Upper Indus means basically the Indus main stem upstream of Tarbela, particularly the 300-mile long Upper Indus Gorge, and the tributaries of the Indus in this area. Topographically the area would appear quite wellsuited for dam construction, particularly for hydroelectric purposes taking advantage of the steep river gradient (about 7,000 feet fall in a 300-mile stretch). There is one site -- Skardu, about 315 miles upstream of Tarbela at the head of the Gorge -- which, again from a purely topographic point of view, appears especially suitable for construction of a storage reservoir; it might be technically possible to build a reservoir there of some 35 MAF storage capacity capable of regulating the entire flow of the Indus at that point. 35 MAF is also the estimated annual discharge of the Indus at Skardu. However there is an almost total lack of all the other information required to establish whether or not a dam is feasible there and, with present techniques for dam construction, the problem of accessibility would be almost insuperable. The main portion of the Upper Indus Gorge is separated from the rest of West Pakistan by high mountain ranges; access to the area is over the 13,000-foot Babu-Sar Pass, closed by snow for eight months of the year, and thence along rough and generally narrow jeep tracks dug out of the side of the vast piles of glacial debris and silt which form the banks of the rivers.

7.53 Chas. T. Main tentatively formulated a project consisting of an earth and rockfill dam with concrete gravity spillway for Skardu on the basis of aerial photography carried out under the Study, 1:15,000 contour maps prepared by the Survey of Pakistan and reconnaissance reports by WAPDA and its consultants. Foundation conditions at Skardu are totally uncertain; Skardu site was not visited on the ground by the dam sites consultant in the course of the Study nor has it previously been studied in any detail. For purposes of their desk study Chas. T. Main made arbitrary assumptions about foundation conditions. They drew rough outline plans for reservoirs of 5.2 MAF and 8.0 MAF capacity, and calculated that the smaller project might, on their assumptions, cost between approximately $425 million and $510 million while the larger one would cost between about $500 million and $590 million. These costs include an allowance of about $110 million for the access road. Chas. T. Main did not include any power facilities in their project designs since the long distance transmission over rugged terrain at very high elevations that would be involved makes it doubtful whether power installations would be justified. On the other hand regulation of the Indus at this point would considerably increase the value of downstream hydroelectric facilities. No discharge or sediment load data were available for Skardu at the time Chas. T. Main made their study, though WAPDA is in process of establishing a gauging station there. It is likely that this data, when gathered, will indicate a very much lower sediment transport on the Indus at Skardu than at Tarbela or Kalabagh so that a reservoir of about 8 MAF size should have very much longer life than reservoirs downstream.

Thal Storage Scheme

7.54 This scheme, consisting of an enormous shallow reservoir of some 21 MAF gross storage capacity formed by a long semicircular dike or bund around an area of rather poor agricultural potential on the left bank of the Indus in the upper part of Thal Doab, was proposed by Tipton and Kalmbach (T & K), consultants to WAPDA, in February 1967. The dike would extend in a broad arc from the vicinity of Panjgirain on the left bank of the Indus southwards and then across the doab to a point some eight miles from the Jhelum, where it would turn northward and run generally parallel to the Jhelum River, terminating some 15 miles south of the Chasma-Jhelum Link. It would have a crest level of elevation 615 feet and would be some 115 miles long with a maximum height of about 70 feet above existing ground level. The average height would be about 50 feet. T & K propose that the embankment, requiring about 300 million cubic yards of fill, be constructed from local alluvium compacted in layers with a puddled core. Allowing 15 feet for freeboard and assuming a minimum pool elevation of 560 feet T & K estimate that the live storage capacity of such a reservoir would be about 20 MAF. To fill such a reservoir within the two to three months when surplus flows occur on the Indus about 100,000 cusecs of diversion channel capacity would be required. An 80,000 cusec channel, some 12 miles long, would extend from a new barrage on the Indus at Panjgirain, some 35 miles south of Chasma, to the reservoir. An additional 20,000 cusecs of diversion capacity would be provided by a feeder canal, some 17 miles long, taking off from the Chasma-Jhelum Link. Releases would be made into the Jhelum upstream of Trimmu by way of outlet works of about 50,000 cusecs capacity. The cost of the scheme, according to preliminary T & K estimates, is about $590 million.

7.55 Though the live storage capacity of the reservoir could be as much as 20 MAF, the actual yield of the reservoir would be substantially less. T & K estimate annual seepage and evaporation losses at 1.7 MAF and 3.5 MAF respectively, but they judge that more than 1.5 MAF of the seepage could be recovered by construction of a drain suitably sited immediately downstream of the dike embankment. Allowing for annual operational losses of about 3.7 MAF, T & K state that the mean annual yield of the reservoir would be about 12 MAF and, with full use of Tarbela regulation, this could be increased to about 14 or 15 MAF.

7.56 The scheme, as proposed, appears to have many attractive features but there are clearly many aspects which will require careful and possibly prolonged investigation before final conclusions are possible. If the yield is taken as 13.5 MAF (12 MAF plus 1.5 MAF recoverable seepage) then the cost of an acre-foot of annual yield capacity would be about $44, considerably cheaper than the unit cost of storage behind the high dams discussed in preceding paragraphs. As off-channel storage the rate of sedimentation would be low. T & K believe that it might be possible to develop some 50 feet of head between minimum pool level and the Jhelum River for power generation at the outlet works; but the more important gain to power would be in the scope that the availability of this large amount of storage capacity might offer for keeping up the head longer through the winter at Tarbela. However, one major operational disadvantage of the scheme is that unrecoverable losses, though they are hard to predict, will undoubtedly be high and this could be a serious matter in conditions where, as pointed out in Chapter II, it is water and not land that represents the ultimate constraint on irrigation development.

7.57 Before the feasibility of the Thal scheme can be assessed or its advantages and disadvantages weighed against those of other potential second-stage storage projects much consideration will need to be given to aspects such as foundation conditions, seepage rates, the suitability of local materials for embankment construction, siltation rates, actual feasible reservoir capacity, the extent to which water would be lost to evaporation and the extent to which it might be regained elsewhere in the Province in the form of rainfall. Owing to the great length of the bund involved special care will need to be taken to ensure that no major foundation or construction material supply problems are overlooked because the cost of overcoming them might prove very high. Another matter which will call for careful study is maintenance of the long bund and seasonally operated channels. Costs of such maintenance would tend to be high.

Second Stage Storage -- Assessment

7.58 The basic conclusion which stands out in these brief descriptions of alternative projects for second-stage development of the Indus is that existing knowledge is entirely inadequate for reaching a sound judgment as to which might be best. The additional information needed is basically of two types. First, more data are required about aspects such as river stages and discharges, type and quantity of silt load and evaporation at different locations and different times of year; collection of these data requires establishment of hydrometric stations at strategic locations and sustained observation of daily conditions over long periods of years. This general type of data is needed to enable a better understanding of the whole Indus River system, and observation should not be confined to potential dam sites already identified, for the growth of knowledge and the evolution of water-control techniques may reveal opportunities that are not yet even conceived. Second, more data are needed regarding geologic aspects such as foundation conditions, the process of silt generation, and permeability of local materials. This information will be gathered in special surveys and studies. WAPDA's Surface Water Circle has proposed establishment of a number of additional hydrometric stations, particularly in the Upper Indus area, and the Bank Group thinks that these should be established as early as possible because the longer the record the more useful will the data be for decisions regarding second-stage storage -- that have in fact to be taken within the next 10-15 years. As for the more specific studies the Bank Group thinks that priority should be given to further exploratory work at Kalabagh, particularly on the geological side, including drilling of boreholes and adits in the foundation rock, laboratory test of rocks and identification of sources of construction materials; to extensive field investigations and thorough studies of the silt problem on the Upper Indus, including studies of the effects of snowmelt and glacial movements, and, in connection with silt studies, work on geological aspects of potential dam sites in the Upper Indus which might be developed either on a small scale for purely local purposes or on a large scale for regulation of downstream flows; and to further investigation and consideration of the many uncertain aspects implicit in Tipton and Kalmbach's imaginative scheme for off-stream storage at Thal. Limited field investigations should also be undertaken at Gariala to confirm the feasibility of the project. The basic approach regarding specific project proposals should be first to undertake sufficient field work and laboratory tests to confirm the feasibility of the project and the approximate cost, and then, some five years before construction would begin, to commence an intensive program of detailed investigation and project design work. Five years is by no means too long. It was shown above that, in the case of Tarbela, it took a year to fix the site, two more years to establish project feasibility with reasonable certainty, three more years to prepare definite plans and another two years to reach the stage when construction might start.

7.59 In its tentative program of surface storage development the Bank Group has included Kalabagh (without sluicing) for second-stage storage on the Indus and it has scheduled it for completion in 1992 in order to meet the IACA "low ultimate" surface storage requirements taking account of the gradual depletion of storage capacity at Tarbela. There was a number of reasons for this choice. Despite the attractive features of Skardu, such as its suitable topographic formation and its likely low rate of siltation, knowledge about geologic conditions is completely inadequate for saying whether savings could be made on the costs of constructing a dam there rather than at Kalabagh sufficient to outweigh the very high costs that would be involved in gaining access to the site. As for the interesting Thal scheme, it has too many novel aspects and there are too many uncertainties about its basic feasibility to warrant its inclusion in a development program; but these aspects should be investigated at an early date to see whether the proposed development program cannot be radically improved by including substantial cheap storage there. For the present, though, the choice would appear to be between Kalabagh and side-valley storage. And the Bank Group believes that the present evidence markedly favors Kalabagh, out of these two.

7.60 The existence of Tarbela will so much reduce the sediment inflow to Kalabagh, if the latter is built within 15-20 years of Tarbela, that it would appear preferable to build Kalabagh, as second-stage storage, as a non-sluicing rather than a sluicing structure. In that case it would probably be worth installing some 1,125 mw of generating capacity at Kalabagh. The hydroelectric plant would have a firm capability of approximately 350 mw, and by about 1990 the power system should be sufficiently large to be able usefully to absorb the contribution of a further hydroelectric project (beyond Mangla and Tarbela) with capability that would fluctuate heavily over the course of the year. Gariala, on the other hand, would have no firm power capability. Secondly, the Study has brought out the very large capacity (about 76,000 cusecs) of the canals that would be required to carry water from Tarbela to Gariala and the consequences of this for the cost of the project. The best available cost estimates indicate about $650-975 million for the Gariala project against about $540-735 million for Kalabagh. Thirdly, Chas. T. Main's backwater studies at Kalabagh appear to indicate that the danger of flooding at Attock, which had before been thought to be serious, is likely to be a relatively minor addition to what it would be without the dam. It may prove possible to achieve some reduction in the estimated costs of land acquisition, which are extremely high in the case of Kalabagh (about $200 million). It is true that Gariala might be built with somewhat larger storage capacity than non-sluicing Kalabagh and that its storage capacity would have a considerably longer life. However as siltation increased at Kalabagh, a pumped storage scheme might be feasible at Dhok Abbaki and in any case the contribution that its power plant could make to meeting loads would become more substantial. Moreover, a project on the main stem, with power capability, would be much more flexible than Gariala as a component of the total system that will probably eventually be built with large-scale low-siltation storage at Skardu, Thal or possibly at Gariala itself.

7.61 Therefore the Bank Group recommends that detailed investigations of the Kalabagh Project should be undertaken at an early date so as to check the validity of the assumptions made here regarding the project and to leave time, if these assumptions prove significantly invalid, for undertaking thorough investigations elsewhere before the need for construction of second-stage storage on the Indus arises. These investigations at Kalabagh should include subsurface exploratory works and seismic studies, detailed survey of the site, access routes and reservoir area, sediment sampling and material analysis.

Further Storage Projects on Tributaries

7.62 As pointed out at the beginning of the chapter, the potential for development of surface water storage to serve the main irrigated areas of West Pakistan is heavily concentrated on the Indus River itself. The tributaries are very much smaller and their flows are already, particularly with the completion of Mangla, much closer to full use; moreover, being more heavily dependent on monsoon rains than the Indus, their flows show much greater variability from year to year. There are many opportunities for development of small-scale storage works for local purposes -- both agricultural and hydroelectric -- but these are not the subject of this report. There is also a number of opportunities for relatively small-scale storage development in connection with major hydroelectric projects -- as, for instance, the Kunhar Project, briefly discussed in Chapter VIII below -- and there are possible sites of a somewhat comparable nature on the Indus main stem, as at Bunji and Chilas and elsewhere in the Upper Indus area. Because of the extent to which their flows are already used and the year-to-year variability of these flows, further storage development of sizable scale on the tributaries will be very closely linked to the irrigation needs of the particular sectors of the overall irrigation system which are served by these tributaries.

The Project for Raising Mangla

7.63 All the impounding structures of the Mangla Dam Project are designed for raising it 40 feet to elevation 1274; this would permit a 48-foot increase in full reservoir level (to elevation 1250 feet SPD) -- somewhat greater than the increase in the dam height because the larger surface of the higher reservoir would mean that floods could be handled with a smaller rise in reservoir elevation. Raising the maximum reservoir elevation to 1250 feet would permit an increase in live storage capacity in the neighbrohood of 3.5 MAF. Detailed studies have been made of this project and the most recent estimate of cost amounted to US$217 million, with US$130 million in foreign exchange.

7.64 According to the IACA projections of irrigation water requirements shortages will arise in the canal commands of the eastern Punjab in the 1980's. It is at this time that the areas with groundwater of poorer quality that has to be mixed with surface water before it is usable for irrigation will be coming under development. IACA recommends construction of a new trans-Punjab link canal, above the TSMB link, and taking off from the tail reach of the Chasma-Jhelum Link on the Jhelum River, as discussed in Chapter VI. This would enable more of the eastern Punjab to be commanded from the Indus and would add significantly to the flexibility of the system. At the same time, as the cropping intensity of the mixing zones grows the requirement of such areas for rabi surface supplies will increase. Additional storage at Mangla would help to meet this need. It is true, as indicated by Tables 43 and 45 that the kharif surplus available for storage at this time on the Jhelum will be declining; for instance, according to the IACA projections, it would be possible to fill a reservoir at Mangla only to the extent of 7 MAF even under mean-year conditions at the stage of ultimate development in the reference year 2000. Capacity of Mangla, raised the full 40 feet, but allowing for siltation, is expected to be about 8 MAF by this time. Thus many questions will have to be answered before it is firmly decided to raise Mangla. It may be preferable, as IACA tentatively suggest, to add less than the full 40 feet to Mangla Dam. On the other hand, it might be about this time that the system would be in transition from inter-seasonal storage, which has been the main concern of this report, to over-year storage; it would be quite logical to make the first step towards this stage on the very variable Jhelum River just as the tributaries rather than the Indus itself have in the past been first to see each new stage of development. Over-year storage would mean storing water from years of high flood for use in low-flow years, and obviously this could only be done with substantially larger storage capacity than necessary for inter-seasonal transfers alone. Raising of Mangla will also be intimately related to the construction of the proposed trans-Punjab Link Canal; the latter might postpone the need for additional storage at Mangla for some years, but it might also be operated in such a way as to reduce the load of kharif requirements that had to be borne by the Jhelum and thus leave larger surpluses for storage at Mangla.

The Swat-Ambahar Project

7.65 The Swat River is a tributary of the Kabul; existing developments there include the Upper Swat irrigation scheme, based on the Amandara headworks and the Lower Swat system of canals which draw their water from the Munda headworks. IACA estimated that, at full development, these projects will utilize, in an average year, all but 4.75 MAF of the Swat River flow. Of this, only about 2.0 MAF would be "untimely" and therefore available for storage. There are indications of promising storage possibilities in the basin, but lack of data on dam sites allowed only an indicative desk study to be made by Chas. T. Main. This was in reference to a possible dam at Ambahar in the Lower Swat Gorge, about 13 miles upstream from the Munda headworks. It would appear possible to construct a very high dam in this area. As outline by Chas. T. Main, a rockfill dam about 710 feet high would create a reservoir with a gross storage capacity of about 2.4 MAF, of which 2.0 MAF would be live. Large variations in storable run-off could be expected from year to year. There are possibilities that additional water could be brought from the Kabul but the cost would be high. However, the high head available at Ambahar would permit generation of a considerable amount of power even from the relatively small flows available in the Swat River; the project would have value for peaking purposes in the low flow season, although the transmission distances would be substantial. Much necessary data regarding the project, such as sediment records and geological information, are lacking and the inclusion of this project in the program is based on the assumption that further investigations verify the possibilities. Chas. T. Main estimated the cost of the project at $145 million.

Chiniot Project on the Chenab

7.66 The Chenab River, in West Pakistan, presents no suitable sites for large-scale storage development, but there is one possible small project which might prove useful for regulatory purposes in connection with the operation of the massive link canal system. The project consists of an offstream reservoir of 1.4 MAF capacity which might be created in an abandoned channel of the river near Chiniot, some 110 miles downstream of Marala, by construction of extensive earthen dikes. The reservoir would have to be connected to the river by a canal. Water could only be stored there for short periods because of the permeable nature of the reservoir floor and the danger of waterlogging the surrounding farmlands. The costs of the project would be quite high at over $100 million and thus it has not been included in the proposed program, but experience in operation of the enlarged canal system might show the need for such a centrally located project which could be used to take small temporary surpluses and balance up month-to-month canal supplies.

Financial Requirements of the Proposed Program

7.67 One of the objectives of the Indus Study is to indicate the order of magnitude of investment needed over the 20-year period 1965-85. This chapter has emphasized the uncertainties involved -- not only with regard to actual requirements for surface storage but also regarding the projects which further investigation may show to be most appropriate and their costs. However a reasonable estimate of financial requirements between 1965 and 1985 can be made for the program of surface storage given in Table 48. The Bank Group believes that this program is as sound as such a program can be made at this time and that it is consistent with the proposals made elsewhere in the report for integrated development of all the water and power resources of West Pakistan. This program envisages completion of three surface storage projects, apart from Mangla, within the two decades 1965-85 -- Raised Chasma Barrage, Tarbela and Sehwan-Manchar. However several additional projects -- Raised Mangla, Chotiari and Kalabagh -- would be completed shortly after 1985, and expenditures on them would therefore commence within the 20-year period.

7.68 Besides the program of surface storage projects the Bank Group has also proposed a program of investigations, particularly with regard to the silt problem in the Upper Indus and identification of the best scheme for second-stage storage on the Indus. This program was mentioned in preceding paragraphs and is discussed in detail in Volume III, Chapter VIII. It is difficult to be precise about the costs involved, but the Bank Group has estimated that about $2.5 million (with a 36 percent foreign exchange component), excluding taxes, may be required annually up to about 1970 and $3 million thereafter. Total estimated costs of the investigation program for the period 1968-75 are shown in Table 56, and a breakdown is given in Volume III, Chapter VIII.

Table 56

Preliminary Estimate of Cost of Investigation Program for Surface Water Storage, 1967/68-1974/75

	US $ Million
Collection and analysis of basic hydrological and meteorological data	5.9
Identification of second-stage storage	5.5
Detailed investigation of second-stage storage	7.5
Master planning	2.0
	20.9

These estimates are not intended to cover the costs of the existing network of hydrometric stations maintained by WAPDA and the Irrigation Department. They are intended to cover the costs of the silt studies recommended by the Bank Group. Other estimates have been made indicating that the sums required for investigations may be even higher. The Bank Group believes strongly that a substantial allocation for these activities should be included in development budgets in the coming years, because large sums are scheduled to be spent on surface water projects throughout the Perspective Plan period and the availability of adequate data will enable those sums to be spent much more effectively than would otherwise be the case. Without the data and the requisite analyses of them Tarbela may be filled with silt quite rapidly and costly mistakes may be made either in selecting less than the best future projects or designing too conservatively or too radically for them.

7.69 Table 57 brings together the estimated annual costs of the proposed surface storage projects and investigations program over the years 1965-85. The first seven columns indicate the estimated economic costs of the projects and investigations program; the figure used for Tarbela is somewhat different in that it includes the allowances for inflation and financial contingency shown in Table 55. The eighth column sums them by years; the ninth column indicates the estimated foreign exchange component of the total program. The last two columns show the estimated cost of the whole program, including allowances for duties, taxes and interest during construction, first in U.S. dollars and then in Rupees.

Table 57

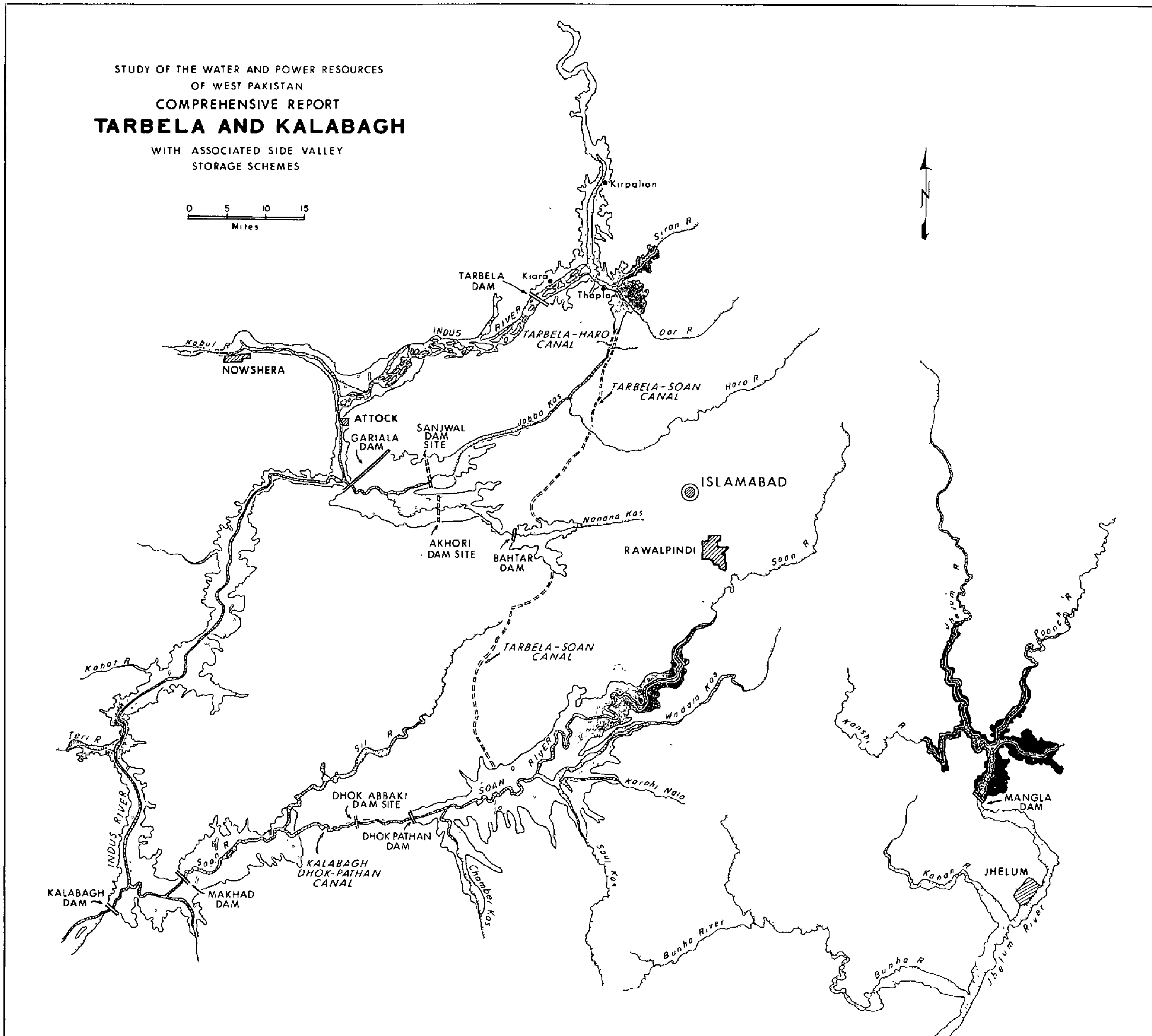
Estimated Annual Cost 1965/66-1984/85 of Surface Water Storage Program
(Million US$)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	Raised Chasma (1972)	Tarbela a/ (1975)	Sehwan-Manchar (1982)	Raised Mangla (1986)	Chotiari (1990)	Kalabagh (1992)	Investigations	Total Annual Expenditures		Interest during constr. b/	Estimated Taxes c/	Total Financial Requirements	
								Total	F.E.			$ mlns.	PRs mlns.
1965/66	0.3	1.4						1.7	0.7		0.3	2.0	9.5
1966/67	0.6	20.4						21.0	7.1		3.4	24.4	116.1
1967/68	3.9	99.4					1.9	105.2	59.2		16.8	122.0	580.8
1968/69	5.6	103.1					2.5	111.2	68.5	0.5	17.8	129.5	616.4
1969/70	3.9	100.3					2.5	106.7	66.2	0.8	17.1	124.6	593.1
1970/71	2.7	98.8					2.5	104.0	61.6	1.0	16.6	121.6	578.8
1971/72	1.1	76.1					2.5	95.4	56.7	1.1	15.3	96.1	457.4
1972/73		71.0					3.0	89.0	53.2		14.2	88.2	419.8
1973/74		68.6	1.0				3.0	77.6	46.7		12.4	75.0	357.0
1974/75		60.4	3.0				3.0	86.8	50.4		13.9	80.3	382.2
1975/76		53.0	6.0				3.0	77.0	43.6	0.5	12.3	74.8	356.0
1976/77		22.5	25.0				3.0	71.5	38.9	1.3	11.4	63.2	300.8
1977/78			35.0				3.0	58.0	29.6	3.2	9.3	50.5	240.4
1978/79			40.0				3.0	48.0	23.2	5.7	7.7	56.4	268.5
1979/80			40.0	0.4			3.0	48.4	21.9	8.4	7.7	59.5	283.2
1980/81			35.0	1.2		0.8	3.0	40.0	18.0	11.2	6.4	57.6	274.2
1981/82			26.0	4.0		2.5	3.0	35.5	16.2	13.4	5.7	54.6	259.9
1982/83			10.0	28.5		4.0	3.0	45.5	22.0	16.1	7.3	68.9	327.9
1983/84				59.5	1.0	10.0	3.0	73.5	38.6	4.5	11.8	89.8	427.4
1984/85				69.0	2.0	16.0	3.0	90.0	48.1	9.3	14.4	113.7	541.2
	18.1	775.0	221.0	162.6	3.0	33.3	50.9	1386.0	770.4	77.0	221.8	1552.7	7390.6

a/ Excludes civil engineering work and all mechanical and electrical items for power plants. Total cost figure therefore differs from that presented in Table 14 by $40.7 million, being the cost of civil engineering works for the first four power units.

b/ Compound interest at 6 percent per annum, assuming equal monthly disbursements within a year. Interest during construction included for all projects except Tarbela.

c/ Taxes taken at 16 percent of annual expenditures excluding taxes, as implied by Table 55.


STUDY OF THE WATER AND POWER RESOURCES
OF WEST PAKISTAN
COMPREHENSIVE REPORT
TARBELA AND KALABAGH
WITH ASSOCIATED SIDE VALLEY
STORAGE SCHEMES
0 5 10 15
Miles
Kirpalian
Siran R
TARBELA DAM
Kiara
Thapla
Dor R
INDUS RIVER
TARBELA-HARO CANAL
Kabul R
NOWSHERA
TARBELA-SOAN CANAL
Haro R
Jabba Kas
ATTOCK
GARIALA DAM
SANJWAL DAM SITE
ISLAMABAD
Nandna Kas
AKHORI DAM SITE
BAHTAR DAM
RAWALPINDI
Soan R
Kohat R
Teri R
Sil R
Wadala Kas
Jhelum R
Poonch R
Kansh R
MANGLA DAM
SOAN RIVER
Karahi Nala
DHOK ABBAKI DAM SITE
DHOK PATHAN DAM
KALABAGH DHOK-PATHAN CANAL
Soan R
Soal Kas
Chamber Kas
INDUS RIVER
KALABAGH DAM
MAKHAD DAM
Kahan R
JHELUM
Bunha River
Bunha R
Jhelum River

VIII. EVALUATION OF ELECTRIC POWER PROGRAM

Introduction

8.01 The Bank Group's Power Report is essentially based on the work and findings of Stone & Webster. However, in reviewing Stone & Webster's report, the Bank Group has been influenced by the views expressed by the Government of Pakistan on the consultants' findings, by their own studies of the West Pakistan power system and by developments which have taken place since the consultants completed their field work late in 1965 and their report in May 1966. Some of these interim developments resulted in substantial changes in the basic data underlying the power program recommended by Stone & Webster. Foreseeing the recurrence of such changes in knowledge about fuel reserves, expectations regarding future loads, etc., the Bank Group was anxious to develop techniques for handling these matters which would be useful not only for its own evaluation of the Stone & Webster program, but also for the future revisions of the power program that will be necessary as knowledge and expectations continue to change. The Bank Group devoted particular attention to the question of the amount of natural gas that might wisely be used for power generation given the reserves assumed to be available in the Province and the growth of requirements of natural gas for purposes other than power generation. The Bank Group also tried to develop techniques for linking the forecast of power loads to the overall Perspective Plan for the growth of the provincial economy. To assist in the formulation and evaluation of power development programs in the light of expectations regarding power loads, fuel reserves, alternative sources of generation, alternative transmission possibilities, etc., the Bank Group developed a computer model which effectively simulates the operation of the electric power system of West Pakistan month by month for the 20-year Perspective Plan period 1966-85.

8.02 The Bank Group's Report, in accordance with the objectives of the Indus Special Study, concentrates on the determination of a feasible action program for the development of the West Pakistan power system over the decade 1965-75 and a tentative indication of the kind of developments that would seem likely to be appropriate for the decade 1975-85.

The Structure of the West Pakistan Power System

8.03 West Pakistan is served by four regional power systems, shown in Map 5 at the end of this chapter. These systems, which are not interconnected, serve the following areas:

(1) the North, which is an extensive area tied together by a 132-kv grid; it contains all of the hydroelectric capacity in the Province, and has a capability at the maximum hydro output of approximately 522 mw;

(2) the Upper Sind, centering on a gas-fired 50-mw steam station at Sukkur;

(3) the Lower Sind, which has both gas-fired steam and gas turbine plants, with a total capacity of about 30 mw centered on Hyderabad;

(4) Karachi, West Pakistan's largest city and largest seaport and industrial center, with a generating capacity of about 250 mw.

Apart from these four main electrical systems in the Province, there are many small isolated generating plants with related distribution facilities, most of them serving individual municipalities or industrial installations. Very much the largest of them is a 15-mw coal-fired station at Quetta.

8.04 The bulk of power facilities in the North and in the Sind, as well as the 15-mw Quetta plant, are owned and operated by the West Pakistan Water and Power Development Authority (WAPDA), an autonomous Government agency. Karachi is served by the Karachi Electric Supply Corporation (KESC), a stock company in which the Government holds a controlling interest. WAPDA also runs some of the small isolated stations in the Province, while others are in the hands of municipal utilities or private industrial enterprises. In 1965 about 65 percent of the electrical energy generated in West Pakistan was supplied by WAPDA, about 18 percent by KESC, about 14 percent by industrially owned generating equipment, and the remaining three percent by privately owned utilities.

Recent Growth of Electricity Consumption

8.05 Tables 58 and 59 give an impression of the growth of electricity consumption among different groups of consumers and in different geographical areas between 1960 and 1965. Residential and commercial sales, as well as industrial sales, have more than doubled in these five years; but sales for agricultural pumping in 1965 were about six times what they were in 1960.

Table 58

Total Sales of Energy to the Various Classes of Customers by Utilities in 1960 and 1965

Class of Consumer	1960 Million kwh	1960 Percent of total	1965 Million kwh	1965 Percent of total
Residential & Commercial	193	16.5	488	15.4
Industrial	576	49.3	1,321	41.5
Bulk and other uses	116	9.9	216	6.8
Agricultural Pumping	87	7.4	538	16.9
Total Sales	972	77.8	2,563	80.6
Losses and Theft	197	22.2	617	19.4
Total Utility Generation (Net)	1,169	100.0	3,180	100.0

In the Northern Area total sales grew about 25 percent per year and in Karachi the growth was 18 percent per year. In the North, agricultural pumping grew almost two and a half times as fast as industrial sales. The electric energy generated and peak demands on public utility systems in West Pakistan in 1960 and 1965 are shown in the following table.

Table 59

Energy Generated and Peak Demands (net) 1960 & 1965

	1960		1965	
	Energy Mln kwh	Demand Megawatts	Mln kwh	Demand a/ Megawatts
North	777.4	152	2,296.0	409
Sind & Baluchistan	31.9	25	174.0	34
Private Utilities	67.6	-	66.0	-
KESC	292.7	50	644.0	121
Subtotal	1,169.0	227	3,180.0	564
Industrially owned	520.0		544.0	
TOTAL	1,689.0		3,724.0	

a/ Actual demand. The non-suppressed demands (excluding load shed as a result of shortages of capacity) were estimated as follows: North, 473 mw; Sind & Baluchistan 44 mw; KESC 136 mw.

Load Forecast

8.06 Stone & Webster prepared a detailed 20-year load forecast for each of the four main power markets identified above and for the Quetta system. Hypothetical 1965 figures were used as the basis for the load forecast rather than the actual figures cited in Tables 58 and 59 chiefly because of the downward bias imparted to the actual figures by the load shedding and voltage reduction that took place in that year; 1965 loads met by small independent utilities within the WAPDA service areas were also included in the base year figures because these loads and any increase that takes place in them will be largely met by WAPDA in the future. Stone & Webster projected requirements of electric energy in each area under several different heads -- such as industrial, residential, commercial, agricultural -- and then assigned appropriate hours of use to each category in order to determine peak loads. The agricultural load forecast (i.e. tubewell pumping) was made on the basis of data supplied by the irrigation and agriculture consultant (IACA) regarding number of tubewells to be constructed, average utilization rates, monthly pattern of tubewell pumping, etc. Forecasts of other categories of electric energy requirements were made by Stone & Webster on the basis of a number of factors, such as historic performance, known firm and committed loads, and long-term economic growth forecasts.

8.07 The resultant load forecasts may be summarized as follows. (They are shown in detail in Table 47 of Volume IV.) Total net electrical energy requirements are expected to increase from slightly under 4,000 million kwh in 1965 to nearly 30,000 million kwh in 1985. The average annual rate of increase over the 20-year period 1965-85 would be 10.6 percent, ranging from 14 percent during the Third Plan period to eight percent in 1980-85. Industrial consumption of electric energy would grow from 1,800 million kwh in 1965 to 13,500 million kwh in 1985, at an average annual rate of 10.5 percent, falling from 13 percent per annum in the Third Plan period to eight percent per annum in the period 1980-85. Residential consumption of electric energy would grow from about 380 million kwh in 1965 to about 3,700 million kwh in 1985 or at an average annual rate of 12 percent, falling from nearly 14 percent in the Third Plan period to about 10 percent in the period 1980-85. Agricultural consumption of energy would grow from about 570 million kwh in 1965 to about 5,050 million kwh in 1985 or at an average rate of 11.6 percent, falling from 18 percent per annum in the Third Plan period to about 7 percent per annum in the period 1980-85.

8.08 Table 60 summarizes the final forecast of energy and peak loads, both net of station use, for the electric utilities in the various areas of West Pakistan. It consists of Stone & Webster's forecasts of requirements of the various classes of consumers, except agricultural pumping, (so-called Basic load) and IACA's final forecast of the pumping requirements.

Table 60

Forecast of Energy and Peak Loads, 1965-85
(Excluding industrially owned generation)

Area	1965	1970	1975	1980	1985	Annual Rate of Growth(%)
Energy (million kwh)						
North	2,480	4,606	7,228	10,589	15,063	9.5
Upper Sind	31	271	650	976	1,518	21.5
Lower Sind	152	349	778	1,405	2,309	14.6
Baluchistan	16	43	85	134	210	13.8
Karachi	710	1,675	3,520	6,055	9,300	13.8
Total Utility	3,389	6,944	12,261	19,159	28,400	11.2
Peak Load (mw)						
North	473	889	1,402	2,021	2,878	
Upper Sind	8	45	105	162	250	
Lower Sind	31	73	154	266	424	
Baluchistan	5	12	22	32	48	
Karachi	136	309	642	1,114	1,730	
Total Utility	653	1,328	2,325	3,595	5,330	

In 1965, about 73 percent of the total utility generation was consumed in the Northern Grid, and 21 percent in Karachi. By 1985, the Northern Grid is estimated to consume 53 percent of the total, and Karachi 33 percent. The pattern in 1985 reflects the expected continued rapid development of industry in the South.

8.09 The Bank Group subjected the consultants' final load forecasts, as given in Table 60 to a careful scrutiny. Great uncertainty inevitably surrounds projections 20 years into the future. Yet, because Tarbela Dam would take eight or nine years to build and because the generating capacity and transmission lines added during the next few years would soon become part of a power system dominated by Tarbela, 20 years seemed the minimum perspective required for wise decision making. In this connection it was helpful that the Pakistan Planning Commission had prepared a general sketch of how the economy as a whole might grow between 1966 and 1985 and that the irrigation and agriculture consultant had prepared a plan for the development of the agricultural sector over the same 20-year period. As part of its review of the Stone & Webster forecast the Bank Group considered the consistency of the load forecast with these other projections. Since 90 percent of the present and perspective power load is accounted for by three categories -- industrial, residential/commercial and agricultural (tubewell pumping) the Bank Group concentrated its effort on these.

Agricultural Pumping

8.10 The growth of pumping load is mainly dependent on the number of tubewells installed and their capacity; the forecast of pumping load adopted in this report, including its monthly pattern, is consistent with the recommendations made in the agricultural section of the report regarding the installation of public tubewells and the electrification of private wells. The wells installed by WAPDA under the SCARP program (Salinity Control and Reclamation Program) have so far generally been shut down daily for two hours at times when generating capacity was short. This has resulted in a reduction of system peak demand by some 20-40 mw. The irrigation consultant and power consultant conducted studies which showed that interruption of the public tubewells at the time of daily system peak would continue to be physically feasible and economically worthwhile. Interruption of the peak pumping load was, therefore, built into the load forecasts according to the working criteria established by the consultants that drainage wells (i.e those pumping saline water in excess of 3,000 ppm) would be shut down for the four-hour evening peak, while about 75 percent of the public wells in usable groundwater areas would be shut down for two hours a day, 35 percent in the first two hours of daily peak and 35 percent in the second two hours of daily peak. The pumping load forecasts shown in Table 61 below are all given net of this amount of interruption.

Residential and Commercial Load Forecast

8.11 The growth of residential and commercial load is mainly dependent on the increase of family incomes, which enables additional families to become consumers of electricity and existing electricity consumers to purchase more electrical appliances and increase their consumption of electricity, and on the extent to which the utilities are able to extend the distribution system into new areas. The Bank Group tried to evaluate the prospects in these fields in the light of the growth of family incomes projected in the Perspective Plan, the heavy emphasis on agricultural development implied by the Perspective Plan and by the agricultural section of this report, the extensive development of ground-water pumping in the Indus Basin which is in view, and the funds which might be available for extension of the rural distribution system. The Bank Group's studies (described in Volume IV and its Annex 3) led to the conclusion that, if the trained manpower and organizational capability were available to put in the distribution lines, then the number of residential consumers might grow somewhat more rapidly than Stone & Webster had projected; however, the Bank Group's estimates suggested that current average consumption per household might be rather below the figure adopted by Stone & Webster and that average consumption might grow somewhat more slowly than suggested by them. Rural electrification would tend to be restricted by the availability of finance. The composite effect of these various factors might be a slightly slower growth of the residential load than projected by Stone & Webster, especially in the early years of the Perspective Plan period.

Industrial Load Forecast

8.12 The growth of industrial load will depend heavily on the overall industrial growth rate in the Province and on the type of industry responsible for most of the growth. The Bank Group took the view that the rate of industrial growth implied by the Perspective Plan was somewhat below what might actually be achieved, especially in the early years of the Plan period. At the same time a relatively high proportion of the industrial growth, particularly in the early years, might be in industries which are exceptionally heavy consumers of electric power, such as cement, fertilizer and certain petrochemical industries. These industries were separated out from the general industrial category, and remaining industries were grouped together in classifications such as consumer goods, capital goods, etc., the growth of each of which could be projected separately over the Perspective Plan period; separate projections of output in both physical and financial terms were made for the cement and fertilizer industries. The average industrial growth rate implied by the long-term growth framework underlying the Bank Group's studies was somewhat more than 10 percent per annum over the whole of the 20-year period, 1966-85, but it was higher initially -- about 13 percent for instance, in the Third Plan period. The fertilizer industry would grow much more rapidly than other industries at an average rate of about 15 percent over the 1966-85 period and about 30 percent per annum in the Third Plan period. On the basis of certain assumptions about existing and future power intensities of different industries and industry groups (i.e the amount of electric energy consumed by the industry per PRs 10 of net output) projections of the growth of the output of different industries such as those given above were translated into projections of the growth of the power requirements of the different industries. The result of these studies was a projection that the overall industrial load in the Province might grow at about 15 percent per annum through the Third Plan period -- more rapidly than industrial output because of the importance of power-intensive industries -- and about 10-11 percent per annum in the remaining years of the Perspective Plan period. This meant that the industrial load might grow initially slightly more rapidly than Stone & Webster had projected; after 1970 the effect of various divergent trends would be somewhat slower growth in industrial load than they had suggested but also one that tailed off less rapidly than they implied.

8.13 These economic evaluations of the consultants' load forecast (as given in Table 60) thus led to the general tentative conclusion that, in terms of the growth of total electric energy requirements, the consultants were slightly on the optimistic side. The Bank Group took the view that a tendency to err slightly on the optimistic side was correct, given the long-term capacity planning purposes for which the load forecast was being used.

8.14 Because of the importance of the subject of high-voltage transmission among the questions requiring decision the Bank Group also evaluated, as best it could, Stone & Webster's projection of the geographical distribution of future power loads. This evaluation led to the conclusion that while loads might be somewhat differently distributed within the North or the South (e.g. greater growth in Upper Sind due to the fertilizer industry there), nevertheless the general balance between North and South projected by Stone & Webster seemed reasonable. In other words, loads might be expected to grow exceptionally rapidly in the Sind, and also somewhat faster in Karachi than in the Northern Grid area. Thus the predominance of the Northern Grid area in consumption of utility-generated electricity would tend to fall, from about 70 percent of the Provincial total in 1965 to about 55 percent in 1985.

Contingency Load Forecasting

8.15 The Bank Group's belief that the load forecast given in Table 60 represents a reasonable basis for purposes of long-term planning is of course based on its judgment of what now seems likely to occur. Obviously things can change rapidly in a country that is developing as rapidly as Pakistan has been doing in recent years. This makes it particularly important to keep the load forecasts under constant surveillance and it also suggests the value of contingency planning -- or planning against a number of different load forecasts in order to minimize the chance of being caught unprepared. As regards surveillance of load forecasts, the Bank Group feels that there are some deficiencies in WAPDA's existing procedures for forecasting loads five years ahead and it also believes, along with Stone & Webster and Harza, that greater attention should be given to longer term load forecasting and to coordination between load forecasting and general economic planning. These matters are discussed fully in Volume IV of this report and its Annex 1, where the existing load forecasting procedures are described in some detail, some techniques are developed for relating load forecasts to long-term economic planning and some specific suggestions are put forward for the improvement of load forecasting in West Pakistan. As regards the use of alternative load forecasts for purposes of contingency planning the Bank Group has attempted to give an indication of the way in which this approach can be helpful by considering a higher forecast of basic load in the North as an alternative to the forecast given in Table 60. The Bank Group believes that Stone & Webster's forecast of basic load in the North is sound. However, there are some major uncertainties surrounding it. The requirements of electric power for construction of Tarbela, for instance, could be higher than assumed in Table 60, and there is uncertainty about the extent to which the transfer of Government from Karachi to Islamabad and the Government's emphasis on industrial development outside Karachi may result in greater growth of large scale commercial and industrial load in the Northern Sind and the Punjab. The Stone & Webster load forecast was carefully built up item by item to take account of prospective loads in the North. However, another higher load forecast for the Northern Grid has been made by Harza, not on the basis of individual loads expected, but simply as a rough extrapolation of load growth (from the base year figures developed by Stone & Webster for 1965) at annual rates declining from about 14 percent per annum during the Third Plan period to about 10 percent per annum during the Sixth Plan period.

8.16 Thus the Stone & Webster forecast has a more solid analytical basis, but the Harza forecast is a useful means of preparing for any unexpected future load growth. Table 61 compares the two forecasts of basic load in the North, the main forecast adopted by the Bank Group (i.e. Stone & Webster) and the contingency forecast (i.e. Harza). Both forecasts have been used in conjunction with the final forecast of pumping load which has come out of IACA's studies.

Table 61

Alternative Load Forecasts for Northern Grid Area

	1965	1970	1975	1980	1985	Annual Rate of Growth(%)
Main Forecast(million kwh)						
Basic Load	1,820	3,100	4,600	7,040	10,270	9.0
Pumping Load	680	1,514	2,628	3,547	4,793	10.3
TOTAL	2,500	4,614	7,228	10,587	15,063	9.5
Contingency Forecast(million kwh)						
Basic Load	1,820	3,480	5,900	9,596	15,453	11.3
Pumping Load	680	1,514	2,628	3,547	4,793	10.3
TOTAL	2,500	4,994	8,528	13,143	20,246	11.0
Projected Peak Loads(mw)						
Main Forecast	473	889	1,402	2,021	2,878	
Contingency Forecast	473	967	1,591	2,521	3,928	

The Bank Group has worked primarily in terms of the main load forecast given in the above table, but it has also considered the implications of the contingency forecast for some of the major decisions facing West Pakistan in the development of its power system.

The Existing Power Situation and Current Programs

8.17 In recent months the Northern Grid area and Lower Sind have been confronted with a serious power crisis, while the other two main power markets -- Karachi and the Upper Sind -- appear to have an adequate supply of electricity. The situation in the Northern Grid area has been especially acute, largely as a result of unforeseen mishaps to the units at the main thermal station in the North at Multan and delays in the completion of a new thermal station at Lyallpur. By the middle of 1966 WAPDA had a peak capacity of about 550 mw net (160 mw at Warsak hydro station, 85 mw on eight small hydroelectric stations on rivers and canals, 250 mw in four modern gas-fired steam units at Multan, 26 mw in two new gas turbines at Lahore and about 25 mw in miscellaneous small thermal units). Peak demand in August was estimated at about 520 mw net, but the peak which could actually be met was only about 400 mw. Equipment failure at Multan had resulted in outage of one complete unit and reduction in capacity of the three other units. The necessity for load shedding grew to even larger proportions in the winter of 1966/67 as a result of the reduction in the capabilities of the hydro units that occurs with the reduced river flows in the winter months.

8.18 The Lower Sind system has been overloaded for a number of years and load growth consequently suppressed. Peak demand in 1966 was estimated by WAPDA at about 38 mw, but due to the failure of a boiler in a new 15-mw steam unit, the peak load actually met was only about 28 mw.

8.19 These shortages which have resulted in serious loss of agricultural and industrial production over the last six months or more should be largely overcome during 1967. By the end of April 1967, with the increase of flows in the rivers and the reduction in tubewell loads the worst of the power crisis was over. By the middle of the year the first two units at Mangla were in operation (minimum combined capacity in March-May about 90 mw and maximum capacity in August-September about 260 mw) and two 66-mw steam units were soon due to be completed at Lyallpur. In the latter part of 1967 four 13-mw gas turbines should be added to the Lahore station. Therefore, if proper use is made of the time when there will be surplus capacity on the system due to high flood flows on the Jhelum in order to repair the Multan units, it may be possible to bring them back to full-rated capacity. In such an event the total net capacity on the system by March 1968 would be as follows:

Table 62

WAPDA Northern Grid Net Capability, March 1968
(mw)

Warsak Units 1-4	100
Mangla Units 1-2	90
Small hydels	75
Multan steam station	250
Lyallpur steam station	124
Lahore gas turbines	78
Miscellaneous thermal	23
TOTAL	740

Net capability of 740 mw in March 1968 would compare with projected load of about 600 mw on the main load forecast used here and 620 mw on the contingency load forecast. Both these loads are given net of interruption of public tubewells at the peak.

8.20 The existing capacity in the Lower Sind area of about 30 mw should be increased by about 28 mw during 1967 as a result of final completion of the 15-mw steam unit at Hyderabad and installation of a 13-mw gas turbine at Kotri. WAPDA plans to add two more 13-mw gas turbines at Kotri during 1968 and by the middle of that year a 132-kv transmission connection should be completed between Hyderabad and Karachi. Karachi has a net capability of about 250 mw at the present time, against a 1966 peak load of about 136 mw. The main units on the Karachi system are two 33-mw steam units at West Wharf and two new 66-mw units at Korangi. The Upper Sind system had a capability of about 25 mw in 1966 (in two 12.5-mw steam units at Sukkur) against a peak load of about 8 mw. Two more 12.5-mw steam units have been added to the Sukkur steam station in early 1967 so that the Upper Sind now has a net capability of 50 mw.

8.21 Orders have also been placed for a number of additional generating units to be installed within the next few years. The third unit at Mangla is expected to be ready for service late in 1968 and the fourth unit late in 1969 or early in 1970. Negotiations for supply of two 100-mw steam units from Czechoslovakia for installation in the Upper Sind area by about 1970 or 1971 are being finalized by WAPDA. A double circuit 132-kv link between the Northern Grid and the Upper Sind is also being completed so that the Northern Grid would be able to draw about 120 mw from the Upper Sind. The World Bank has recently approved a loan to KESC for addition of a 125-mw steam unit at Karachi, which should be completed during 1969. Table 63 compares anticipated capability and anticipated loads in the critical month in each of the four main market areas in 1970, on the assumption that both the Czech units at Mari will be completed by that time.

Table 63

Generating Capability and Peak Loads, 1970
(mw)

		Capa-bility	Peak Loads Main Forecast	Contingency Forecast
Without Transmission Link				
Northern Grid	(March)	830	813	879
Upper Sind	(October)	250	45	45
Lower Sind	(October)	84	73	73
Karachi	(October)	375	309	309
With 132-kv Transmission Link				
North/Upper Sind	(March)	1,080	852	918
Karachi/Lower Sind	(October)	459	382	382

the last two lines in the table indicate the situation that will exist if the 132-kv links between the North and the Upper Sind and between Karachi and the Lower Sind are completed, as presently scheduled. The table indicates that additions to generation and transmission capacity for which commitments have already been made are sufficient to meet all anticipated increases in load; indeed the second Czech unit in the Upper Sind could be deferred to 1971 if anticipated loads are of the order projected in the main load forecast used here. As regards the South (Karachi/Lower Sind) capacity additions already described will be sufficient to meet anticipated loads with a reserve of about 80 mw. Such a reserve would be adequate on criterion generally adopted in these studies -- 12 percent of thermal capability and five percent of hydro capability -- but it would not be adequate on the largest-single-unit-out criterion since the largest unit on the Southern system at that time would be the 125-mw Korangi C unit. To ensure full security of supply in the South in 1970 it may be advisable to add several gas turbines. The program presented in the following pages includes 26 mw of gas turbines at Hyderabad in 1970, partly with a view to this need for additional reserves in that year and partly because additional gas turbines will subsequently be required in the South to firm up the EHV transmission link between Upper Sind and Karachi proposed below for the early 1970's.

Stone & Webster Bulk Power Supply Program

8.22 To meet the loads which they had projected over the 20-year period 1965-85, Stone & Webster developed a program of generation and transmission investments for supplying power throughout West Pakistan. There are four main features to the Stone & Webster program. First is the Tarbela Dam, the hydroelectric potential of which Stone & Webster had investigated and compared with alternative means of power generation in their 1964 report on the first phase of the Indus Special Study. The bulk supply program developed by Stone & Webster in the second phase of the study included the Tarbela Dam, completed in 1975, so that its power potential could be gradually realized in the following years. The second important component of the Stone & Webster program is 380-kv transmission interconnection, starting with a line between Mari and Karachi in 1971 and embracing all main load centers by the time that Tarbela comes on line in 1975. Third, and closely linked with the transmission recommendations, is a heavy concentration of thermal development at Mari (Upper Sind area) to provide all main load centers in the Province with thermal power produced by cheap gas there. Stone & Webster envisaged that all the reserves of the Mari gas field, as estimated at the time they were reporting (five trillion cubic feet), would be committed to supporting 1,500 mw of locally sited generating facilities. The fourth important feature of the Stone & Webster program was a continuation of thermal development based on Sui gas at Karachi.

8.23 Stone & Webster thus envisaged that all the generating equipment installed by the public utilities between 1965 and 1985 would be either hydroelectric or gas-fired thermal units. Their program did also make allowance for installation of a small 125-mw nuclear plant by the Atomic Energy Commission in the early 1970's, which would supply power to Karachi. The recommended hydroelectric development, including two additional units (Nos. 5 and 6) at Warsak, eight units at Mangla and 12 units at Tarbela, would have a firm capability of about 1,450 mw. This was based on the assumption that the Tarbela Reservoir would be drawn down to a minimum level of 1332 feet each year while the Mangla Reservoir would be drawn down to a minimum level of 1075 feet each year. New gas-fired plant would be installed mainly at Mari (about 1,500 mw) and Karachi (about 1,400 mw). Substantial seasonal interchange of power was envisaged, with hydro energy being sent south to the Sind and Karachi in the summer flood months and early winter when the reservoirs were nearly full and with energy generated at Mari being sent to Karachi in most months of the year and to the Northern Grid area in the spring when the reservoirs were at minimum levels. This program, which was drawn up after consideration of a large number of alternatives including various numbers of units at Mangla and Tarbela and various phasings of their introduction, different drawdown levels and reservoir release patterns at Mangla and Tarbela, alternative sources of thermal generation and alternative transmission patterns -- is explained in detail in Volume IV, Chapter V.

8.24 Table 64 indicates the schedule of installation of generation and transmission equipment proposed by Stone & Webster. The figures given in the table for the capability of the hydro units represent capabilities in the critical ten-day period on the system at the time the units are introduced. Besides the equipment listed in the table Stone & Webster also included in their program a further 32 mw of coal-fired thermal plant at Quetta and a 220-kv link between Mari and Quetta in 1981. They also recommended retirement of about 30 mw of small-scale generating equipment in Karachi and the Northern Grid over the next 10 years. Thus West Pakistan would, according to the Stone & Webster program, have a power system with a capability of 5,557 mw at the time of minimum hydro capability (May) in 1985. The forecast power demand would be somewhat over 5,000 mw at that time.

Table 64

Stone & Webster's Generation & Transmission Program, 1965-85
(mw)

Generating Equipment	Northern Grid Hydro	Northern Grid Thermal	Upper Sind Thermal	Karachi/ Hyderabad Thermal	Total
Existing 1965	155	277	25	275	732
1966-69	197	176	51	101	525
1970-74	277	-	390	250	917
1975-79	598	-	300	325	1,223
1980-84	400	-	540	880	1,820
1985	-	-	240	-	240

380-kv Transmission Equipment

1971	Mari-Karachi single circuit.
1973	Mari-Lyallpur single circuit.
1974	Second Mari-Karachi circuit; Tarbela-Lyallpur single circuit.
1977	Second Tarbela-Lyallpur circuit; Second Lyallpur-Mari circuit.
1982	Third Tarbela-Lyallpur circuit.
1983	Third Lyallpur-Mari circuit.

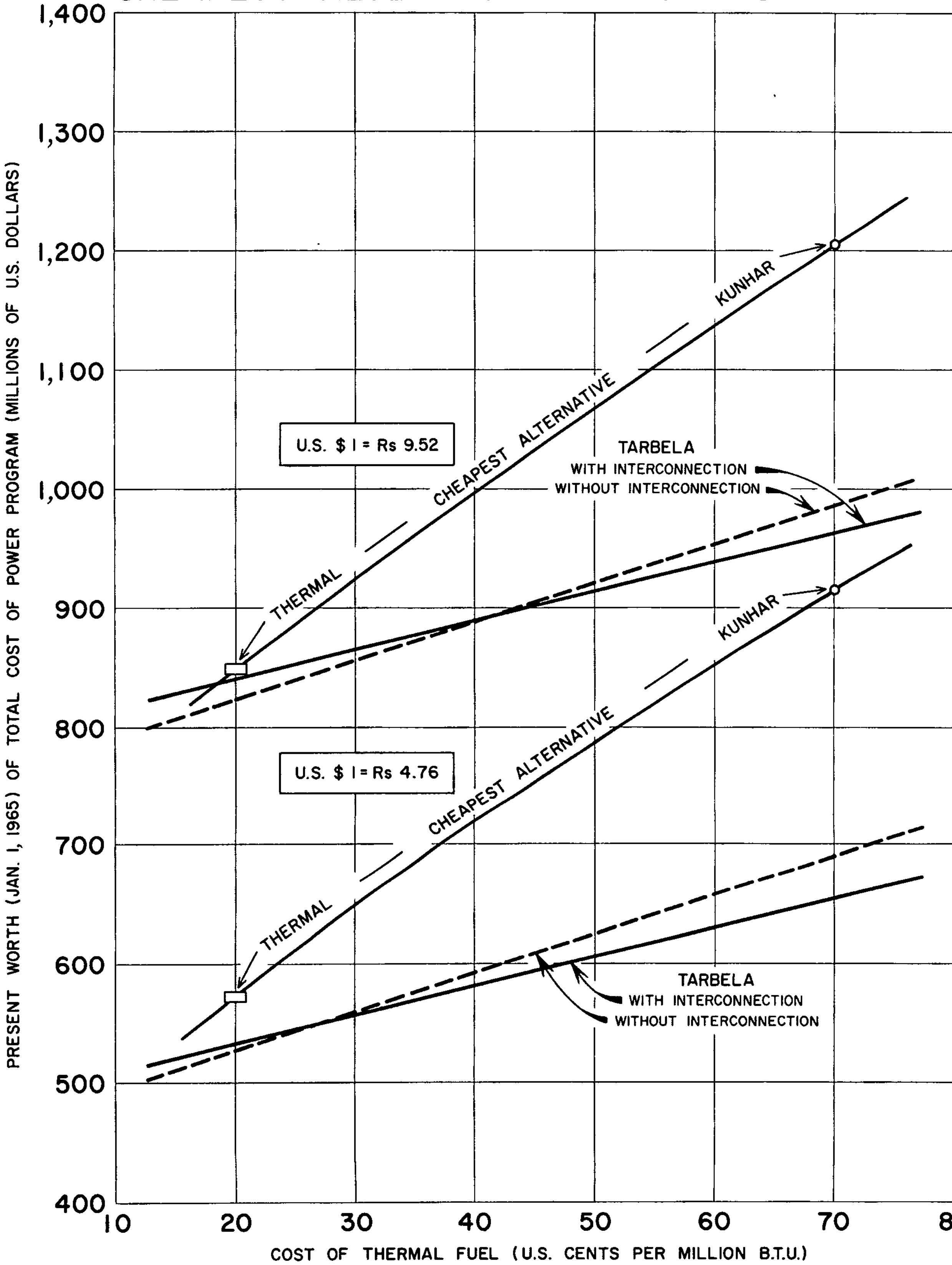
Bank Group's Adjustments to Stone & Webster's Program

8.25 The bulk power supply program for West Pakistan proposed in this report differs in a number of important respects from the program proposed by Stone & Webster, although many of the basic concepts put forward by the power consultants have been retained. The differences arise from a number of sources. Between the time that the power consultants completed their report and the time that the Bank Group completed its evaluation of the power consultants' program, one very important change occurred in the basic framework of information within which a power program for West Pakistan has to be drawn up: the best estimate of recoverable gas reserves at Mari was reduced from 5 trillion cubic feet to about 1.8 trillion cubic feet, resulting in a reduction of about 25 percent in the estimated total thermal value of the main usable gas reserves in the Province. This change in knowledge about fuel reserves required reevaluation of some of the most important proposals made by Stone & Webster, particularly with regard to transmission; to the extent that indigenous fuel reserves for thermal generation of electric power were scarcer than had previously been supposed, this also had an effect upon the power benefits attributable to the proposed hydroelectric projects. Other important differences between the Stone & Webster program and the Bank Group program arise from the fact that other parts of the Indus Special Study had been brought further along by the time that the Bank Group came to finalize its recommendations; this affected the drawdown level at Mangla, the release patterns at Mangla and Tarbela and the growth and monthly pattern of the assumed tubewell pumping load. There are other adjustments and elaborations to the program proposed by Stone & Webster which have resulted from the Bank Group carrying further investigation of certain particular items in the program, sometimes at the specific suggestion of the Government of Pakistan: the Bank Group, for instance, proposes substantially different scheduling of the hydro units at Warsak and Mangla and of the installation of the 380-kv transmission lines between Karachi and Lyallpur and also draws out some important implications of the proposed power program for the extension of the Province's gas pipeline system. There are some other relatively minor changes in the proposed program which result from the fact that commitments for installation of generating equipment over the next few years made since Stone & Webster completed their report differ from those envisaged by them. Some of the adjustments made by the Bank Group -- such as the suggestions for earlier installation of certain transmission lines and the heavier emphasis on nuclear installation following completion of 12 units at Tarbela -- result from a combination of the sources of change mentioned in the preceding lines. Almost all the changes proposed have been tested and examined with the aid of the computer model which the Bank Group used to simulate the operation of the West Pakistan power system for the 20-year planning period (see Volume IV, Annex 10).

The Evaluation of Tarbela

8.26 One of the subjects to which the Bank Group devoted prime attention because of its central position in the whole power program was the hydroelectric potential of the Tarbela Dam. The power benefits of the dam, which had been evaluated in the first phase of the consultants' and the Bank Group's studies in 1964/65, had to be reconsidered in the light of the conclusions reached in the second, comprehensive phase of the Indus Special Study. One study of the joint power and irrigation benefits of the dam was made in the context of the question as to what would be lost by postponing completion of the dam from 1975 to 1985. This study, which clearly indicated the advantages of early completion of the project, was described in Chapter VII on the Surface Water Storage Program. Another approach adopted by the Bank Group was to estimate the value of the power benefits that would accrue from construction of the dam by 1975 as opposed to its complete elimination from the proposed program. In order to identify the net power benefits of Tarbela (defined as the savings that would result from meeting projected power loads with a program including Tarbela rather than one excluding it) Stone & Webster had, as part of their 1964 report on Tarbela, prepared an alternative program excluding Tarbela for meeting projected load growth in the Northern Grid area. This program included a hydroelectric project on the Kunhar River (a tributary of the Jhelum). The present worth (at eight percent discount rate) of the cost (operating and capital) of this alternative program, which Stone & Webster considered the most favorable for meeting system demand for both energy and power, amounted to about

COMPARISON OF TARBELA WITH OR WITHOUT SYSTEMWIDE INTERCONNECTION WITH CHEAPEST ALTERNATIVE PROGRAMS



(2R) IBRD - 3310

$206 million or about $80 million more than the present worth of the cost 1/ of the program including Tarbela. The Bank Group prepared a number of power programs excluding Tarbela for meeting projected Province-wide load growth and it compared them with programs including Tarbela under different assumptions regarding the price of thermal fuel and the value of foreign exchange. It found that the net power benefits of Tarbela were not very sensitive to changes in assumption regarding the value of foreign exchange, but as illustrated by Figure 10, they were very sensitive to changes in assumption regarding the price of thermal fuel -- ranging from about $40 million at a fuel price of 20 cents per million Btu to about $220 million at a fuel price of 70 cents, with calculations using the current foreign exchange rate. At current financial fuel prices the net benefits attributable to Tarbela were in the neighborhood of $110-120 million.

The Scarcity Value of Thermal Fuel

8.27 Because of the sensitivity of the power benefits of Tarbela to different assumptions regarding the price of thermal fuel and because many other decisions concerning the scheduling of the introduction of the hydro units and transmission lines and the type of thermal equipment that should be installed depend intimately on the value attributed to the Province's fuel reserves the Bank Group devoted considerable attention to trying to determine the real economic value of thermal fuel in West Pakistan. This involved consideration of the Province's estimated reserves of natural gas, coal and oil and of the likely growth of demand for these fuels for purposes other than power generation, particularly for major alternative uses such as fertilizer production. Estimated indigenous reserves of oil are very small and known coal reserves are of relatively low thermal value and mostly located in places where exploitation would be costly, so that main attention was focused on the natural gas reserves. These are concentrated chiefly in the Upper Sind region, particularly in the Sui field (estimated reserves six trillion cubic feet) and in the Mari field (currently estimated reserves 1.8 trillion cubic feet), but there is also a number of other significant fields -- Sari Sing near Karachi, Khandkot and Mazarani in Upper Sind and Dhulian in the Potwar Plateau in the North. The reserves in these fields were considered together and compared against the projected growth of non-power uses of natural gas; it was found that if all the natural gas currently estimated to be available and not already committed were reserved for purposes other than power generation, then they would be exhausted about the year 2000. Therefore, to the extent that they were used in the interim for power generation the date when they would be exhausted would occur earlier. For the purposes of the analysis it was assumed that once exhausted, the fuel needs which

---

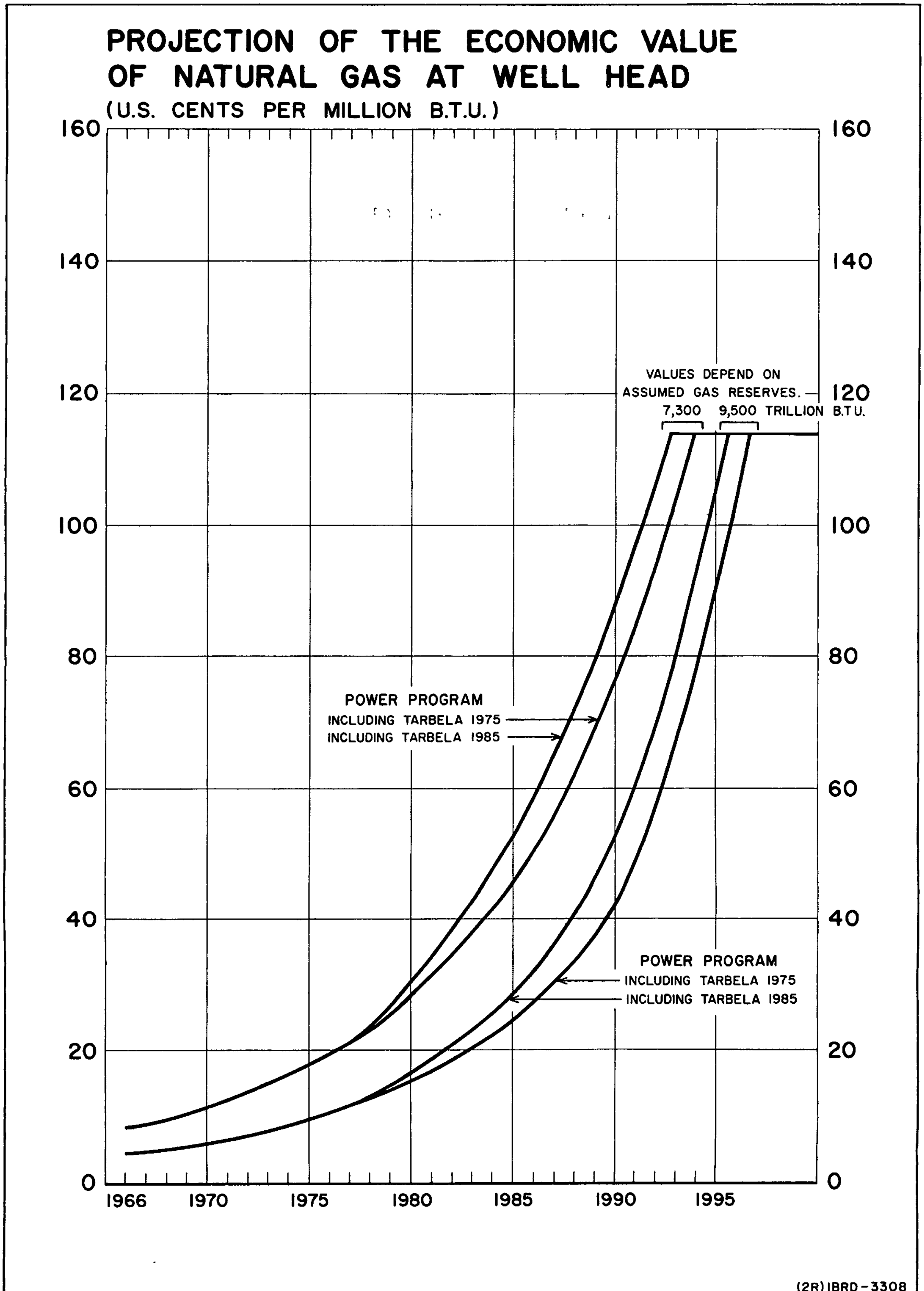
1/ Costs of the program including Tarbela excluded the costs of the main reservoir structures, because these costs were all considered on the irrigation side.

they had been meeting would have to be covered by imported liquid fuels. Consideration was given to the international price at which liquid fuel might be assumed to be available in the year 2000 and also to the heavy burden on foreign exchange available to West Pakistan at that time which would occur as a result of the need to import large quantities of fuel. The purpose of these studies was to reach a figure for the real burden on the Pakistan economy that would be involved by the need to import fuel supplies once gas reserves were exhausted and thereby to reach a reasonable basis for rationing out available gas reserves in the interim. The figure finally adopted for this purpose was $1.14 per million Btu of imported fuel delivered to the Upper Sind in the year when gas reserves were exhausted (i.e. around 2000). The sacrifice involved by using gas for power generation in any year instead of conserving it for non-power uses could then be defined as the discounted present worth in that year of the burden that would be incurred by the need to import fuel in the year of exhaustion of gas reserves. Taking account of the amount of gas that would be required for power generation in a program including Tarbela and applying this approach to current estimates of gas reserves, it was found, for instance, that the economic value of gas at well head would be approximately eight cents per million Btu in 1965, 11 cents in 1970, 18 cents in 1975, 28 cents in 1980 and 45 cents in 1985. If Tarbela were to be eliminated from the program or postponed to 1985, then the draft on the natural gas reserves for power generation would be substantially higher, the reserves would be depleted more rapidly and hence the economic value of thermal fuel would be higher in the later years of the Perspective Plan period. Other similar sets of calculations were made for the assumption of gas reserves larger than currently estimated. Figure 11 shows the results of these calculations under the different assumptions regarding the size of gas reserves and the timing of Tarbela.

8.28 The various components of the recommended power program -- the units at Mangla and Tarbela and the transmission lines, etc., and the proposed timing of their installation -- were considered and verified for validity within the fuel price framework set on the approach described in the previous paragraph. Major items in the program were also considered in terms of a set of fuel prices in different parts of the Province termed 'financial' and roughly corresponding to the fuel prices presently paid by the electric utilities. It was roughly estimated that the net power benefits of Tarbela, estimated at about $110-120 million on the basis of current financial fuel prices, would be at least $150 million if thermal fuel was attributed its real scarcity value.

<u>EHV Interconnection Between the Major Power Markets</u>

8.29 Both Stone & Webster and WAPDA's consultants, Harza, have recommended that the major power markets of West Pakistan be linked by EHV transmission lines in the early 1970's; and both based their recommendations to a significant extent upon the assumption that substantial reserves of natural gas were available at Mari with little use for purposes other than power generation. When it became known


PROJECTION OF THE ECONOMIC VALUE OF NATURAL GAS AT WELL HEAD
(U.S. CENTS PER MILLION B.T.U.)
160
140
120
100
80
60
40
20
0
1966
1970
1975
1980
1985
1990
1995
VALUES DEPEND ON ASSUMED GAS RESERVES.
7,300
9,500 TRILLION B.T.U.
POWER PROGRAM
INCLUDING TARBELA 1975
INCLUDING TARBELA 1985
POWER PROGRAM
INCLUDING TARBELA 1975
INCLUDING TARBELA 1985

(2R) IBRD-3308

that Mari gas reserves might in fact be only a fraction of what had been previously estimated, Stone & Webster expressed strong doubts as to whether EHV interconnection should still be introduced at the time they had recommended.

8.30 The Bank Group considered programs with and without interconnection and with different amounts of thermal development in the Mari vicinity. It found, on the basis of calculations in terms of both current financial and projected economic prices for natural gas, that its analysis confirmed the doubts raised by Stone & Webster regarding the validity of EHV interconnection if thermal development in the Mari vicinity had to be limited to 400 mw, as had at one time been suggested. However, the approach to the price and use of natural gas reserves briefly described above suggested that, with reserves as currently best estimated, it would appear reasonable to use substantial amounts of Sui gas over coming years for firing the thermal plants which are a necessary complement to Mangla and Tarbela as sources of electric energy. Moreover, the site provisionally selected by WAPDA's consultants for generation on the basis of Mari gas was at Gudu, close to the Indus River and almost equidistant from the Mari and Sui fields. The Bank Group, therefore, tested a power program including interconnection and 1,100 mw at Gudu and requiring in total over the 20-year period 1966-85 about one trillion cubic feet of Sui quality gas (for generation in Karachi and the North as well as at Gudu). It found that such a program would have significant advantages over a program excluding interconnection. The difference between the two programs in terms of rate of absorption of hydro energy is illustrated by Figure 12. In quantitative terms, allowing for the saving in generating capacity reserves, the saving in thermal fuel requirements in the South resulting from the availability of hydro energy there, and the saving in pipeline capacity for gas transmission, all of which would occur with interconnection, the Bank Group found that the program including interconnection showed savings over the best program without interconnection with a present worth of the order of $20-25 million when foreign exchange costs were valued at the current exchange rate and of about $10-15 million when foreign exchange was valued at a shadow rate of twice the official rate.

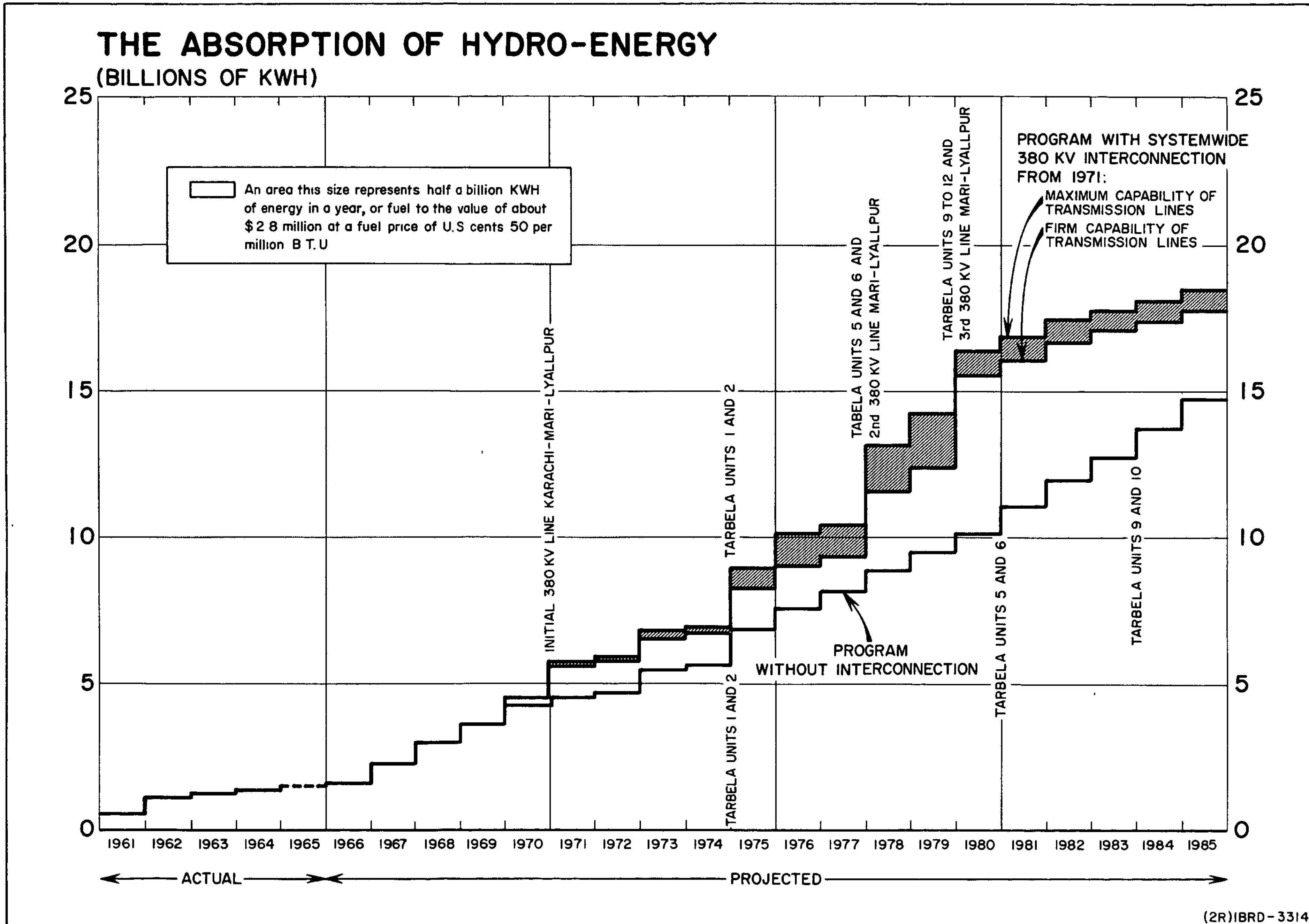
8.31 These savings of a with-interconnection program would be offset to some extent by the costs of gas pipelines to carry fuel from Mari and Sui to the Gudu site; but there is a number of other advantages to interconnection which were not taken into account in the quantitative analysis. In the first place, if the Northern Grid has still to generate all its own power requirements in the pre-Tarbela years, it will probably be more costly than assumed in the quantitative calculations to supply sufficient thermal fuel since either additional gas pipeline capacity will have to be installed or expensive imported fuel oil will have to be used to meet peak fuel requirements. In the second place, the quantitative comparisons between the with and without-interconnection programs were made in terms of the same series of economic prices for natural gas whereas a program excluding interconnection would in fact involve a heavier draft on natural gas reserves than one including it and so, on the approach to fuel pricing described in preceding paragraphs the fuel prices applicable to the without interconnection program should be somewhat higher. In the third place, the EHV transmission lines may be able to carry somewhat more hydro energy southward than has been assumed in the quantitative analysis, as illustrated by the hatched blocks in Figure 12. Finally, there are more general and intangible, but none the less important, advantages to interconnection such as the flexibility which it will add to the overall power system.

The Timing of Interconnection

8.32 The main comparisons among programs made by the Bank Group were all based on the assumption that, if 380-kv interconnection were introduced, then a complete link from Lyallpur to Mari to Karachi would be available by 1971. In order to check this proposed timing, the Bank Group made several short-term comparisons between different schedulings for EHV interconnection. The conclusion drawn from these studies was that there were advantages to having the complete EHV line in 1971 or 1972 but that these advantages were particularly strong in the case of the link between Mari and Lyallpur. Therefore, in contrast to Stone & Webster, the Bank Group would attach higher priority to the Lyallpur-Mari line than to the Karachi-Mari line. Nevertheless the Karachi-Mari line should be completed by 1975 at the latest, for a large part of the benefit of the whole EHV system occurs in the form of thermal fuel savings in the South resulting from availability of hydro energy there, and these savings will become particularly important when the units begin to be installed at Tarbela. The main disadvantages that will result from postponement of the EHV link between Mari and Lyallpur beyond 1971/72 are that additional thermal capacity may then have to be installed in the Northern Grid area which would be relatively little used for a decade or more after completion of Tarbela Dam and that special difficulties would arise in meeting peak requirements of thermal fuel in the North in the early 1970's, as pointed out in the last paragraph. To the extent that loads in the North in the early 1970's follow more closely the contingency load forecast than the main load forecast, the case for early EHV interconnection between Mari and Lyallpur will be reinforced.

Operation of Mangla and Tarbela Reservoirs

8.33 For purposes of power planning the Bank Group has used the final monthly release patterns developed by the irrigation and agriculture consultant on the basis of low winter flows in the rivers and with a view to meeting the needs of both power and irrigation to the extent that they are reconcilable. Irrigation requirements in fact dominate, but, by increasing the use of tubewells for meeting irrigation requirements in the early part of the rabi season, advantage can be taken of the greater



VOLUME I
FIGURE 12

availability of hydropower in this period when the heads on the turbines are higher, and more water can be retained in the reservoir until later in rabi, thereby increasing the capability of the hydro units and insuring against a deficiency in natural river flows for irrigation purposes in these months.

Table 65

Tarbela and Mangla Release Patterns
(% of live storage)

(positive figures: releases; negative figures: storage)

	Mangla	Tarbela
October	23	0
November	15	8
December	10	11
January	10	21
February	24	26
March	18	19
April	0	10
May	-24	5
June	-36	-45
July	-31	-55
August	- 9	0
September	0	0

In practice, there will be deviations from these release patterns above, depending on the natural flows available in each year and the tubewell pumping capability available, etc., but small changes in the release patterns will have the effect only of transferring the availability of hydro energy from one month to another and possibly requiring compensating changes in the amount of thermal energy produced.

8.34 The most critical aspect of reservoir operation from the point of view of power planning will be the levels to which the Mangla and Tarbela Reservoirs are drawn down each spring because this will have a substantial effect on the capability of the hydroelectric stations in this period and it will consequently affect the amount of complementary thermal capacity required to meet loads. Sacrifice of 400,000 acre-feet of potential rabi irrigation supplies from Mangla, by raising the minimum drawdown level from 1040 feet to 1075 feet, results in raising the head on the Mangla turbines throughout the critical period by 35 feet and consequently increasing the firm capability of 8 units by about 140 mw. At Tarbela the firm capability of 12 units can be increased by about 270 mw by sacrificing some 700,000 acre-feet of potential initial live storage capacity and keeping the minimum reservoir level up to 1332 feet. Alteration of the drawdown levels on the reservoirs will also have some effect on the energy available from the hydroelectric units, particularly in the season of minimum drawdown. It is estimated that maintenance of the higher drawdown level at Mangla would increase the total amount of energy available in the mean year by about 250 million kwh, while maintenance of the higher drawdown level at Tarbela would increase mean-year energy output by about 300 million kwh.

8.35 In practice of course the minimum drawdown level at Mangla or Tarbela is a continuous variable, but the Bank Group focused attention on the two discrete alternatives for each reservoir mentioned in the last paragraph in order to secure an indication of the relative order of priority that should be attached to the needs of agriculture and of power in long-term planning. Estimates of the power benefits which would arise from maintaining a higher rather than a lower drawdown level at each reservoir were derived from comparison, on the power system simulation model, of two alternative power programs. One was built on the assumption that the reservoir would be drawn down each year of the 20-year plan period to the lower level and the other on the assumption that it would be drawn down to the higher level. The program based on the assumption that the higher drawdown level would be maintained required installation of less thermal capacity. The difference in present-worth costs of the two programs, which was taken as indicating the net benefits to power of maintaining the higher drawdown level, resulted mainly from this reduced need for thermal capacity and, to a smaller extent, from fuel savings possible with the higher drawdown level. Estimates of the agricultural benefits of drawing down to the lower level rather than the higher level were derived from the Bank Group's linear programming analysis of investment in irrigation and agriculture (see Economic Annex, Part II) on the assumption that the resultant increase in the availability of irrigation water would be released gradually over the year in accordance with the release patterns assumed respectively for the two reservoirs. The linear programming analysis worked in terms of two ten-year periods, 1965-75 and 1975-85, and the program indicated the shadow prices or marginal values of small increments or decrements to the annual supply of irrigation water in these ten-year periods.

8.36 The results of this analysis suggested that the marginal benefits to be derived from allocating a little more water to power (i.e. retaining it in the reservoir) or to agriculture (i.e releasing it) were quite close. The analysis tended to confirm the results of other studies in that it indicated a high marginal value for supplies of irrigation water in the decade 1965-75. The marginal value to irrigation of the last 400,000 acre-feet at Mangla in this decade appeared to be greater than the value of the higher drawdown level to power, thus suggesting in general that greater benefit would be derived from drawing down Mangla fully to 1040 until 1975. After Tarbela is completed in 1975 the marginal value of additional irrigation supplies will be considerably less, partly because of the sizable addition to rabi water supplies made by Tarbela itself and partly because of the substantial opportunities that will then exist for increasing irrigation supplies by overpumping in the public tubewell fields. It appeared that, as far as could now be foreseen, an appropriate general presumption would be that Mangla might generally continue to be operated to the lower drawdown level in the decade 1975-85 but that Tarbela should probably be operated to 1332 feet, at least in that decade.

Annual Operating Decisions and Hydrological Uncertainty

8.37 While these comparisons give an indication of the general order of priority attaching to the claims of irrigation and power on storage capacity they fail to show how much the priority of the claims of one sector over those of the other will fluctuate from year to year according to the specific circumstances obtaining in each year. Some aspects of these circumstances may be reasonably predictable -- the likely demands for irrigation water and for power and the availability of alternative supplies -- from tubewells in the case of irrigation water and from thermal equipment in the case of power. Even the predictable benefits of maintaining the higher rather than the lower drawdown level will fluctuate much from year to year because, for instance, the additions to power system capability that will represent the next steps in power system development in some years (e.g hydro units) will be much more expensive than the additions to power system capability (e.g gas turbines) in other years; maintenance of the higher drawdown level and consequent postponement of the next step in power system development will therefore bring much greater savings to the power sector in some years than in others. There are other aspects of the circumstances of any particular year which will be much less predictable -- e.g. the chance that flows may be high enough to maintain the higher drawdown level without detriment to the agricultural sector or the chance that serious outages of thermal equipment or transmission equipment may occur. In consideration of these uncertainties, attention also must be given to the losses that would be incurred by WAPDA and by the Pakistan economy should these uncertain factors turn out at their worst. It may be possible to weight these losses with certain probability factors (e.g. the probability that flows will not be sufficient to permit retention of the higher drawdown level without detriment to irrigation supplies). Some estimates of the losses that would be incurred by an unexpected requirement to draw down fully to 1040 feet at Mangla, for instance, instead of 1075 feet (see para 6.30 of Volume IV) suggest that they would not be very large. And it may be that in certain years the savings to be had from adding to capacity only the amount required assuming maintenance of the higher drawdown level would be sufficient to outweigh the losses that might occur (if it proved necessary to draw down fully) when these losses were weighted by an appropriate probability factor. Moreover, it may be possible to develop rate structures for large industrial loads with a built-in provision for occasional peak shaving and this could further reduce the losses that would arise from an unexpected shortage of capacity. Consideration of these various factors may thus permit planning for maintenance of a higher drawdown level in certain years than would otherwise appear prudent.

8.38 This need to reconsider reserve requirements, rate structures and the new uncertainty factors bearing on the power system stems essentially from the fact that Mangla will be an entirely different type of generating plant from any presently in existence on the power system of West Pakistan. If the Mangla Reservoir is drawn down each year to 1040 feet, the capability of each unit will fluctuate between about 45 mw in the period of minimum drawdown and about 130 mw at the time when the reservoir is full; even with a minimum drawdown level of 1075 feet the capability of each unit will still fluctuate between about 60 mw and 130 mw over the course of the year. Thus, provided that a release pattern of some similarity to that given in Table 8 is adhered to and that adequate capacity is installed on the system as a whole to meet loads in the period of minimum drawdown, then generating capacity reserves will be very ample or even excessive throughout most months of the year. The possibility of a power crisis of the proportions and duration experienced over the last nine months would then be remote. The same will be all the more true after the power units begin to be installed at Tarbela.

Peaking at Mangla and Tarbela

8.39 Another aspect of reservoir operation which will be important in certain months, especially in years of low river flow, is the extent to which the reservoirs can be used for pondage and their power units consequently used for peaking purposes. Peaking at Mangla and Tarbela will essentially involve storing some water over a day and then releasing a large quantity in a short space of time, as contrasted with maintaining an even discharge over the day. Tarbela is sufficiently far upstream of irrigation structures, and the Bong escape and Rasul Barrage provide sufficient re-regulation capacity at Mangla that there would appear to be no danger of sharp fluctuations in discharges causing scouring or other damage downstream. At Mangla it will probably be necessary to maintain a constant minimum discharge sufficient to meet the irrigation requirements of the Upper Jhelum Canal but this will preempt only a portion of flows, so that remaining flows can still be used for peaking purposes if required.

The Peaking Role of Thermal Plant

8.40 The heavy seasonal fluctuation in the capabilities of the units at Mangla and Tarbela will greatly affect the role which will be played by thermal equipment on the system. The type of service which the thermal units will be called upon to perform, if the system is run in the most economical way, will tend to be much more in the nature of peaking than it has been. This will apply especially to the thermal units in the Northern Grid as units are added at Mangla, but it will also apply to the Mari units and, when the South is linked by EHV transmission to the Northern Grid, it will also apply to many of the units there. These considerations have an important effect upon the type of thermal equipment that will be appropriate for installation and also on the means that should be adopted to meet the fuel requirements of the thermal plants.

8.41 It was pointed out above in discussion of the timing of transmission line construction that one of the main reasons for pressing ahead with early EHV interconnection between Lyallpur and Mari was to avoid the need for installation of additional thermal equipment in the North which would scarcely be used for ten years or more as units were being introduced at Tarbela. Thermal capacity installed in the vicinity of Mari would be able to play a triple role -- helping to meet local loads and loads in the South as well as loads in the North during the short period in each year when hydro capacity was at a minimum. However, the load factor on thermal equipment installed in the Mari area still appears likely to be relatively low. The Bank Group's simulation of the operation of the power system indicates that thermal capability in the Upper Sind will, when required to meet Northern Grid loads, be brought into play in the critical months between base load (met by hydro) and peak load (met by local thermal generation). To a much greater extent -- in most months of most years -- it will supply power to help meet loads in the South but there, too, its contribution will generally be utilized between base load met by hydro energy from the North and nuclear energy, on the one hand, and peak load met by local thermal generation on the other. Partly with a view to the low load factor that would be experienced on thermal equipment in the Mari area, Stone & Webster recommended that the first 150 mw of thermal plant installed at Mari (coming on line in 1969-71), should be gas turbines and that the next plant should be an extended rating steam turbine. The Bank Group's adjusted program includes about 400 mw of thermal capacity in the Upper Sind area during the period 1970-74 and studies suggested that all the equipment installed should be suitable for heavily fluctuating operation and a relatively large proportion of it should be in the form of gas turbines.

Thermal Fuel Supply

8.42 The Bank Group also devoted considerable attention to the question of the best means of supply of thermal fuel in the different areas of the Province as the impact of Mangla and later of Tarbela is gradually spread throughout the power system by EHV interconnection. The conclusions of these studies may be briefly summarized. Consideration of the situation in the South over the next decade, taking into account the scarcity value of natural gas and of foreign exchange in this period, suggested that in general it would be more beneficial to expand the capacity of the gas pipeline from Sui sufficiently to meet peak requirements of fuel for thermal generation in the South up to the time that EHV interconnection becomes available rather than to restrict expansion of the pipeline and meet peaks with fuel oil. This general conclusion might be altered under three sets of circumstances: (a) if the peak requirements were very sharp and expected to be very short-lived; (b) if it appeared that the Sari Sing field would be likely to prove an economic source of fuel supply for Karachi; or (c) if it appeared likely that Sari Sing could be developed for gas storage purposes and the need for additional gas transmission capacity all the way from Sui could consequently be reduced. Under these circumstances it might prove economical to meet peak fuel requirements on a short-term basis with fuel oil. Once EHV interconnection between the North and the South becomes available KESC's thermal fuel demands will have a much lower annual load factor than they do now. Moreover, the Bank Group's studies suggest that, if the recommended program is adopted and loads in the South are of the order projected here, then KESC's peak requirements for thermal fuel may not, within the Perspective Plan period rise substantially above the level reached immediately prior to interconnection since hydro energy and Mari energy would continue to make sizable contributions to meeting the load in the South through the 1970's and nuclear power would become important in the early 1980's. Thus, following interconnection, the storage potential of Sari Sing might become particularly valuable, and even if it proves infeasible to develop Sari Sing for storage, it might become worthwhile at that time to meet KESC's peak requirements of thermal fuel with oil and to release to other consumers a portion of the pipeline capacity previously committed to supplying KESC with gas.

8.43 As regards the thermal plants in the North, the Bank Group's studies suggested that, if electrical interconnection is completed in 1971/72 and thermal development is concentrated in the Mari vicinity, then peak-day requirements of thermal fuel for meeting the main load forecast used in these studies would not increase above their 1966/67 level before about 1980. If loads turned out to be closer to the contingency load forecast, then peak-day fuel requirements might rise somewhat above their 1966/67 level -- perhaps to about 95 MMcf/day. However, the overall annual load factor on thermal plant in the North appeared likely to be quite low over the next 10-20 years -- not usually above about 30 percent on the main load forecast or 40 percent on the contingency load forecast even on the most economical plant (Lyallpur steam units). Moreover, the load would be heavily concentrated in a few months of each year (in the spring), implying that any firm base load on the plants throughout the year would be small. These considerations suggest that thought should be given to the possibility of meeting peak fuel requirements in the North with imported fuel oil and releasing the gas pipeline capacity presently committed to WAPDA for serving other consumers rather than expanding the gas pipeline to Multan and Lyallpur to meet WAPDA's needs.

Additions to the Power System during the Fourth Plan Period (1970-75)

8.44 Table 63 above suggested that existing commitments of the electric utilities for additional generation and transmission equipment would be sufficient to meet prospective loads up to 1970. The Bank Group proposes completion of a 380-kv link between the Northern Grid and Mari in 1971 and construction of Mangla units 4-8 between 1970 and 1974. It also proposes addition of 400 mw of capacity in the Mari area during the Fourth Plan period, about half of it in the form of gas turbines. Depending on a number of factors, particularly whether or not it is decided to commission the fifth tunnel at Mangla for irrigation purposes, it may prove economical to install units 9 and 10 at Mangla in this period in place of some of the gas turbines at Mari since the Mangla units would be able to operate on base load throughout most of the period of minimum reservoir level under mean-year flow conditions.

8.45 The Bank Group's program is designed to meet the main load forecast adopted in this report. Provided that both Czech units at Mari can be installed by 1970 and that the 132-kv Mari-Lyallpur link is completed by that time and the 380-kv Mari-Lyallpur link completed by 1971, the program proposed by the Bank Group is also sufficient to meet the contingency load forecast for the Northern Grid through the year 1971 with ample reserve. By 1972 reserves would appear inadequate, unless the complete Lyallpur-Karachi 380-kv tie is in place by that time. Therefore, the Bank Group's program seems adequate for both load forecasts until about 1972/73. The very large additions to capacity in the North which are being provided during 1967 should enable Northern Grid loads to be fully met again by the winter of 1967/68, and so actual sales will begin to provide a better indication of what the load in the North really is and of how it may grow. Load growth should be carefully observed and the prospective loads of the early 1970's should be reassessed in 1969 in order to see whether they are likely to be closer to the main load forecast or to the contingency load forecast. If they are close to the latter, an additional 200 mw of capacity at Mari, over and above that proposed in the Bank Group's program, will need to be installed in 1973-75.

8.46 The chief factors affecting the development of the Karachi/Hyderabad power system in the Fourth Plan period will be the date of interconnection with the North and the date when the Karachi nuclear plant becomes available as reliable capacity. Regarding the nuclear plant, the Bank Group has made the same assumption as Stone & Webster -- that 25 mw of its capability will become available as reliable capacity for KESC in 1971 and the remaining 100 mw in the following year. If 26 mw of gas turbines are added at Hyderabad in 1970 and the EHV transmission link with Mari is installed by 1971, then there would be sufficient firm capacity available in the South to meet the projected peak. Without the EHV link local capacity in the South may not be adequate to meet projected loads with full security of supply (i.e reserves adequate on the single-largest-unit-out criterion); so that it may be necessary to install gas turbines or to hasten completion of the the nuclear plant if it appears that the EHV link will be delayed beyond 1971. The EHV link should anyway be completed by 1974/75. The Bank Group's tentative program includes a 125-mw Korangi unit No. 4 in 1975. This unit could be postponed longer, as Stone & Webster proposed, if more capability could be conveniently located in the Mari vicinity.

8.47 The Bank Group's program envisages completion of the first two units at Tarbela in time to meet the critical period in the power system in the spring of 1975. If it proves impossible to meet this schedule it may be necessary to install additional thermal capacity to cover the loads of that year. This would be unfortunate, since the additional thermal capacity would likely not be used very much in the following years as units were being introduced at Tarbela. Therefore, if a delay does appear likely in completion of the Tarbela units, 1975 may be one year when planning for maintenance of a higher drawdown level at Mangla and the careful screening of projected loads will be particularly relevant.

Utilization of Tarbela Potential and the EHV System

8.48 In the period 1975-80 three main sets of decisions can be identified: the scheduling of units at Tarbela, the steps that should be taken to expand the EHV transmission system, and the type and location of thermal capability to be provided to firm up the hydroelectric units and help stabilize the transmission system. How the capacity at the Tarbela units should be brought in will depend on details of the load growth that cannot be foreseen with sufficient accuracy at the present time to make a firm judgment. Various schedulings of the Tarbela units were tested on the power simulation model and these studies suggested that, with a drawdown level to 1332 feet the best schedule might be to bring in the first four units in 1975 and 1976 and to postpone the remaining eight for the introduction of two per year in 1978 and 1979 and the last four in 1980 when the capacity of the interconnected system to absorb additional supplies of energy will have grown. The inexpensive units at Warsak could be added in 1977-79 to provide useful peaking capability once the critical period has become May. The expansion of the 380-kv transmission system during 1975-80 would consist mainly in construction of lines from Tarbela to Lyallpur and the addition of further links between Lyallpur and Mari. These lines will not have sufficient capacity to carry the full potential output of Tarbela in the summer months; neither could the Northern Grid absorb the full potential of Tarbela in these months. Hence it would be necessary to increase considerably the transmission line capacity all the way to Karachi in order to find a use for the full output of Tarbela in the summer. This expense would not be justified for such a short period. According to the main load forecasts underlying these studies there will be a need for an additional 400 mw of thermal capability in the system besides the 125-mw Korangi unit 4 at Karachi in the period 1975-80 even if all 12 units at Tarbela are installed. The additional thermal capacity will be required, firstly, to add capability that will operate at a low load factor to provide megawatts when the reservoirs are fully drawn down and, secondly, to provide capability at both ends of the EHV transmission line to help stabilize it. Thus in the period 1975-80 the Bank Group envisages the installation in the North of 12 units at Tarbela, two units at Warsak, 200 mw at Mari/Sui and 200 mw in Karachi.

Kunhar and Raising Mangla for Power

8.49 The Bank Group gave attention to two possible hydroelectric developments that might be brought in within the Perspective Plan period after the completion of 12 units at Tarbela -- first, Kunhar and, second, raising Mangla for power programs -- and it was found that, as far as could be foreseen, neither would be attractive in the early part of the 1980's. One of the main considerations working against them was the fact that a sizable portion of the energy and capability which they would add would occur in the summer flood months when Tarbela would, at this time, still be producing more energy than could be absorbed.

Nuclear Generation

8.50 By about 1980 the Bank Group believes that, as far as can now be foreseen, there will be a strong case for extensive nuclear development in the South. Before 1980 nuclear plant does not look very attractive for a number of reasons. The most important of these is that, before that time, nuclear equipment, even in Karachi, would have a load factor of only about 50 percent as a result of hydro energy from the North and supplies from the small Atomic Energy Commission nuclear plant preempting base load in most months. Since most of the fuel cost on nuclear equipment occurs in the form of fixed charges on the cores, there is a heavy penalty to low load factor operation. After 1980 the load factor attainable on nuclear plant in the North (about 20-30 percent) would still appear to be too low to warrant installation of nuclear equipment there. But in the South loads should be adequate by the early 1980's to give a 400-mw nuclear unit a load factor of better than 80 percent; and by 1985 a second 400-mw nuclear unit could have a load factor, even after absorption of substantial quantities of hydro energy, of nearly 70 percent, according to the Bank Group's studies. Moreover, by the early 1980's loads on an interconnected system would be growing rapidly enough to absorb reasonably quickly nuclear units of 400 mw; present technological trends in nuclear development suggest that this is the minimum size at which substantial economies will be obtainable. By the early 1980's the technology and capability of the world nuclear industry and the industrial base in West Pakistan should also have developed far enough to make it possible to construct nuclear units of 400-mw size at reasonable cost in the Karachi area. In considering nuclear development it must be borne in mind that technology is developing extremely rapidly in this field and that even the optimistic views expressed in this paragraph may prove, within a few years, to have been short-sighted.

Use of Indigenous Coal for Electricity Generation

8.51 There will be need to install additional thermal capacity in the late 1970's or early in the 1980's to firm up the capability of the Tarbela units in the season of minimum reservoir levels. The Bank Group believes that, as far as can now be foreseen, this will best be accomplished with additional gas-fired plant. However, there is a possibility that the situation regarding gas reserves might prove stringent enough at that time to make a mine-mouth plant at the Lakhra coal field appear attractive. A coal-fired plant would be considerably more expensive than a gas-fired plant in capital costs as well as operating and maintenance costs but if the price at which coal were available was sufficiently far below the scarcity price of gas at that time then generation on the basis of coal might be worthwhile. The Bank Group's analysis on assumptions favorable to coal suggests that coal would have to be available at a price per Btu about 20 percent below the price of gas to make coal attractive. In terms of economic prices this might be the case about 1980 if gas reserves turn out to be no larger than the lowest of current estimates of reserves.

System Development After 1980

8.52 The Bank Group foresees substantial thermal development in the vicinity of the Mari and Sui gas fields in the early 1980's despite the fact that it might not be possible to guarantee to gas-fired plants established at that time a lifetime supply of gas for high load factor operation. There is of course a possibility that more gas may be discovered over the intervening 15 years. If gas reserves appeared to be becoming short, it would be possible to keep the load factor on the Mari/Sui units down by developing further hydro plants or nuclear installations to meet base load. Even if gas reserves available for power use were completely exhausted the Gudu location would be quite suitable for generation on the basis of imported fuel oil to meet seasonal peaks in the North. Conversion of gas-fired plants to the use of oil is not expensive. Moreover, if imported fuel oil did have to be used to generate power to meet seasonal peaks in the North, its use at Gudu instead of in the Northern Grid area itself would save a lengthy rail haul. The exact proportions of plant that should be based on gas, imported oil or coal or able to use both oil and gas will of course depend on many unforeseeable factors. The tighter the gas situation the more attractive would it be, for instance, to use Lakhra coal for thermal generation for Karachi and the Sind intermediate between base load and peak load. Nevertheless, the concept of a heavy concentration of thermal development in the Mari/Sui area is one that seems well adapted to making the most economic use of known resources in West Pakistan, while it also has the advantage of providing a high degree of flexibility for meeting future contingencies.

The Bank Group's Proposed Power Program

8.53 The bulk power supply program proposed by the Bank Group and set forth in detail in Volume IV and its annexes is summarized in the following tables 66 and 67.

Table 66

Bank Group's Generation and Transmission Program, 1966-85
(mw)

	Northern Grid		Upper Sind	Karachi-Hyderabad	Total
	Hydro	Thermal	Thermal	Thermal	
Generating Equipment					
Existing 1965	155	277	25	275	732
1966-69	135	202	25	187	549
1970-74	225	-	400	151	776
1975-79	664	-	200	325	1189
1980-84	292	-	700	700	1692
1985	-	-	-	400	400

Table 66 (continued)

380-kv Transmission Equipment

1971	Mari-Lyallpur single circuit; Mari-Karachi single circuit
1974	Second Mari-Karachi circuit
1975	Tarbela-Lyallpur single circuit
1976	Second Mari-Lyallpur circuit
1978	Second Tarbela-Lyallpur circuit
1979	Third Mari-Lyallpur circuit
1980	Third Tarbela-Lyallpur circuit

Distribution

8.54 The growth of the power system implied by the load forecasts adopted in this report will require a very substantial expansion of the distribution system. In order to serve the projected number of new domestic, commercial and industrial customers and to permit the proper functioning of the desired number of tubewells, Stone & Webster estimated that at least 20,000 miles of new distribution line would have to be constructed by WAPDA alone by 1970 and another 35,000 miles by 1975. Stone & Webster were doubtful whether WAPDA would be able to achieve these targets. They felt that the power wing of WAPDA had concentrated most of its efforts towards large projects involving power generation at the neglect of the electric distribution system. The distribution system had been made to bear an unreasonably high proportion of budget cuts, and insufficient efforts had been made to train technicians for distribution line work. Some of the figures recently made available by WAPDA suggest that achievement in terms of miles of line construction during the Second Plan period may have been somewhat better than implied by the figures available to Stone & Webster. However, the WAPDA figures are not wholly reassuring. The rate of connection of public tubewells appears to have declined from 1,000 in 1960/61 to 138 for the two years 1963/64 and 1964/65; and the rate of village electrification had also declined from the levels achieved during the earlier years of the 1960's. It would seem, therefore, that whatever the performance in the field of urban distribution, there remains a real difficulty in making rural connections, either under the village electrification program or under the tubewell program. Stone & Webster recommended that these two programs should be combined. With this the Bank Group agrees. They felt that this would make possible the attainment of higher rates of village electrification. Nevertheless, there is no question but that the electrification of customers in general and of tubewells in particular will make great demands on the resources of finance and trained manpower available to WAPDA and that it will not be easy to reach the targets set.

Financial Requirements

8.55 Load growth has been curtailed in all the four major power systems of West Pakistan in recent years by shortages of capacity, particularly in the Northern Grid area and Lower Sind. Expansion of

Table 57

SUMMARY OF PROGRAM
POWER GENERATING EQUIPMENT AND TRANSMISSION LINE INSTALLATION
(mw)

	Generating Equipment						
	Northern Grid		Upper Sind		Lower Sind and Karachi		EHV KV Transmission Line
1966	Existing	467(Oct)	Existing	50(Dec)	Existing	280(Dec)	
1967	Lyallpur-Steam Mangla 1, 2	124 90(Mar)			Hyderabad-Steam Kotri GT	15 13	
1968	Lahore GTs	52			Kotri GTs	26	
1969	Mangla 3	45(Mar)			Korangi "C"	125	
1970	Mangla 4 Mangla 5, 6	45(Mar) 90(Mar)	Mari-Steam	100	Hyderabad GTs	26	
1971	Retire	(15)	Mari-Steam	100	Karachi-Nuclear	25	Lyallpur-Mari-Karachi (s/c)
1972					Karachi-Nuclear	100	
1973	Mangla 7, 8	90(Mar)			Retire	(15)	
1974			Mari GTs	200			Mari-Karachi (s/c)
1975	Tarbela 1, 2	180(Mar)			Korangi 4	125	Tarbela-Lyallpur (s/c)
1976	Tarbela 3, 4	180(Mar)					Lyallpur-Mari (s/c)
1977			Mari/Sui 5	200			
1978	Critical changes to May Tarbela 5, 6 Warsak 5, 6	 146(May) 80(May)					Tarbela-Lyallpur (s/c)
1979	Tarbela 7, 8	146(May)			Korangi 5	200	Lyallpur-Mari
1980	Tarbela 9, 10 Tarbela 11, 12	146(May) 146(May)					Tarbela-Lyallpur (s/c)
1981					Korangi 6	300	
1982			Mari/Sui 5a Mari/Sui 5b	200 200			
1983					Karachi-Nuclear	400	
1984			Mari/Sui 6	300			
1985					Karachi-Nuclear	400	

the distribution system has been insufficient to keep up with the growth of demand for new connections. Inadequate effort has been made on the maintenance side, both as regards generation and distribution. Thus backlogs have grown -- of deferred maintenance, of customers awaiting connection, and of additional generating capacity required.

8.56 It is partly for these reasons and partly because of the heavy cost of the EHV transmission system which the Bank Group believes WAPDA should commence during the current plan period that the Third Plan capital requirements of the power program proposed in this report represent a larger proportion of total plan investments than was spent on the power sector during the Second Plan. The capital requirements of the program proposed are also substantially above the Third Plan allocation so far made for the power sector. Estimated Third Plan capital requirements of the power program proposed by the Bank Group are PRs 3,017 million against an original Third Plan allocation of about PRs 2,178 million. The recent revision of the Third Plan has raised this allocation to about PRs 2,400 million which is still somewhat short of the Bank Group's proposal.

8.57 The following table compares actual capital expenditure on power with the total investment in each year of the Second Plan period and also indicates projected figures for each Five Year Plan period through 1985 on the basis of the Bank Group's proposals and some preliminary estimates that were made available by the Pakistan Planning Commission regarding total investment in West Pakistan over the Third and subsequent plan periods up to 1985. The table covers only public sector investment in power (i.e. excluding industrially owned).

Table 68

Actual and Projected Investment in Power Compared to Total Investment (Public & Private) in West Pakistan, 1960-85
(PRs million)

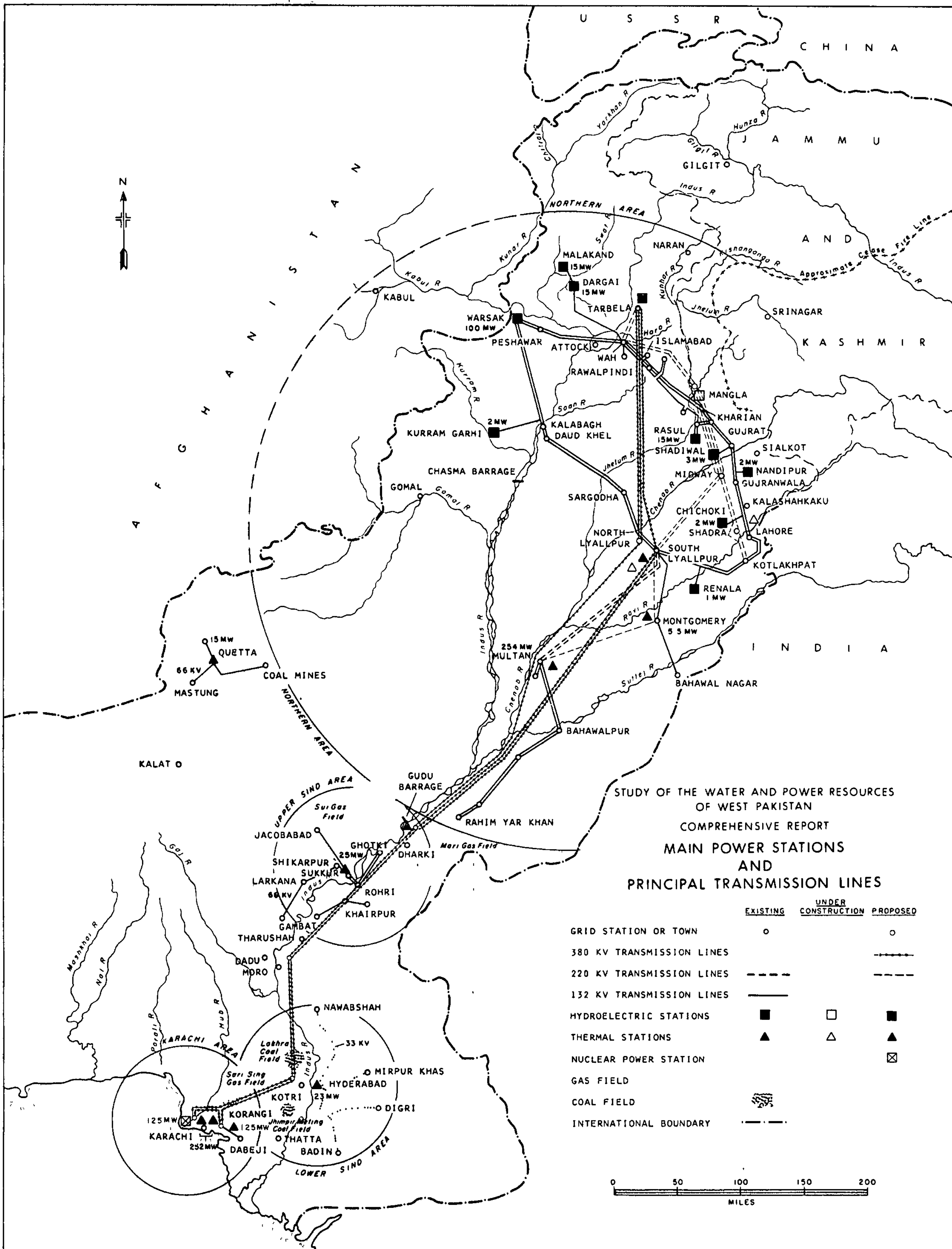
	Investment in Power	Total Investment	Power as a % of Total
Actual			
1960/61	208	3,023	6.8
1961/62	273	3,528	7.7
1962/63	213	4,410	4.8
1963/64	258	4,753	5.4
1964/65	242	5,260	4.6
Subtotal Second Plan	1,194	20,974	5.7
Projected			
Third Plan	2,849	27,250	10.5
Fourth Plan	3,468	38,200	9.1
Fifth Plan	3,676	53,200	6.9
Sixth Plan	4,031	68,000	5.9

The relatively heavy burden proposed for the Third and Fourth Plan periods represents a measure of the catching up that needs to be achieved. Projected expenditures on the power sector increase in absolute terms in later Plan periods but they decline as a proportion of total investment projected under the Perspective Plan to levels consistent with those recently achieved.

Tariffs and Accounts

8.58 The large size of these capital requirements emphasizes the importance of keeping the level and structure of tariffs in West Pakistan under constant review. In 1965 the Harza Engineering Company, consultants to WAPDA, made a study of WAPDA's tariffs. Harza did not recommend any major changes in the tariff structure but proposed the elimination of certain anomalies and inequities in that structure. Their report focused more on the reduction of losses by improving the administration of the power system rather than on revising the tariffs in the immediate future. Harza pointed out that the very large amount of energy lost between generation and sales represented substantial losses in revenue. If the losses and unaccounted for could be reduced to about 15 percent of the total amount of energy sent out in 1963/64 the improvement in income would have been about 50 percent of the actual net earnings in that year. The Bank Group and also Stone & Webster are in agreement with the recommendations of Harza regarding the need for a major effort to reduce losses. One part of this effort would involve improvement of WAPDA's accounting and recording procedures so that management could be provided with a stream of up-to-date financial and statistical statements permitting analysis of operating results and trends and identification of where the responsibility for successes and failures lie.

8.59 WAPDA's rate of return on net fixed assets in operation, calculated according to the World Bank's normal procedure, averaged 7.58 percent for the four years 1960/61 to 1963/64. For the latest year, 1964/65, for which financial information is available, WAPDA's rate of return declined to 5.83 percent. The large capital expenditure which will be required for system expansion and the recent decline in WAPDA's rate of return suggest that there is need for revision in the level and structure of WAPDA's tariffs. The agricultural tariff is a case in point. Harza pointed out in their report that bills under the agricultural tariff were 37 to 44 percent lower than bills which industrial consumers would pay for the same load and consumption. Harza recommended that sales to agricultural consumers under the present agricultural tariff should be available only to those who agree to discontinue the operation of their pumps during the critical load periods. This change of practice was not accepted by WAPDA. In effect, therefore, other consumers still bear the burden of the subsidy which is granted to agricultural pumping by these non-compensatory rates. Pumping requirements are expected to increase substantially in the next decade. The Bank Group believes that it will be necessary for WAPDA to raise agricultural pumping rates, to raise rates to some or all non-agricultural customers or to ask that the subsidy be covered by allocations from the


STUDY OF THE WATER AND POWER RESOURCES
OF WEST PAKISTAN
COMPREHENSIVE REPORT
MAIN POWER STATIONS
AND
PRINCIPAL TRANSMISSION LINES
EXISTING
UNDER CONSTRUCTION
PROPOSED
GRID STATION OR TOWN
380 KV TRANSMISSION LINES
220 KV TRANSMISSION LINES
132 KV TRANSMISSION LINES
HYDROELECTRIC STATIONS
THERMAL STATIONS
NUCLEAR POWER STATION
GAS FIELD
COAL FIELD
INTERNATIONAL BOUNDARY
0
50
100
150
200
MILES
U S S R
C H I N A
J A M M U
A N D
K A S H M I R
I N D I A
A F G H A N I S T A N
N
NORTHERN AREA
UPPER SIND AREA
KARACHI AREA
LOWER SIND AREA
GILGIT
NARAN
MALAKAND
15MW
DARGAI
15MW
TARBELA
KABUL
WARSAK
100 MW
PESHAWAR
ATTOCK
WAH
ISLAMABAD
RAWALPINDI
SRINAGAR
MANGLA
KHARIAN
GUJRAT
KALABAGH
DAUD KHEL
2MW
KURRAM GARHI
RASUL
15MW
SHADIWAL
3MW
SIALKOT
2MW
NANDIPUR
MIDWAY
GUJRANWALA
CHASMA BARRAGE
GOMAL
SARGODHA
CHICHOKI
2 MW
KALASHAHKAKU
SHADRA
LAHORE
NORTH
LYALLPUR
SOUTH
LYALLPUR
KOTLAKHPAT
RENALA
1 MW
MONTGOMERY
5.5 MW
254 MW
MULTAN
BAHAWAL NAGAR
15MW
QUETTA
66 KV
MASTUNG
COAL MINES
KALAT
BAHAWALPUR
GUDU
BARRAGE
RAHIM YAR KHAN
Sui Gas Field
Mari Gas Field
JACOBABAD
GHOTKI
25MW
DHARKI
SHIKARPUR
SUKKUR
LARKANA
66 KV
ROHRI
KHAIRPUR
GAMBAT
THARUSHAH
DADU
MORO
NAWABSHAH
Lakhra Coal Field
33 KV
Sari Sing Gas Field
MIRPUR KHAS
HYDERABAD
23MW
KOTRI
DIGRI
125MW
KORANGI
125MW
Jhimpir Meting Coal Field
KARACHI
252MW
DABEJI
THATTA
BADIN
Yarkhan R
Hunza R
Gilgit R
Indus R
Chitral R
Swat R
Kunar R
Kabul R
Kishanganga R
Kunhar R
Jhelum R
Haro R
Approximate Cease Fire Line
Kurram R
Soan R
Gomal R
Chenab R
Ravi R
Sutlej R
Gaj R
Mashkai R
Nal R
Porali R
Hub R

Government. The Bank Group believes that WAPDA should aim for a rate of return calculated in the same manner as the figures above of not less than 8 percent.

8.60 KESC had a study of its tariffs made in 1964/65 by Gilbert Associates. Gilbert pointed out that KESC's present tariffs are extremely complex, hard to understand and difficult to use in calculating bills. Some of the rates are based upon horsepower of demand and some upon kilowatts of demand. Some of the rates run to five decimal places. Some rates are gross with a discount for prompt payment and others offer no discount. The fuel adjustment is a large portion of an industrial consumer's bill because the present base was established some years ago when fuel was cheaper. The changes proposed by the consultant would simplify all of the rates mentioned above and reduce the existing 11 rates to 7. There would be total elimination of free energy, kilowatts would be used instead of horsepower, several tariffs for residential and commercial consumers would be replaced by one tariff through one meter. The fuel adjustment would bring it into line with the present costs of fuel and there would be a uniform discount for prompt payment of all bills. On the whole, the new tariffs might yield about 5 percent more than the existing tariffs.

8.61 KESC's rate of return on average net fixed assets in operation ranged between 10.6 and 13.4 percent over the years 1960 to 1964, but it declined to 10.2 percent in 1965. KESC declared cash dividends of 10 percent for a number of years except that in 1963 and 1964 stock dividends were declared and in 1965 a combination of 6 percent cash and a 4 percent stock dividend was declared. KESC's financial position has been sound in the past but the cost of doing business has recently risen, while the average revenue received per kilowatt-hour has declined. The generous tax exemptions which have been allowed to KESC for new facilities placed in service has been helpful but these exemptions may sometime in the future be withdrawn. The Bank Group believes that the Government should permit KESC to charge tariffs to maintain revenues sufficient to provide the company with an annual rate of return of at least 8 percent on its average net fixed assets in operation so that it can continue to obtain from internal cash generation the local currency it will require for its expansion program.

IX. ORGANIZATION AND IMPLEMENTATION

Institutional Framework of Water and Power Development

9.01 The centerpiece of the institutional framework for public development of the water and power resources of West Pakistan is the Water and Power Development Authority (WAPDA), established as a semi-autonomous Government agency in 1958. It was initially set up as a body which would be more flexible than the traditional Government departments and would have responsibility for the planning and execution of all major engineering works for development of the Province's water and power resources. However it was soon decided that it would be desirable to give WAPDA full responsibility for the operation of the power system in order to ensure close coordination between planning and construction of major power facilities and sale of energy to consumers, including the reclamation tubewells which were expected to become a very important part of the total power load. Consequently the Electricity Department of the Government of West Pakistan was transferred to WAPDA in 1959. Responsibility for operation of the irrigation system remained with the Irrigation Department.

9.02 WAPDA will bear responsibility for planning and execution of most of the major investment schemes recommended in this report -- in particular the Tarbela Dam, the public tubewell projects, and the main power generation and transmission projects. It is already responsible for execution of the major construction work under the Indus Basin Project. Since its inception, WAPDA has had dynamic leadership and has successfully performed a large amount of work. Not being restrained by normal departmental regulations, WAPDA has been able to attract and absorb funds needed for the implementation of large projects. All divisions of WAPDA have regularly enlisted expatriate and local consultants for the study, planning and supervision of projects.

9.03 Despite its leadership and the quality of much of its top staff, WAPDA has inevitably had growing pains, given the large volume of work it was called upon to perform, and it has not always been able to keep up with targets. This applies in particular to the execution of the public tubewell program. During the Second Plan period a total of about 2,100 public wells was installed; the largest achievement in any one year was in fact in 1960-61 when 1,000 wells were energized. In each of the fiscal years 1964/65 and 1965/66 less than 200 wells were placed in operation against a target in the WAPDA Master Plan of over 2,000 wells for 1966. The Third Plan target for additional supplies of groundwater to be provided by WAPDA projects is 14 MAF by 1970. The actual achievement during the Second Plan period was 2.5 MAF. Another example of the difficulties WAPDA has faced is in operation of the power system. The power crisis of 1966/67 revealed deficiencies in the operation of the system and in plant maintenance, the consequences of which were aggravated by the delay in completion of the new Lyallpur plant.

9.04 Some of the construction work involved in execution of the program recommended here and a great deal of the responsibility for successful operation of the irrigation schemes proposed will lie with two traditional line departments of the West Pakistan Government -- the Irrigation Department and the Agriculture Department. Both of these bodies have responsibilities spanning the Province. The Irrigation Department operates some tubewells and undertakes some construction work for irrigation purposes outside the Indus Basin but its primary responsibility is the day-to-day operation of the entire surface water distribution system, including collection of irrigation revenue. As such, it has built up a cadre of engineers in its upper levels with great experience in water use and supply. Since canal remodeling work must be very closely integrated with the operation of the canal system, in order to minimize interruption of supplies, IACA recommends that responsibility for most of this work should be borne by the Irrigation Department.

9.05 The Provincial Agriculture Department has extremely wide responsibilities, covering virtually all aspects of agriculture (including animal husbandry) throughout West Pakistan; agriculture represents more than 40 percent of provincial income. The Agriculture Department will play a critical role in enabling the farmers to derive the results which are projected from the programs recommended here. Specifically its main contributions will be in research to identify new crop varieties, pesticides and other inputs and to discover the best practices for their application; in extension work to spread existing knowledge and the results of further research work among the farmers; and in expansion and improvement of the livestock sector which is expected to play such an important role in future agricultural development in West Pakistan. The Department will not be able to fulfill these roles effectively unless a wholehearted effort is made to strengthen it. Primarily this will involve substantial improvement in the pay, conditions and facilities which it is able to offer to prospective employees so that it may obtain both better-quality personnel and more personnel than it now generally has. The Department has suffered seriously in the past from shortage of well-qualified staff. Careers in agriculture have not carried prestige, salaries have been low, opportunities for advancement limited, and working conditions poor. Field Assistants are expected to cover 15,000 acres and the Agricultural Assistants supervising them 60,000 acres -- but neither have been provided with adequate transportation facilities to enable them to work effectively. Field assignments usually require living in areas where housing and school facilities for families are poor, but officers posted to extension services usually receive neither housing nor a housing allowance. Trained research staff are not provided with adequate assistance or facilities, and they move to more remunerative administrative work which makes less than best use of their training. Sustained and rapid progress in agriculture will not take place without a vast improvement in two services as critical as research and extension.

9.06 Two other agencies which will play a major role in the recommended tubewell project areas are the Agricultural Development

Corporation (ADC) and the Land and Water Development Board (LWDB). Both of these agencies, which combine responsibility for water and land development and for provision of other agricultural inputs in certain designated areas were established largely with a view to overcoming the rigidity and lack of coordination among the line departments. ADC, formed in 1961 as a result of a recommendation of the 1959/60 Food and Agriculture Commission, has been given responsibility for supply of certain inputs throughout the Province and specific responsibility for water supply, agricultural inputs and extension work in four areas that are being brought under surface-water irrigation -- Thal, Taunsa, Gudu and Ghulam Mohammed commands. It has dynamic leadership, which has helped to mobilize the divisions of the old line departments in the areas where ADC has worked, but it has lacked adequate numbers of experienced agricultural staff. The LWDB is an even newer body, established in 1964 at the suggestion of the Revelle Panel specifically to promote development in the SCARP areas. It has a high-level membership, being chaired by the Provincial Chief Secretary and having as members the secretaries of all Government departments concerned with agriculture; it meets only about once every two months. Its main activity until now has been in the SCARP I area, for which it appointed a Project Director in overall command of developmental activities. The staff, who are seconded from the regular departments, carry out extension, reclamation, input supply and irrigation activities. The main differences from the situation elsewhere are that the extension coverage is somewhat more intensive and that all officers in the area concerned with agriculture and irrigation are responsible to the Project Director within an integrated project program.

9.07 Most of the new inputs which have been provided to agriculture in recent years have been channeled via one or other of the agencies discussed above, but there is a gradual growth of private enterprise activity in support of agriculture which could become very important in future years. This has developed in the context of a limited liberalization of the external relations of the economy and of a continuing improvement of the terms of trade of agriculture with other sectors of the economy, which has meant that farmers have had somewhat more earnings to reinvest in agriculture and somewhat more incentive to do so. Partly as a result of this and the improved availability of imported raw materials, private enterprise has played a major role in drilling private tubewells and manufacturing and installing pumps, casings and engines. Distribution of fertilizer was also handed over to private enterprise for a brief period in 1964 and 1965 and it was withdrawn not because it was unsuccessful but because, in a way, it was too successful: stocks were run down so fast that shortage and consequently a black market developed, so that the Government felt it could secure more equitable distribution, while the shortage lasted, through official channels.

9.08 It will be essential that as much use as possible is made of private enterprise because, as is natural in any country undertaking a rapid development effort, all Government departments suffer from a severe shortage of qualified staff especially at the lower levels. With good Government officers being in short supply it is important that as many as possible of their responsibilities be transferred to market channels so that they may concentrate on overall supervision of market operations and on the work which generally cannot be handled by others -- such as education, and development and introduction of new inputs and new practices. A part of the difficulty in securing sufficient numbers of good-quality Government staff has been shortage of funds, and it may be that the effort to economize on current expenditures in order to maximize public savings and investment has been carried too far. There are signs that economizing on current expenditures may have become a false economy in some directions: in agricultural education and extension work, where it tends to lessen the ability of the farmer to respond to investments in water and other inputs; in maintenance of the irrigation system, where it leads to gradual deterioration and eventual need for much more extensive repairs than would have been necessary had maintenance been regular; and in investigations, such as groundwater quality studies and monitoring of project development, where it leads to lack of sufficient data for planning purposes and consequent mistakes which have later to be remedied, with much delay and added cost. Thus selected additions to Government current expenditure, designed to strengthen the departments concerned with agriculture and irrigation development and to improve the quality of their staff, could have high returns.

9.09 With the variety of Government agencies concerned with agricultural development -- and there are other important bodies besides those mentioned above such as the Agricultural Development Bank (ADB) which is playing an increasingly important role in provision of credit, and the Cooperative Development Board -- there inevitably arise problems of inter-agency coordination. As pointed out, the ADC and the LWDB were established specifically with a view to overcoming this problem, and they have been to a limited degree successful in the project areas where they have operated. Nevertheless the problem of coordination -- in planning, project construction and operation and implementation of Government policy -- remains serious. IACA reports that there have been occasions when two agencies have been planning independently of one another for the same area. Insufficient effort is made to ensure that plans made by one agency reflect the best judgment and experience available in other agencies; in particular until recently the Agriculture Department seems to have been drawn little into WAPDA and Irrigation Department project planning. Differences of opinion are brought out only at later stages and reconciliation involves wasteful delays. Since WAPDA builds the main water development projects, the Irrigation Department distributes much of the water from them and the Agriculture Department is concerned with effective final use of the water, there is clearly need for close coordination in the common development effort and less concern with narrowly construed institutional interests. The ADC and the LWDB, being new, have had their own difficulties in establishing effective working relationships with the existing administrative structure. The logical place for coordination of both planning and policy implementation would seem to be the West Pakistan Planning and Development Department. Presently the Department has insufficient technical and professional staff to perform an effective coordinating role. The problem is sufficiently important and the savings to be had from more effective deployment of human and financial resources are sufficiently large that early attention should be given to establishing mechanisms and obtaining the qualified staff needed for continuous coordination.

"Implementation Capacity"

9.10 It is clear that shortages of effective organization and well-qualified personnel with initiative have been a serious brake on development in the past, as would be expected in any large and rapid development effort. Anxious to prepare a plan of action that would be feasible of execution, the Bank Group and its consultants essayed the difficult task of identifying approximately the rate of progress that might be achieved in each direction of activity, with a major effort. These are obviously matters of judgment and, as such, they leave plenty of room for disagreement. Nevertheless to disregard the facts that "implementation capacity" is scarce and that there are administrative and organizational limits to the pace at which activity can be expanded in any particular direction would be conducive to wishful thinking rather than to effective planning.

9.11 Many of the administrative limits to achievement adopted by the Bank Group and its consultants for planning purposes have been set at an extremely generous level; if judged solely in the light of past experience they would simply be termed unrealistic; they assume a much more massive effort than has so far been made to promote agricultural development, an effort which can only be anticipated because of the Government's declared policy to eliminate dependence on food supplies from abroad and to make "high priority for agriculture" a reality rather than an intention. Some impression has already been given of the extent of the change required in the amount of money, status and attention accorded to agricultural extension, education and research. It is difficult to express the required effort meaningfully in quantitative terms, because so much depends on the quality of the service and the inputs provided. Improved seed is a case in point. The target of the Second Plan was to cover 50 percent of the area under major crops with improved seed by 1964/65; actual achievement was, according to the Second Plan Evaluation, 11 percent or not greatly more than the area covered at the start of the Plan. The 1975 targets assumed in the Bank Group's projections are 40 percent of the rice acreage, virtually the entire cotton acreage and 50 percent of the wheat acreage; this would imply an increase over the 10-year period of more than 400 percent in the area planted with improved seed. More significant than the quantities projected is the Bank Group's assumption that the improved seed that gets into the hands of the farmer will be of high quality and high germination rate and will not be adulterated as it often is now. This will require a very substantial expansion of seed multiplication farms under Government supervision and much more effective quality control than has so far been maintained.

9.12 It is not only in the agricultural field that the recommended program is administratively ambitious. It was pointed out above in pp. that WAPDA actually electrified in 1965/66 less than 10 percent of the number of wells envisaged in the Master Plan target for that year. Fulfilment of the Action Program will mean completing in almost each year of the Fourth Plan period as many public tubewells as were completed in the whole of the Second Plan period, or about ten times the recent annual achievement. Furthermore this large tubewell effort would take place at a time when a number of WAPDA's most competent engineers would still be burdened with the completion of the IBP works and with the construction of Tarbela. The recommended canal remodeling program -- about a million acres by 1975 -- would be no small job for the Irrigation Department either.

9.13 The recommended power program will also impose a very heavy burden on the administrative and managerial resources of West Pakistan, but it is essential if growth in the agricultural and other sectors of the economy is not to be constrained by shortages of power as it was by the 1966/67 power crisis. During the Second Plan WAPDA more than doubled its number of customers and built about 15,000 miles of distribution line; the heavy concentration on new large-scale power projects and on connecting new customers led to some neglect of maintenance. During the current plan and the Fourth Plan this backlog in maintenance has had to be made up and, at the same time, according to the Bank Group's estimates, about 60,000 miles of new distribution line will be required. The recommended program also envisages a very substantial investment over the next decade in 380-kv EHV transmission, a field new to West Pakistan, and an approximate trebling of the utilities' installed generating capacity between 1965 and 1975. WAPDA takes the view that the load growth may be even higher than projected by the Bank Group. Whichever magnitude turns out to be right, it is clear that planning and construction will have to be enormously expanded and greatly improved if West Pakistan is to build a power system commensurate with its needs.

Project Planning and Construction

9.14 As far as the planning and implementation of the proposed water and power projects are concerned, the main foreseeable bottlenecks are shortage of engineers and procedures that are still too loose to ensure the smooth flow of needed construction materials and completion of each stage of project execution according to schedule. The shortage of engineers can to some extent be remedied by continued use of foreign contractors and consultants, but there can be no adequate replacement for sufficient numbers of Pakistani engineers experienced in local conditions. Engineering education has expanded rapidly in recent years, but still the output of graduate engineers during the Third Plan will be only about 3,800 against a requirement, according to the Third Plan document, of an additional 7,000 engineers between 1965 and 1970. By 1975 IACA estimate that 1,000 more engineers than are presently employed on the public tubewell program will be required for project planning and construction alone. In addition, supervision and operation of completed tubewell projects will by that time require about 300 more engineers than presently engaged in it, and the Bank Group believes that special attention should be devoted to finding enough high-caliber staff with administrative as well as engineering ability for the critically important task of managing the tubewell projects once in operation. There is a limit to the rate at which formal education facilities in engineering can be expanded, without sacrificing quality, because of the shortage of good teachers. More on-the-job training is required for recent graduates. Greater use could also probably be made of opportunities for on-the-job training to upgrade promising young men who may lack full formal training in engineering; such men could be used in supervisory positions where technical training is less important than good general experience in construction, operation or maintenance. More advantage could probably be taken of consultants for on-the-job training purposes.

9.15 It will be impossible to execute the large tubewell program proposed unless procedures for investigation, design, land acquisition, contracting, supplying components, and designing and building the electricity distribution system, are greatly tightened and, as much as possible, routinized. The public tubewell projects proposed here are of considerably smaller size than those considered hitherto; they average about half a million acres each. IACA recommended the smaller size for public projects mainly to leave as large an area as possible for private development in those areas where private tubewell growth shows promise. This would reduce the burden on the public authorities. The smaller scale of the projects would also make their construction and operation considerably more manageable. Construction stages would be shorter and the projects should come into operation more rapidly. Delays will be minimized by good initial investigations of the physical conditions -- groundwater, topography, electrification problems, etc. -- in the area to be covered, by better scheduling of procurement and by the improved coordination both within departments (e.g. between WAPDA Power and Water Wings) and between departments that was already called for. With one SCARP project completed and four underway, enough experience should have been gained that potential bottlenecks can be foreseen and the requisite steps taken at each stage of the progress of a project to see that they do not recur.

9.16 The Bank Group believes that difficulties in project execution will generally be better overcome by adjusting the existing organizational structure and strengthening weaker parts rather than by establishing further new organizations. This applies in particular to the tubewell projects and to work in the power field. One suggestion that has been put forward is that some of the responsibilities of WAPDA's Power Wing be transferred to a new organization; the Bank Group is not convinced that this would be a prudent move at the present time. The Power Wing has done a reasonably good job under rather difficult circumstances and through trial and error has gained much valuable experience. Establishment of a new organization would not ease the basic problem of shortage of qualified and experienced people; indeed it would more likely only exacerbate this problem since the new organization would have to have its own separate management hierarchy and more people in both the new and the old organizations would have to devote time to ensuring proper coordination between them. New organizations, such as municipal power distribution agencies, would also likely encounter even more difficulties than WAPDA does in securing adequate financing for distribution work because they would lack the financial strength of WAPDA. The Bank Group believes that reassignment of responsibilities in different organizations at this time would rather tend to delay than to expedite work on the expansion of the distribution and transmission systems needed for the tubewell program and to connect the large numbers of new customers anticipated. It would be more prudent to concentrate on strengthening the Power Wing.

Management and Operation of System and Projects

9.17 Efficient operation of the evolving water system and of the various projects proposed, especially the tubewell projects, may soon prove to be a more serious problem than actual construction. An experienced body of engineers exists in the Irrigation Department for operating the surface water distribution system, and WAPDA is developing ability for the efficient day-to-day running of the power generation and transmission system, but there are a lot of new problems coming, many of them problems of reconciling different interests, and thus requiring more coordination. Another aspect of day-to-day operation which needs closer attention on both the power and the water sides is maintenance.

9.18 Over the coming two decades, and especially in the next few years, the irrigation system of West Pakistan, having remained basically a system for diversion of natural river flows with the aid of barrages for a century, will be going through a critical transitional phase. Established rights to surface water and the procedures that have been used for allocation of the flows available each year will no longer be appropriate means of deriving the greatest possible benefit from the water supplies that will be available. It will be necessary to continue to allocate water each year largely on the basis of predetermined requirements rather than on a demand basis because of the rigidities of the system. But these requirements will need to be reviewed annually in the light of interim system development. Most of the Mangla storage will be required to replace the rabi flows of the eastern rivers but the intra-seasonal regulation capacity of the dam will make it possible to fit flows better to crop needs than has been possible in the past. Completion of the link canals from the Indus will add to the flexibility of bulk water allocations between areas, but new diversions will be required to enable them to provide enough water to replace Sutlej and Ravi flows. The irrigation supplies that become available from the groundwater aquifer with the gradual spread of tubewell fields will need to be taken into account in calculating surface-water requirements; and in some cases, first probably in SCARP IV, groundwater will be able to substitute for some of the current surface supplies, thus releasing them for use elsewhere. Tarbela will further alter the nature of the system, adding substantially to total rabi water availability and providing more capacity for fitting water supplies to crop needs. Thus the water system will be evolving rapidly and major new policy decisions will be required.

9.19 The Bank Group believes that a Provincial Irrigation Authority should be constituted at the highest level to give adequate recognition to the broad range of administrative, legal, sociological and technical considerations that should be brought to bear in formulation of these evolving policies. This body would be responsible for basic decisions on barrage allocations, reservoir release patterns and drawdown levels and other major policy issues such as the use of tubewell fields in relation to surface water deliveries, and it would be concerned with both power and irrigation aspects of these matters. The Authority would ensure that all Government agencies concerned with irrigation cooperate in the formation of new policies and water allocations, but it would not itself be expected to undertake the detailed analyses of water distribution. The Bank Group believes that for this purpose there should be set up a semi-independent study group or working party staffed by, say, the Irrigation and Power Department, WAPDA, Agriculture Department and the Planning and Development Department. The study group would need to be well staffed with technical officers competent to carry out the detailed calculations and analyses required and fully conversant with the practical problems of irrigated farming and of operating the irrigation system.

9.20 Representation of the Power Wing in the derivation of policies for operation of the works, such as Mangla Reservoir and the tubewell fields, which have implications for power as well as irrigation, will be important but improvement is also vitally needed in operations of the Power Wing less directly related to water resources. The chief dispatchers of the power systems must be clothed with sufficient authority to direct the flow of electricity from generating stations to load centers as required and to order the start up or closing down of generating stations to meet fluctuating demands. After the power systems in the North and the South are interconnected by EHV transmission lines a central dispatching station will be needed. The Power Wing's billing, collecting and accounting procedures need improvement. The present accounting system does not provide management with sufficiently detailed and up-to-date statistics to analyze operating results and trends and to know where responsibility for successes and failures lies. Losses on the WAPDA systems are presently unduly high, about 20 percent of the total energy sent out from the generating stations; even a small reduction could lead to substantial increase in net income, but a sizable reduction should be possible with improvement of the distribution system, better meter reading and billing procedures, and more efficient operation of a denser transmission and distribution network.

9.21 As the complexity of the irrigation and power systems increases the need for effective and carefully programmed maintenance will become increasingly important. Maintenance has been somewhat neglected in the past, partly due to shortages of personnel and partly due to lack of adequate financial provisions, and this neglect has led to some serious deterioration of works, sometimes with disastrous consequences as in the case of the Multan power plant. Deterioration of the distribution network on the WAPDA power system has led to a situation where accidents occur too often, and it also accounts in part for the large distribution losses on the system. It is urgent that WAPDA take the necessary steps to provide and train more manpower for work in this field and to allocate sufficient funds for renovation of the distribution network. More attention is needed for canal maintenance. IACA found many of the canals to be in such a state that further deterioration could result in the need for extensive and costly repairs. Better maintenance of the canals will become increasingly important because the changes that are being made in the overall system may cause some additional damage (e.g. scouring because the water will have deposited most of its silt load in the reservoirs) and because reliable operation of the canals will be critical in a tightly integrated system. Canal maintenance will have to be carefully scheduled and fitted in with the program for tubewell maintenance to ensure the availability of irrigation supplies from one source or other in accordance with crop requirements.

9.22 Once construction of each of the public tubewell projects is completed the critical task will be to operate the new water-supply system efficiently and to ensure the availability of the complementary agricultural inputs that will enable the farmers to get the best results from the added water. The Bank Group attaches such importance to the latter task that it has diverged somewhat from IACA's proposals regarding project management. Concerned about the need for efficient management on the water side, IACA felt that integration of surface and groundwater supplies required that both be under a single unified control; they recommended that the Irrigation Department take over responsibility for operation of the tubewell fields. The Bank Group felt that the Irrigation Department had too many responsibilities elsewhere to be able to give the tubewell fields sufficient attention. It was also dubious whether private enterprise would be able to come into a project area in sufficient force initially to promote and provide inputs that had been relatively little used before. An integrated project management, fully responsible for all aspects of project operation, seemed to be required, somewhat along the lines of the existing concept of ADC and LWDB. Emphasis should therefore be placed on strengthening and improving these relatively new organizations. They would provide a Project Director, with full responsibility for the overall success of the project, and with a staff of engineers, extension workers etc., seconded from the line departments but fully responsible to the Project Director. This approach will help to ensure that sufficient emphasis is given to improved farm practices and to use of more material inputs as well as to water. An important task of the project management should be, as IACA pointed out, monitoring project development starting with the pre-project condition: lack of sufficient data on agriculture in West Pakistan is an obstacle to effective project planning and the execution of a project provides a very good opportunity to help remedy this deficiency. The integrated project management should in no sense discourage the development of private enterprise for supplying inputs and the activities of the regular line departments in the area; it should in fact withdraw once the project is well underway and major changes have been accomplished, in favor of an organization more representative of the local farmers.

9.23 There is one other aspect of water development policy which has received considerable emphasis throughout this report and which has important institutional implications: the potential contribution to be made by the private sector. The Bank Group sees public and private tubewells as essentially complementary, since neither alone can meet the urgent need for greater amounts of irrigation water. Public tubewell projects should be planned for areas where a public program has a clear advantage over private development and where private investment is not likely to be very significant. The Bank Group feels that when the detailed feasibility studies are made for the public projects recommended in this report special attention should be given to the question whether some parts or possibly all of a proposed project area might not wisely be left to private initiative in order to free public funds for activity elsewhere. It is very important to draw up a public program of manageable size because scheduling an area for public development will discourage some of the private development that would otherwise have taken place there and, if the public project then gets seriously delayed, an important and avoidable loss of production will have been sustained. Besides providing this degree of security for investors in private tubewells, the Government should take other measures to stimulate private water development. Many of the private tubewells presently installed have technical deficiencies which could have been avoided. Technical advice should be readily available to farmers and landowners on procurement and construction matters, types of equipment available, water quality, irrigation requirements and water management. Such advice would cover not only tubewells but also other water works such as small dams and watercourse alignment; increasingly, advice and assistance may be required to help organize cooperative use of facilities. Credit may also become more important as the further spread of private tubewells comes to depend more on the smaller farmers and more attention should be given to the possibility of stimulating private development in this way, for instance by a more aggressive credit policy on the part of the Agricultural Development Bank and sustained increases in its lending resources. The extension service should help farmers who are enterprising enough to install their own irrigation works to make the best use of them. The Bank Group strongly advocates measures of this sort, i.e. direct help in the form of technical advice and services that will not otherwise be provided.

Promotion of Farm Inputs

9.24 Very great stress has been laid in this report on the contribution to the increase of agricultural production that must come from the adoption of improved farm practices and greater use of agricultural inputs other than water. For the project areas the line departments will have to provide the personnel for promoting improved farming and the Project Directors will have overall responsibility for performance. However, even if the whole public tubewell program can be completed by 1975, Project Directors will be responsible for only about 10 million acres. Promotion of new inputs in the remaining three quarters of the farm area, both irrigated and unirrigated, in the Province will be the responsibility of the Agriculture Department staff, the ADC, and private enterprise. It is one of the most important conclusions of this report that such areas can profitably absorb large quantities of new inputs and adopt improved practices even before additional water is provided. Moreover a sizable portion of this area should see rapid development of private tubewells for increasing water supplies. It is the magnitude of this responsibility which underlines the need for the vast improvement in the Agriculture Department called for earlier. Even for the project areas it is largely the Agriculture Department that will be the source of extension staff and it will be responsible for the research work necessary to test and develop the new inputs and to evolve the cultural practices which will produce the best results from the inputs.

9.25 As with water development, the public sector should dispose its resources in such a way as to give maximum encouragement and opportunity for the growth of private enterprise in supplying and promoting agricultural inputs; public resources should be allocated in such a way as to maximize the return on the combined public and private investment of effort and finance in promoting better agriculture. As in water development, again, however, there will be many areas of activity where private enterprise will not come in rapidly and the Government must take a strong lead. There are essentially four aspects to the work involved in achieving widespread adoption of an input and, because promotion of better agriculture must be a continuing process, they must all be carried on simultaneously. The first stage is research and testing of new inputs, and this must remain very largely a Government responsibility in West Pakistan. The second aspect is ensuring the widespread physical availability of supplies -- and this is where private enterprise should be able to make the largest contribution. The third part of the effort must be provision of incentives to the farmer to adopt the new inputs, both in the form of an overall price structure for agricultural goods which is conducive to investment of farmers' effort and savings in agriculture and in the form of subsidies for specific inputs and provision of credit for purchase of such inputs. The fourth aspect to the job of promoting new inputs is extension work to show the farmer what is available and how to use it; this may be the most important part of the work and though private enterprise again can help to some extent the main task will remain with the Government.

9.26 Progress in agriculture will depend heavily on applied research and extension; this is especially the case for new crop varieties and effective plant protection. Research is vitally needed to develop new and improved varieties, more efficient plant protection methods and better understanding of soil, crop, water and fertilizer relationships, but, as presently set up, the research service is not capable of making the needed contributions. It suffers from the lack of qualified personnel and supporting facilities noted earlier for the Agriculture Department as a whole. It tends to be overly academic and isolated from the farmers whose day-to-day problems need to be solved. Building an efficient and contributing research branch will not be a simple task and it will take more than the addition of a few more staff members or some new equipment. The critical needs for improvement of the research service are generous financial support, patience and understanding of the uncertainties which are a necessary part of research, the infusion of a spirit of service to the agricultural community, dedicated leadership and a conscious orientation towards the problems facing West Pakistan's agriculture today.

9.27 As instanced above in the case of new varieties, the Bank Group has set rather ambitious targets for the spread of new inputs; official targets, for example for fertilizer and improved seed, are even more ambitious. It is clear that a massive expansion of the distribution network will be needed. At present the ADC and the cooperatives bear the main responsibility for fertilizer distribution, but this input is probably one which could be most effectively handled by private enterprise, provided that fertilizer is made available in adequate quantities. Shortages have occurred because of the heavy dependence on imports, but large amounts of foreign exchange are now being allocated. One commercial enterprise plans to distribute fertilizer from its plant now under construction through its own sales organization; other large domestic fertilizer plants now being planned may do the same. Production and distribution of improved seed is a field in which Government supervision will have to play a much bigger role; past efforts to promote improved seeds have suffered severely from adulteration by growers and distributors. Planned multiplication on an expanded network of registered growers supplied with nucleus stock under close Government supervision will be necessary to maintain the quality of the seed; if quality is not maintained and the germination rate falls this can have very serious effects on the readiness of the farmers to use the new varieties. Private suppliers, under Government supervision, may gradually be able to take over from the Government departments a major part of the burden. Adoption of plant protection measures will not become widespread until the relatively large increases in yields that are attainable with fertilizer and better seed have been achieved and until research has developed simpler and more certain techniques. Effective plant protection depends so much on application at the right time that the farmer must bear a large part of the responsibility. At present the extension service carries almost the entire responsibility for plant protection, and, according to IACA, it is not very effective. Responsibility for provision of plant protection materials should gradually be transferred to the greatest extent possible to private enterprise to give the extension service more time for other activities. Farm mechanization and the spread of improved hand tools and animal-drawn equipment are other fields where private enterprise, with Government supervision, could play a bigger role than it does now. The Government will have to take steps to ensure that dealers are able to stock adequate spare parts and are prepared to offer continuing and dependable servicing facilities: some control may also be necessary on the variety of equipment made available. But the rapid growth of domestic production and servicing facilities for private tubewells suggests that private enterprise could handle the distribution and servicing of farm machinery effectively.

9.28 The most important financial measure that must be taken by the Government for promotion of new inputs, as for promotion of improved agriculture in general, is maintenance of a strong price framework for agricultural commodities which gives proper rewards to the farmers. A gradual improvement in the effective prices for agricultural products played a significant part in stimulating greater interest in agriculture during the Second Plan. There would still appear to be some room for further improvement in the price paid to the farmer for selected farm products. The Government did recently raise the official support price of wheat to PRs 17 per maund which appears to be somewhat above the international market price for wheat at the current exchange rate but is substantially below the international price at a shadow rate which possibly might be considered more relevant (say approximately double the official rate). Apart from a favorable price structure for farm products, there will probably continue to be a need for specific subsidies to encourage the use of particular inputs, indeed it may well be that most help could now be given to agriculture by concentrating on such selective price adjustments for inputs and by spending more Government money on services to agriculture rather than by further raising the general price level for agricultural output. Current subsidies on fertilizer, plant protection and improved farm machinery do appear to play an important promotional role and they will need to be retained until such time as the value of these inputs is so widely recognized among the farmers that they are prepared to buy adequate quantities at unsubsidized prices. It is therefore important that all subsidies be reviewed from time to time to see if the stage has been reached at which they could be dispensed with. One subsidy to the farmers which the Bank Group believes to be of dubious validity at the present time is that on electricity used for pumping purposes. This subsidy appears to have played little role in promoting tubewells; the more important factor encouraging installation of private wells has been the sheer availability of electricity. Since lack of finance is one of the major factors limiting the expansion of the electricity-distribution system and since the Power Wing's rate of return on capital invested is already below what the Bank Group would consider a reasonable level, serious consideration should be given to raising the price charged the farmer for electricity. The Bank Group would also urge thorough consideration of the possibility of raising water charges as a means to alleviate the budgetary stringency which is such a serious problem in the execution of development programs. Water is an accustomed input, the critical importance of which is already widely understood by the farmers, so that increased water charges should have no disincentive effect. Indeed higher charges for water, more commensurate than those presently levied with the heavy costs involved in building and operating the irrigation system, could help to improve the utilization of water just as the much higher costs of private tubewell water have apparently led to more careful and productive use of water obtained from that source.

9.29 The credit system in general, and especially that for inputs like fertilizer and seed, is very inadequate and it may become a serious block to progress, unless special measures are taken to improve it. Credit on reasonable terms, generally from the Agricultural Development Bank and from the commercial banks, is available only to the larger farmers. The majority of credit made available comes from merchants, zamindars, etc., sometimes at high interest rates, and most of it is spent not on farm inputs but to meet social and subsistence needs; this heavy demand for credit for non-agricultural purposes tends to raise the price of credit in general. Measures are needed to improve the availability of credit and the operation of the cooperative system which will be one important channel of credit, but such measures cannot have a rapid effect. Main reliance for credit will have to continue to be placed on non-institutional sources.

9.30 Perhaps the most critical aspect of the effort to promote improved agriculture and greater use of material inputs is education of, and advice for, the farmers. This is the task primarily of the extension service, and the service is at present entirely inadequate to meet the need, both in terms of numbers of officers and the quality of many of them. General problems of recruitment were referred to previously. The lack of facilities, such as transport, further limits the effectiveness of the available officers. Many farmers would apparently welcome new ideas and advice, but seldom have an opportunity of meeting an extension worker. Much time of the extension service is devoted to administrative chores and to rather ineffective plant protection work. The low status of the extension personnel, and the Field Assistant in particular, makes it difficult for them to contact and work with the more influential farmers in a community. With weak research support, and having only a small base of practical training and experience, the advice which many extension workers are in a position to offer is often of little real value to farmers. Yet it is this extension service which must carry the main responsibility for showing farmers how to use fertilizer to best advantage under specific conditions and for demonstrating to them the best cultural practices that go along with new seed varieties. It is the extension service which must also have the capability of advising the most progressive farmers, who are moving on to use insecticides and farm machinery. It is critical that large investment in provision of improved water supplies in an area be rapidly followed by a concentrated extension effort to enable the farmers to make best use of the added supplies. The Bank Group and IACA have also projected rather rapid development of the livestock sector in face of the increasing demand for meat and milk, and this is a field where technical advice and assistance are extremely badly needed; animal husbandry will have to be closely coordinated with crop production in diversified farms and so it is the agricultural extension service which must develop the capability of providing advice about livestock management and improved feeding practices.

9.31 Despite the need for substantial expansion of the extension service, the Bank Group feels that the problem of quality is so serious that it may be more strategic in the short run to concentrate on recruitment of better personnel and improvement of training rather than to become too preoccupied with meeting given quantitative personnel targets. In fact, present plans for expansion should enable the agricultural universities to turn out enough graduates to meet both the requirements of the Government services (an increase of about 1,600 between 1965 and 1975) and also those of the other departments such as Irrigation, WAPDA and the Education Department. It should also not be difficult to carry out the physical expansion of training colleges for Field Assistants -- an additional six colleges coming into operation during the Fourth Plan period -- that would be necessary to meet the target recommended by IACA of approximately doubling the number of Field Assistants from 3,000 in 1965 to 6,000 in 1975. But whether this full expansion could be carried out simultaneously with a major effort to improve the quality of entrants into agricultural service and of the instruction afforded them is open to question; and the Bank Group would put emphasis on the quality aspect. It welcomes the recent increase in the length of the course for Field Assistants from one year to two, including six months of supervised field work. There should be continuing efforts to make the training more meaningful in the practical terms required for effective work with the farmers.

X. PROPOSED PROGRAMS AND PAKISTAN'S PLANS

10.01 Over the years, and especially during the Second Plan period, Pakistan's Five Year Development Plans have come to play an increasingly important part in the total development effort of the country. The Plans are concerned with setting the overall financial and economic framework of the development effort, establishing specific financial and physical targets, allocating Government development expenditures and proposing policies which will promote economic growth. The First Five Year Plan covered the period 1955-60, but the results were disappointing. The Second Five Year Plan, covering the period 1960-65, was given much greater emphasis by the Government, and many of the policies recommended by the Planning Commission in the Plan document and generally endorsed by the National Economic Council were subsequently officially adopted as part of the national development effort.

10.02 In the course of preparing the Third Five Year Plan the Planning Commission felt the need for a framework which could give explicit recognition to objectives and major structural changes which could not be expected to be achieved in as short a span as five years. Many of the decisions which were taken for the short term would have a critical effect in confining or expanding the scope for choices at a later date and the realization developed that to see the full implications of current recommendations it was necessary to have a longer-term view. Considerable effort was therefore devoted to formulation of a long-term or Perspective Plan built around the major objectives of the country. It was envisaged that the skeleton framework outlined in the Perspective Plan as a means of attaining those objectives would gradually be filled out by various Master Plans that would go into greater detail on the development potential of the different sectors of the economy.

10.03 The objectives of the Perspective Plan (which covers the period 1965-85) are mainly national objectives, covering both East and West wings of the country. For purposes of its projections the Bank Group attempted to interpret the main objectives of the Plan as they would apply to West Pakistan:

(i) doubling of per capita income between 1965 and 1985;
(ii) parity in per capita incomes between East and West Pakistan by 1985;
(iii) full employment at earliest achievable date;
(iv) more equitable income distribution, especially raising the lowest 25 percent of the population;
(v) universal eight-year education by 1985;
(vi) elimination of net capital inflows on public account by 1985.

At the time the Indus Special Study was underway the Planning Commission was working on a quantitative regional breakdown of the Perspective Plan, but no definite framework for West Pakistan was available. Nevertheless helpful guidance was provided by the Planning Commission and during several phases of the Study, especially at the outset, the Perspective Plan was drawn upon in connection with aspects such as projections of population and demand.

Agriculture and the Development Plans

10.04 One of the chief targets of both the Perspective Plan and the Third Five Year Plan is to achieve an average annual growth rate in agriculture in the neighborhood of 5-5.5 percent. This was an ambitious target in the light of past experience -- of less than 2.5 percent average annual growth in agricultural production between 1950 and 1965. However the successes achieved in agriculture during the Second Plan period -- when production grew at more than twice the rate of the previous decade, as noted in Chapter III -- suggested that it would be feasible if sufficient incentive were given to the farmers and they were provided more water, fertilizer, insecticides, etc. Consideration of the long-term experience of relatively stable agricultural exports and growing imports of agricultural goods, discussed in Chapter III, also suggested that it would be essential to achieve a much higher growth rate in agriculture than had been attained in the past if growth of the provincial economy as a whole were not to be restrained. Planning Commission Studies showed that an agricultural growth rate of some 4.5 - 5.0 percent per annum was essential to support the 6.0 - 6.5 percent growth rate in Gross Provincial Product required to meet the target of doubling per capita income between 1965 and 1985.

10.05 Developments since the Third Plan and Perspective Plan were formulated have added to the emphasis that is being placed on growth of agriculture in West Pakistan. When the Third Plan was revised late in 1966 top priority was given to agriculture. The document announcing the Plan revisions stated "The importance of this sector is already recognized in the Third Plan but the need for attaining self-sufficiency in food in the shortest possible time has been sharpened by the growing uncertainty and more difficult terms of PL-480 supplies." Food self-sufficiency had been a somewhat longer term target in the original Third Plan. Now the Government of West Pakistan has developed and adopted a major program designed to eliminate dependence on imported wheat by the end of the Third Plan. The key element in the program is higher yielding wheat varieties introduced from Mexico. Ambitious targets have been set for use of Mexican wheat seed, as discussed in Chapter VI, and absorption targets for fertilizer have been greatly increased. High priority is being given to measures to increase irrigation supplies, particularly from public and private tubewells.

10.06 The Action Program proposed in this report for development of irrigation and agriculture was drawn up largely before wheat self-sufficiency had been adopted as an immediate objective of West Pakistan and primarily on the basis of what the Bank Group and its consultants considered practically achievable and consistent with available resources.

Production was projected on the basis of detailed analysis of areas studied rather than against particular demand targets. Moreover, while prices of commodities were for analytical purposes for the most part held constant so that the focus could remain on the technical aspects of development proposals, this also precluded shifts in production in response to changing market incentives.

10.07 Although the program was thus purposefully evolved somewhat in isolation from demand considerations, some check was finally made against possible future demand to determine whether the Program might meet West Pakistan's requirements. Supply and demand did not show a balance for each commodity. Demand was estimated on the basis of expenditure elasticities for different commodities over time, population assumed rising to about 66 million in 1975 and 87 million in 1985, and a growth rate in Gross Provincial Product of about 4.3 percent per annum. The major shortfalls occurred in foodgrains, but there were surpluses in some other crops. However the Bank Group concluded from its agricultural studies that the production and acreage which it had projected could support a higher overall growth rate than 4.3 percent -- a conclusion strengthened by the analysis discussed in the next paragraph -- and that the surpluses and deficits projected for different crops could be overcome by appropriate adjustments to the cropping patterns. Acreage in crops which appeared to be in surplus could, in many cases, be used for production of deficit crops within the same season and at about the same level of crop-water requirements; in general there seemed to be sufficient flexibility built into the projected development of the irrigation system to cope with the apparent deviations between supply and demand for different crops. However Government price and marketing policies would have to be fashioned in ways which would encourage the necessary shifts in cropping patterns.

10.08 The Bank Group also undertook another more global analysis in the form of a macro-economic projection for West Pakistan from 1962/63 to 1974/75 on the basis of a model very similar to that used by the Planning Commission in preparing the Third Five Year Plan. The model is of the linear inter-sectoral type and relates macro-economic magnitudes such as the overall growth rate or the savings rate to a sectoral growth pattern, which balances the supply and demand relationships between sectors. The model also has a built-in mechanism for adjusting the surplus or deficit on the current account of the balance of payments to equal the difference between projected savings and investment; the adjustment mechanism is import substitution. Thus the model shows the value of import substitutes which must be produced domestically in the year projected if the assumed savings level is to be attained. 1962/63 was adopted as the base year for the projections because that is the only year for which an input-output table for West Pakistan is available. In attempting a 12-year projection the Bank Group had inevitably to use much judgment and make many assumptions, but it believes that the results derived can shed useful light on some of the broader implications for economic growth in West Pakistan of the programs proposed for development of agriculture, irrigation and power.

10.09 The Bank Group's projection suggests that the agricultural growth rate of 4.5 percent per annum projected in this report (see Chapter VI) would be consistent with a growth rate in Gross Provincial Product of about 5.7 percent per annum and, with that overall growth rate, it would be sufficient to provide for self-sufficiency in the major agricultural products. This estimate is based on the assumption that the marginal savings rate of about 24 percent between 1965 and 1975 which is implied by the Perspective Plan will be attained.

10.10 The point is illustrated by Figure 1. All the numbers shown in this figure represent changes between the base year 1962/63 and the projected year 1974/75, rather than absolute quantities. All the underlying projections were made on the assumption that Gross Production Value of agriculture would grow at an average rate of about 5.2 percent per annum and that value added in agriculture would grow at 4.5 percent per annum. The vertical axis in Figure 1 represents the marginal savings rate between 1962/63 and 1974/75; it is also the dividing line between the right-hand portion of the horizontal axis which measures the agricultural surplus in 1974/75, or the quantity of agricultural production in excess of domestic requirements and therefore available for export in that year, and the left-hand portion of the horizontal axis which measures the agricultural deficit in that year. Agricultural deficits or surpluses refer here to deficits or surpluses in meeting the increase of domestic requirements between the base year and 1974/75. The sharply sloping lines in the center of the figure indicate that combination of agricultural surplus/deficit and marginal savings rate which would be consistent with a particular growth rate in Gross Provincial Product between 1964/65 and 1974/75. The more gently sloping lines indicate the corresponding amount of import substitution that would have to be achieved over the ten-year period in order to bring the Foreign Exchange Gap into balance with the Savings Investment Gap in 1974/75. Thus Figure 1 shows that with a marginal savings rate of about 24 percent and an overall growth rate of 5.7 percent per annum, an agricultural surplus of about PRs 250 million could be achieved, sufficient to offset the PRs 250 million of wheat imports in the base year. Not shown on the figure is the fact that there would be an accompanying improvement in the balance of payments on current account of the order of PRs 600 million, resulting from the facts that the amount of investment required to support a 5.7 percent growth rate in 1974/75 is less than the quantity of domestic savings achieved in that year with a 24 percent marginal savings rate in the interim and that, in the logic of the model, the Foreign Exchange Gap is equated with the Savings Investment Gap.

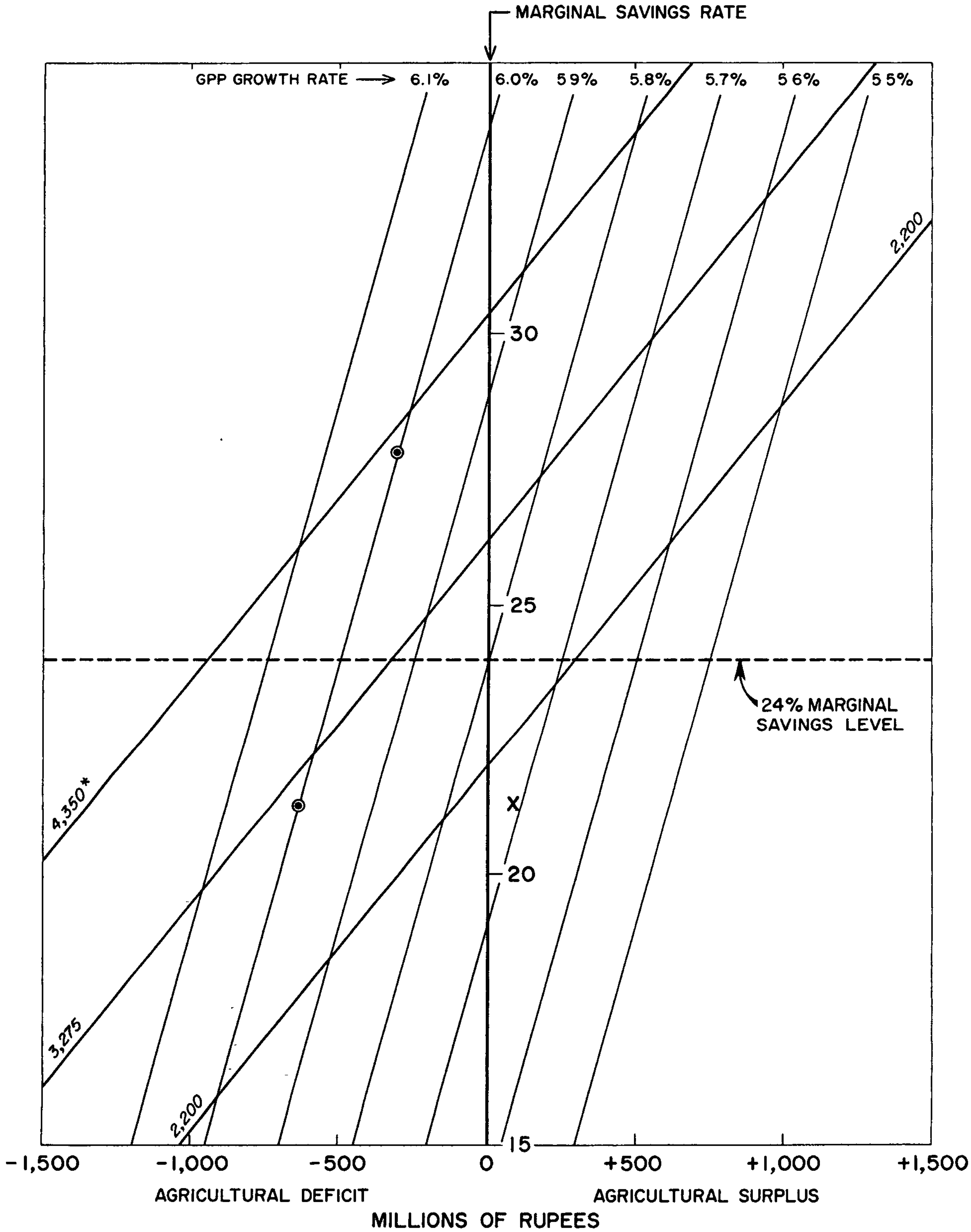
10.11 While this would mean that self-sufficiency in wheat was attained, it would fall seriously short of the Perspective Plan in other respects -- an overall growth rate of only 5.7 percent between 1965 and 1975 against a Plan target of over six percent and an improvement in the balance of payments only half the size of that implied by the Plan. However the choice of growth patterns is not restricted to this single one.

Higher rates of growth in Gross Provincial Product would be possible but they would require some continuing or even increasing imports of agricultural products and larger amounts of import substitution. Two alternative cases, both marked on Figure 1 with circles, have been studied as examples. They represent cases of six percent per annum overall growth rate, with 21 percent and 28 percent marginal savings rates respectively. At the lower savings rate needed imports of agricultural commodities are large, greater import substitution is required than in the case with 5.7 percent overall growth rate and the improvement in the balance of payments is small, less than PRs 100 million. At the higher savings rate a much larger amount of import substitution would be required, but there would also be a slight surplus on the current account balance of payments by 1975. The higher import-substitution requirements mean higher growth is required in the sectors where import substitution is assumed to occur -- manufacturing of consumer goods, intermediate goods and capital goods -- but the requisite growth rates do not appear unreasonable by comparison with those attained in the past or those projected in the Perspective Plan for these sectors.

10.12 It is possible that a six percent growth rate in Gross Provincial Product would be compatible with food self-sufficiency, a substantial improvement in the balance of payments and a relatively small amount of import substitution. This was found to be the case when the analysis was carried out on the assumption that the elasticity of demand for agricultural products is as it was assumed by the Planning Commission in preparation of the Third Five Year Plan. The Bank Group carried out its main analyses, the results of which are shown by the lines in Figure 1, on the assumption that the expenditure elasticity of demand for directly consumed agricultural products is in the neighborhood of 0.85, including an elasticity of demand for food grains of 0.55. These elasticities are in line with the estimates made by IACA on the basis of careful analysis of demand for different crops; they are also consistent with those used in some Planning Commission documents. However a substantially lower elasticity of demand for directly consumed agricultural products -- 0.67 -- was used in the preparation of the Third Five Year Plan; it was derived on the basis of estimated historical experience in Pakistan during the Second Plan period. The Bank Group tested the effects of assuming this lower demand elasticity. It found that it had the effect of reducing the agricultural deficit or increasing the agricultural surplus projected using the Bank Group's coefficients by some PRs 700 million. In terms of Figure 1 it was sufficient to shift the line representing six percent growth rate in Gross Provincial Product over into the right-hand half of the figure, indicating even at a 21 percent marginal savings rate a reduction in agricultural imports between 1962/63 and 1974/75 of over PRs 100 million (see point marked with a cross in Figure 1) and at higher marginal savings rates potential increases in agricultural exports.

10.13 Thus the Bank Group's analysis suggests no necessary incompatibility between a 4.5 percent growth rate in agriculture and a 6.0 percent growth rate in Gross Provincial Product. Indeed, using demand elasticities adopted by the Planning Commission, it would be possible to achieve food self-sufficiency with a 6.0 percent growth rate and also a balance

WEST PAKISTAN: ALTERNATIVE DEVELOPMENT PATTERNS WITH 4 1/2% PER ANNUM GROWTH IN AGRICULTURE



*NOTE: Figures in italics indicate import substitution in millions of rupees

IBRD-3497

of payments improvement nearly two-thirds of that projected in the Perspective Plan, provided that the planned marginal savings rate of 24 percent is achieved. However the Bank Group has preferred to stay on the conservative side by making more ample allowance for growth of domestic demand for agricultural products. If demand for agricultural products grows at this higher rate, then, according to the Bank Group's analysis, it will not be possible to reach both self-sufficiency in agricultural products and a 6 percent overall growth rate. Since substantial imports of capital goods will be needed it would also be difficult under these circumstances to achieve the improvement in the balance of payments projected in the Perspective Plan. The extent of improvement possible would depend on the marginal savings rate achieved and the growth of import-substituting industry. Thus the Bank Group's analysis reconfirms the Planning Commission's conclusion that achievement of a high rate of growth in agriculture is very important to attainment of Pakistan's objectives.

Sectoral Growth Rates

10.14 As regards growth in sectors other than agriculture the Bank Group's projections do all imply some significant differences from the Perspective Plan. Two are especially noteworthy. Considerably more rapid growth in the transport industry is projected by the Bank Group than by the Perspective Plan -- about seven percent per annum as against less than six percent. This result further confirms the great stress that the Bank Group would place on expansion of the transport network -- both arterial links and farm-to-market roads -- as a critical element in attainment of a high agricultural growth rate and a high overall growth rate. The Government appears to be aware of this need. In recognition of the importance of rural farm-to-market roads it was stipulated that one half of the funds earmarked for the Rural Works Program in 1964/65 had to be spent on local road construction. Plans are underway for substantial expansion of the capacity of the railway and of Karachi Port. However execution has not always come up to expectations: less than half the funds allocated for Rural Works in 1964/65, for instance, were actually spent on roads, and there have been very serious delays in procuring the additional locomotives required by the Pakistan Western Railway. The Government's plan for wheat self-sufficiency identified transport as a major potential bottleneck in getting the requisite amounts of fertilizer to the farmer and wheat to the towns. All the studies of the Bank Group reemphasize the need for more rapid expansion of transport facilities than achieved in the past.

10.15 The second noteworthy difference between the Perspective Plan and the Bank Group's tentative projections for West Pakistan concerns growth of consumer goods manufacturing. The Plan projects a growth rate in the neighborhood of three percent. Bank Group projections imply the need for growth at a rate in the neighborhood of at least six percent. Studies suggest that one aspect of the improvement in the relative price situation facing farmers, which was such a crucial factor in inducing the agricultural successes of the Second Plan, was increasing availability of domestic manufactured goods at slightly declining prices through the late 1950's and early 1960's. Maintenance of a price structure which provides proper incentives and rewards to the farmers has been stressed as a critical need at several points in this Volume, and it would seem that an important element in the pattern of incentives would be the availability of manufactured consumer goods, at reasonable prices relative to farm product prices, on which farmers can spend their increasing incomes. The growth rate in consumer goods manufacturing implied by the Bank Group's projections is slightly in excess of projected growth in total consumption in the economy.

10.16 It was in this matter of the growth rate of consumer goods manufacturing that the Bank Group diverged most seriously from the Perspective Plan when it was checking the power load forecast for industry used in the report. As noted in Chapter VIII the Bank Group assumed that the overall industrial growth rate actually achieved might be somewhat above that implied by the Perspective Plan. On that basis it concluded that the projection of industrial load included in the Main Load Forecast used for the power studies seemed reasonable for 1970 and might be a little on the high side by 1975. The macro-economic projections now made with the aid of the Planning Commission's model suggest that the growth assumed for consumer goods manufacturing in the power studies may have been a little on the low side while that for other types of manufacturing was likely somewhat too high. The effect of these different industrial growth rates on the power load forecast has not been checked by the Bank Group in detail because it does not consider the precise sectoral growth rates arising from its macro-economic projection sufficiently reliable. Nevertheless it would appear, in general terms, that the aggregate growth of the industrial sector broadly defined (large-scale manufacturing, small-scale manufacturing, mining and utilities) might, according to the macro-economic projections, lie somewhere between the eight percent per annum projected by the Perspective Plan and the ten percent per annum assumed in the power studies. This would in turn imply that the Main Load Forecast remains a reasonable projection, erring on the optimistic side and thus including some contingency for unanticipated developments.

Investment Requirements of Proposed Programs

10.17 The macro-economic model projections made by the Bank Group, analyzing the development patterns implied by different combinations of growth rates in gross provincial product and marginal savings rates with a 4.5 percent growth rate in agriculture, cannot do more than show alternative possible paths of development which are internally consistent; it gives no indication as to which pattern would produce the largest results for the least expenditure of scarce resources. It is important to hear this in mind in considering the financial requirements of the proposed programs for development of agriculture, irrigation and power. In the past it has sometimes been thought that one of the advantages of giving a large role to agriculture in the development plans was that this sector could provide large increases in output and large increases in employment for relatively low inputs of capital investment; in other words it had a low capital-output ratio. The Bank Group found that the capital-output ratio in agriculture implied by its projections was considerably higher than might be expected on the basis of past experience. For instance the ratio between total investment in irrigation and agriculture over the Second Plan period (excluding the Indus

Basin Works) and the increase in agricultural output over that period has been estimated by the Planning Commission at about 1.9. The Bank Group found that the comparable ratios implied by its program and assuming a rate of growth in agriculture of 4.5 percent would be about 2.7 for the Third Plan and 3.8 for the Fourth Plan period. These are considerably higher than the ratios implicit in the Perspective Plan. Taken at face value, they might appear to imply that less scarce investment capital should be allocated to agriculture and a lesser role should be given to agriculture in the future than hitherto planned. Another growth path involving less emphasis on agriculture and relying to a greater extent on industrial import substitution might be envisaged.

10.18 However the Bank Group believes that such a conclusion would be erroneous and that it is essential to give to agriculture the high priority role that it is attributed in the Perspective Plan, and to allocate the funds needed to support the most rapid development that agriculture can sustain. The explicit objectives of the Pakistan Government with regard to food self-sufficiency and agricultural growth were referred to previously. In addition, it is the Bank Group's view that agricultural growth can play a major role in reducing the foreign exchange shortage which has severely hampered Pakistan's development efforts. Irrigated agriculture, partly because it involves slow gestation projects with long-term benefits, necessarily tends to be relatively capital intensive, and so the need to allocate relatively large quantities of capital to agriculture in West Pakistan should not be unexpected. The heavy effect of irrigation works on the capital-output ratio is illustrated most dramatically by the fact that the ratio for the Fourth Plan, quoted above as 3.8, would be 2.9 if the Fourth Plan expenditures on Tarbela are left out of account on the grounds that the dam will not begin to yield benefits until the very end of the Plan period. Even 2.9 is a moderately high ratio. But here it is worth recalling the essential role these irrigation projects have in the development of a modern agriculture, as well as the relatively high rates of return which were shown in Chapter VI to be typical of the proposed irrigation projects -- rates between about 12 and 25 percent. A recent survey of a wide range of major industries in West Pakistan showed that the average rate of return on total capital invested was about 14 percent per annum, although some industries had higher returns. The figures are not really directly comparable but they are indicative of the fact that the proposed surface water development and the public tubewell projects appear to be very paying propositions. In this connection, moreover, it must be borne in mind that the capital-output ratios and rates of return on the proposed irrigation projects are calculated chiefly in terms of actual financial prices of 1962/63 and average farm prices over the period 1960-65 respectively. There is strong evidence to suggest that the price structure in West Pakistan has been and still is less favorable to agriculture than in many other countries, despite improvements during the Second Plan period. Thus if the capital-output ratios and rates of return on different types of project were calculated in terms of international prices for investments and for products, the rates of return on the irrigation projects would certainly appear even more favorable than shown above relative to projects in other sectors; and the capital-output ratios in irrigation and agriculture would appear lower.

10.19 The heavy capital costs of development in the sectors with which this report is concerned reflect themselves in the need for somewhat greater total investment over the period up to 1975 than projected by the Perspective Plan and for allocation of a larger proportion of total investment to these sectors than has been customary in the past, according to the Bank Group's studies. Tables 69 and 70 illustrate these points. Table 69 shows the Bank Group's estimates of public and private investment required in irrigation, agriculture and power over the Third and Fourth Plan periods. It compares them with total investment in these periods as implied by the Perspective Plan, shown at the bottom of the table, and with estimates of investment during the Second Plan period based on information provided by the Planning Commission.

Table 69

Investment in Agriculture, Irrigation and Power, 1960-75
(PRs Millions a/)

	Second Plan (est. actual)		Third Plan b/ (projected)		Fourth Plan b/ (projected)	
Private - Agriculture and Irrigation	1,500	(7.1)	2,330	(8.5)	4,120	(11.0)
Public - Agriculture	625	(3.0)	1,640	(6.0)	3,200	(8.6)
Irrigation	1,658	(7.9)	2,461	(9.0)	2,836	(7.6)
Surface Storage	-		1,916	(7.0)	2,195	(5.9)
Power	1,194	(5.7)	2,849	(10.5)	3,468	(9.3)
Total	4,977	(23.7)	11,196	(41.0)	15,819	(42.4)
Indus Basin Works	2,910	(13.9)	3,500	(16.7)	-	
Total Plan Investment	20,973		27,250		37,300	

a/ Current prices for the Second Plan period and 1964/65 prices for Third and Fourth Plans.
b/ Investment in agriculture, irrigation and power as projected by the Bank Group.

The figures in brackets represent percentages of Total Plan Investment in each five year Plan period. The table suggests that execution of the programs proposed will require devotion of a markedly higher proportion of total investment to the sectors concerned than has been the case in the past. The increases would occur in all sectors, but they would be particularly substantial in public investment in agriculture and electric power; surface storage works, mainly Tarbela, would represent about 6.5 percent of total investment over the Third and Fourth Plan periods, and part of this investment would be attributable to the irrigation sector, part to power. Table 70 shows estimates of total investment requirements over the Third and Fourth Plan periods derived from the Bank Group's macro-economic projection to 1975. The lower portion of the table reproduces the investment costs of the proposed programs from Table 69 and shows these as a percentage of the projected figures for total investment.

Table 70

Model Projection of Investment Required for Six Percent Growth in GPP
(PRs millions, 1964/65 prices)

	Third Plan	Fourth Plan
Total Investment	31,175	43,050
Proposed Programs	11,196	15,819
Proposed as % of Total	36%	36.7%

These estimates suggest that investment in agriculture, irrigation and power would represent a lower proportion of total investment than implied by Table 69; nevertheless there would still be a substantial increase between the Second and subsequent Plan periods in the proportion of total investment required for these sectors.

Public Sector Financial Requirements

10.20 Public sector development expenditures on agriculture, water and power during the First and Second Plans represented some 50 percent of total public development expenditures in those periods. In absolute terms expenditures on the three sectors more than doubled between the First and Second Plan. The Third Plan, as recently revised, allocates between sectors total public development expenditures about 80 percent above those achieved in the Second Plan. The allocation to agriculture is twice what was actually spent in the Second Plan period. Power has been allocated 15 percent of the total, as in the Second Plan, but the share of the total allowed for water development has been reduced from about 21 percent achieved in the Second Plan to 15 percent for the Third Plan. Allocations for water, power and agriculture together represent about 43 percent of total revised Third Plan public sector expenditures, or somewhat less than in previous Plans.

10.21 Table 71 shows the total public sector financial requirements of the programs proposed in this report for development of water, power and agriculture during the Third and Fourth Plan periods. The financial requirements, as estimated by the Bank Group, include interest during construction at six percent on all investment projects except Tarbela Dam, a substantial part of which is financed out of the sums remaining in the Indus Basin Fund. Table 72 summarizes these costs by sectors and compares them with revised Third Plan allocations.

Table 71

Financial Requirements of Proposed Public Sector Programs by Plan Periods[a]
(PRs. millions)

Third Plan Period		Fourth Plan Period	
AGRICULTURE			
Fertilizer Subsidies	500	Fertilizer Subsidies	700
Plant Protection Subsidies	300	Plant Protection Subsidies	500
Extension and Research	180	Extension and Research	260
Mechanization	214	Mechanization, Forestry, Others, etc.	2,835
Soil Conservation	105		4,295
Animal Husbandry	112	Capital Liability for Credit	350
Colonization	117		4,645
Forestry and Fisheries	304		
Others	364		
	2,196		
Capital Liability for Credit	178		
	2,374		
IRRIGATION & DRAINAGE			
Ongoing Public Tubewell Projects	873	Ongoing Public Tubewell Projects	118
New Public Tubewell Projects	286	New Public Tubewell Projects	975
Canal Remodeling & Other Irrigation	600	Initial Work on Further Wells	315
Surface Drainage	373	Canal Remodeling & Other Irrigation	402
Tile Drainage	39	Surface Drainage	527
Investigations	191	Tile Drainage	184
Flood Protection	74	Investigations	240
Miscellaneous	25	Flood Protection	75
	2,461		2,836
SURFACE WATER STORAGE			
Raised Chasma	85	Raised Chasma	31
Tarbela	1,793	Tarbela	2,065
Investigations	38	Sehwan-Manchar	22
	1,916	Investigations	77
			2,195
ELECTRIC POWER			
Generating Units Completed or Under Construction	356	Proposed New Generating Units	1,017
Proposed New Units	697	Transmission Lines	525
Transmission Lines	590	Distribution Lines & Connections, etc.	1,890
Distribution Lines & Connections, etc.	1,180	General	36
General	26		3,468
	2,849		

a/ Including taxes and duties and interest during construction at 6 percent per annum except on Tarbela.

Table 72

Comparison Between Public Sector Costs of Proposed Programs and Third Plan Allocations
(PRs Millions)

	Third Plan, Revised	Proposed Programs
Agriculture	1,816	2,734
Electric Power	2,176	2,849
Irrigation and Drainage)	2,211	2,461
Surface Storage (excl. Tarbela))		123
Subtotal	6,203	7,807
Tarbela Dam	-	1,793
		9,600

The combined costs of the proposed programs, excluding the costs of Tarbela for which no financial provision was made in the Third Plan documents, would represent about 54 percent of total public development expenditures as now projected. Allocations for expansion of transport facilities, which as pointed out above, the Bank Group believes to be essential to support the projected development of agriculture, would be additional.

10.22 Table 72 shows that the largest difference between expenditure proposed and Plan allocations occurs in the electric power sector, despite the fact that the revised Plan increased the allocation to power by some PRs 250 million. The Bank Group's estimate for the costs of electric power facilities does include about PRs 115 million for Mangla units 1, 2 and 3, which may not be covered under the Plan allocation, but even with deduction of this amount the difference between the figures clearly remains large. The reasons why the Bank Group believes that larger allocations are required for power were discussed at the end of Chapter VIII.

10.23 The shortfall between planned and proposed expenditures on agriculture is also large. The Bank Group's figure corresponds closely to that in the original Third Plan document, which was reduced in the revision of the Plan largely by lowering allocations for fertilizer subsidies, plant protection, mechanization and extension services. In the revision of the Plan the crop production targets were not reduced, and targets for fertilizer absorption and production of foodgrains were increased, as mentioned before. The Bank Group understands that the revised allocation would make available no more than PRs 400 million for fertilizer subsidies, compared with an original Third Plan figure of PRs 678 million. The adequacy of this reduced allocation for supporting the higher consumption targets now projected will have to be kept under close surveillance. The Bank Group considers that the allocations for the extension services are of sufficiently high priority to warrant their maintenance at the original level.

10.24 No official estimates are available for Fourth Plan public sector development expenditures, but it was clear from Tables 69 and 70 that the public sector investment requirements for irrigation, agriculture and power are unlikely to represent a lesser burden percentagewise than in the Third Plan; in absolute terms they will be substantially greater. Quite apart from the funds required for construction of the proposed projects, increasing expenditures will be required for operating and maintaining completed projects if maximum benefits are to be derived from them. It was pointed out in Chapter IX that some critically important services, like education and extension work and maintenance of the irrigation system and the power distribution system, have sometimes been made to bear the brunt of budget cuts. The services depend primarily on budgetary Rupee resources and relatively little on foreign exchange. With the major economic progress that is being achieved in West Pakistan requirements for current operational expenditures inevitably increase rapidly. An instance of this is provided by IACA who projected an increase in the current expenditure of the departments responsible for the irrigation and agriculture development program at a rate above 13 percent per annum, as illustrated in the following table.

Table 73

Current Expenditures for Agriculture and Irrigation Development Program
(PRs Millions)

	1965	1970	1975
Agriculture Department	36	77	231
Land and Water Development Board	10	28	60
Irrigation Department Establishment	36	54	81
Irrigation System Maintenance	138	244	386
	220	403	758

The Third Five Year Plan document projects an increase in current Government expenditure of about seven percent per annum. This may be on the low side if full benefit is to be derived from the human and material capital resources which Pakistan has already built up.

10.25 To meet the capital costs and the increasing current costs of the programs proposed large additions to revenues will be required. It was suggested in Chapter VIII that WAPDA Power Wing should aim for a rate of return (net of depreciation allowances) of eight percent on plant in service and that in particular this might involve increasing the tariffs on electricity sold to farmers; such an increase would still leave water pumped by electric wells substantially cheaper than water pumped by diesel wells, but it would reduce the existing large disparity. The Bank Group believes that there is more general scope for charging the farmer more for water and that this may be the best way to increase Government revenues from agriculture. At present the agricultural sector, despite its size, makes an extremely small contribution to Government revenues. The Bank Group has estimated that tax revenues from farmers net of Government subsidies to them fell from about three percent of value added in agriculture at the beginning of the Second Plan period to about 1.5 percent -- or PRs 175 million -- at the end of the Plan period. Nevertheless the case for increasing taxation on agriculture is much more complex than this bald statement would imply, primarily because of the way in which the price structure has been somewhat biased against agriculture, as pointed out earlier in discussion of the capital-output ratio. The Bank Group believes that there is a case for increasing taxation on agriculture, which would be the chief immediate beneficiary of the large works proposed, but that the measures chosen should be very carefully selected to fit in with a coordinated structure of financial incentives which makes it profitable for farmers to engage in activities that enhance economic growth and non-profitable to engage in activities that absorb resources without contributing substantially to growth. The Bank Group considers irrigation water a suitable vehicle for raising revenue from the farmer just because, unlike fertilizer or insecticide, its value is already very widely appreciated. Evidence from the private tubewell surveys also suggest that higher charges for irrigation water could lead to better and more careful usage. The Second Plan pointed out that "a large subsidy has been implicit in the provision of water" for irrigation: water rates were increased, but they still seem to be very low by comparison with the costs of making water available and even lower by comparison with the benefit that can be derived from water. There would appear to be considerable scope for raising water charges over time, and the Bank Group considers that this source of revenue could make a sizable contribution to the financial effort required to meet the costs of the development program.

10.26 Nevertheless there may be shortfalls in the availability of finance for executing the programs proposed and it is necessary to be prepared for such an eventuality. Throughout the report the Bank Group has tried to emphasize the relative priority which it attaches to different components of the programs. With financing for Tarbela Dam assured and its high priority established it should be carried through to completion according to schedule; the only other major surface storage work for the first decade, Chasma Barrage, is already underway. On the irrigation side Chapter VI discussed in some detail the relative priority of the various public tubewell projects, emphasizing the unanimity of view among analyses regarding the priority position of the three projects scheduled for commencement in the Third Plan and suggesting that the four projects proposed for Bari Doab -- or at least parts of them -- might be deferred in favor of continued reliance on private tubewell development in these areas. In general, it would be important to examine each of the 12 proposed tubewell project areas in detail before the public project started to see if there was not scope for reducing the scale of the project by relying more on private enterprise. There may be some scope, too, for cutting back on the canal remodeling program: the proposed program includes remodeling of canals serving some 330,000 acres in Khairpur East during the Fourth Plan, but it would be possible to phase this out more into the Fifth Plan, following the LIP program; it would also probably be possible to postpone temporarily the canal remodeling proposed for 330,000 acres in Ravi Syphon-Dipalpur Link without involving more than a small amount of underwatering or some minor adjustments in cropping patterns. The area where the Bank Group believes that any proposed cuts should be scrutinized most carefully and avoided if at all possible is the program for agricultural development, including expansion of extension and research and promotion of new farm inputs; a maximum effort here is essential both for immediate production increases and to prepare the way for deriving maximum benefit from Tarbela.

10.27 On the power side, too, there is some scope for cutbacks, apart from the obvious but undesirable alternative of reducing the rate at which new customers are connected. The proposed program includes about PRs 90 million of expenditure in the Third Plan period on the first Karachi-Mari 380-kv transmission line. This could be postponed into the Fourth Plan period, as pointed out in Chapter VIII. As pointed out there also, the Bank Group has been concerned to prepare a power program which could provide a considerably more reliable and adequate power supply service than has been available in the past, because it believes that this is needed; the Bank Group has tried to allow for a level of generating reserves consistent with this principle and it has included transmission-line capacity (for instance in the form of the second Karachi-Mari line in the Fourth Plan period) that is also appropriate for attaining a high degree of reliability in power supply. Reduction of planned generating and transmission reserves would be possible, but it would be at the cost of quality of service. However, in the Northern Grid, the sacrifice in quality of service would be less than what it has been in the past because of the existence of the Mangla hydroelectric station.

Private Investment

10.28 A great deal of stress has been placed throughout this report on the role to be played by private enterprise; any reductions in the scale of the public program that became necessary would further enhance the role to be played by private enterprise in achieving the projected growth of the economy -- particularly in the agricultural sector. Very little information is available regarding past private investment in irrigation and agriculture, but what there is suggests that it may have been running around PRs 300 million per annum or about 3-4 percent of value added in agriculture, and the figure given in Table 69 was based on this assumption. Private investment in irrigation and agriculture was projected in that table to increase rapidly, rising from some seven percent of total investment during the Second Plan to eleven percent of the figure implied by the Perspective Plan for total investment in the Fourth Plan period. The amounts included in these investment estimates to cover private tubewells are based on the IACA projection of private tubewell growth. Since it may be possible to reach a higher rate of achievement in private tubewell installations and since in the long term it should be possible to reach a rate of private investment in agriculture of around 10 percent the Bank Group believes that the figures in Table 69 should be taken as minimum targets.

10.29 The Bank Group has developed some rough estimates, on the basis of available data, suggesting that savings from direct agricultural incomes may have been in the order of PRs 700 million in 1963/64. Besides the PRs 300 million given above as estimated private investment in irrigation and agriculture, about PRs 100 million would appear to have been invested annually in recent years in farm dwellings. These figures suggest that substantial transfers of savings out of agriculture -- perhaps of the order of PRs 300 million per year -- have been taking place and they also suggest that, if appropriate incentive policies are adopted, farmers should be quite capable of reinvesting in agriculture much larger amounts than they do currently.

10.30 To mobilize rural private resources to the maximum possible extent for investment in agriculture and irrigation the Bank Group believes that three specific steps are essential -- in addition to the fundamental general need for a sound financial framework for farming, which was discussed in Chapter IX. First, measures are needed to help channel available savings from savers to investors and to expand the availability of credit for farmers to use along with their own savings for investment; the Agricultural Development Bank should play an increasingly important role in this, with a growing number of branches, and it should be enabled to follow a more expansionist credit policy. Second, increased Government attention to the provision of services, such as extension and rural workshops and mechanics, and more ample financial allocations to current expenditures to support them, as called for above, will play a particularly important role in mobilizing private resources. Various suggestions for technical assistance to private tubewells, for instance, were made in Chapter IX, and implementation of these will require Government expenditures.

10.31 The third and possibly the most important policy required to obtain a maximum contribution from private initiative is provision of sufficient foreign exchange to ensure the availability of imported inputs and materials needed in agriculture. The liberalization of imports during the Second Plan period played an important role in promoting private tubewells. Most of the pumps and engines for the private wells are manufactured in Pakistan, but the gradual freeing of imports of the basic commodities such as pig iron and steel meant that the small shops which produce the equipment could procure the necessary materials. The sheer availability of tubewell equipment meant that there existed opportunities for investment which would not otherwise have been there. The existence of these opportunities in turn encouraged farmers to save sufficient to take advantage of them. Thus provision of foreign exchange had a double effect, promoting both investment and saving. The Bank Group believes that the agriculture sector represents a high priority area for foreign exchange allocations. The linear programming analysis of investment in irrigation was used to study the impact on the composition of the investment program of different assumptions regarding the amount of foreign exchange available for covering the direct import component of capital and current expenditures on irrigation development. The analysis suggested that the value, in terms of increased agricultural production, of the foreign exchange required for the proposed development program would at the margin approximate the scarcity value of foreign exchange in West Pakistan, as estimated by the Bank Group (about PRs 9.52 = US $1.00). This suggested that the size and composition of the proposed program were appropriate to the foreign exchange situation existing in Pakistan, and that it was worthwhile to allocate to irrigation development the amounts of foreign exchange required to execute the program.

10.32 Estimates of total foreign exchange requirements for agriculture, irrigation and power in the years to 1975 are inevitably rather rough, because of uncertainty about the extent to which import-substitution will take the form of production of equipment and inputs for the specific projects and programs proposed. However the estimates that the Bank Group was able to build up, which are discussed in detail in the relevant volumes of the report, combine to show the foreign exchange requirements of the private sector in agriculture increasing much more rapidly than those of any of the other categories studied. Table 74 summarizes the estimates.

Table 74

Foreign Exchange Requirements for Agriculture, Irrigation and Power Development, 1965-75

(PRs millions, 1964/65 prices)

	Third Plan	Fourth Plan
Private - Agriculture and Irrigation	340	1,050
Public - Agriculture	340	400
Irrigation	850	870
Surface Storage	960	1,280
Power	1,530	1,630
Total	4,020	5,230

The projected private sector requirements do include Rs. 450 million for fertilizer imports in the Fourth Plan period, and it is possible that domestic production of fertilizer might expand rapidly enough to reduce this need. However the remainder is allocated to cover import requirements for farm-mechanization, plant protection, and private tubewells and, just as the Bank Group believes that the private sector could outpace the projections of private investment shown in this report, if given proper incentives, so it believes that more foreign exchange may be required to support this investment. In connection with allocations of foreign exchange to the agricultural sector it is well to bear in mind the very important contribution that the sector makes to export earnings. A large increase in export earnings was one of the main successes of the Second Plan. Visible exports increased from about Rs. 760 million in 1959/60 to about Rs. 1,140 in 1964/65. Exports of agricultural commodities, in raw form, made a more than proportionate contribution to this increase, rising from Rs. 320 million in 1959/60 to Rs. 620 million in 1964/65; cotton and rice were the main contributors. Over the Plan as a whole, agricultural commodities in raw form accounted for some 63 percent of visible exports and cotton manufactures, made from domestic cotton, for another 16 percent. The analysis discussed at the beginning of the chapter suggested that West Pakistan may need to import increasing amounts of agricultural commodities if provincial income grows at 6 percent or more; nevertheless this would not exclude simultaneous increases in exports of those commodities in which the Province has comparative international advantage, and the Bank Group believes that West Pakistan may be able to increase its share of the world markets in cotton and rice.

The Growth of Agricultural Employment

10.33 One of the main objectives adopted in Pakistan's Perspective Plan is attainment of full employment at the earliest possible date and at the least an unemployment rate no higher than five percent in West Pakistan by 1975. The current level of unemployment is believed to be about 16 percent. Labor force data are very sparse in West Pakistan and estimates of employment and employment trends are based on rather shaky foundations. The Planning Commission has estimated that agricultural work available in 1965 was equivalent to about 7.6 million man-years. This estimate was based on the assumption that about 395 man-hours are required per cropped acre per year. The Bank Group studied this matter in light of the data gathered by its consultants and reached the conclusion that 395 man-hours per cropped acre was on the high side. A figure of about 300 hours seemed more appropriate.

10.34 On the basis of assumptions developed from Planning Commission documents and from the work of IACA the Bank Group prepared estimates of the amount of employment that might be available in agriculture if production grows at the rates projected in this report. The starting point of the projection is 6.6 million man-years, representing the Planning Commission's figure for employment in the livestock sector together with a figure for employment on crops based on the assumption that about 300 man-hours are required per cropped acre. Allowance is made for increasing mechanization of agriculture at the rates estimated in Chapter VI. Table 75 shows the projected growth in agriculture and the employment estimates derived therefrom.

Table 75

Estimate of Employment in Agriculture, 1965-85

	1965	1975	1985
Crops			
Cropped Acres (millions)	40.72	47.84	54.30
GPV of crops per acre (PRs)	133	184	260
Employment (mln. man-years)	4.7	5.8	6.9
Livestock			
Gross Production Value (PRs mln.)	3.3	5.6	9.8
Employment (mln. man-years)	1.9	2.7	3.9
Total Agricultural Employment	6.6	8.5	10.8
Total Labor Force	16.2	21.2	28.1
Agriculture as % of Total	40.7%	40.1%	38.4%

The estimates of the total labor force given at the bottom of the table are based on the assumption that the labor force was in 1965 and will remain about 31.6 percent of total population. This is the Planning Commission's figure. The population is assumed to be 67 million in 1975 and 89 million in 1985. The table suggests that agricultural employment may increase by about two-thirds between 1965 and 1985, equivalent to an annual rate of growth of 2.5 percent. The proportion of the labor force employed in agriculture would remain little changed. However it should be borne in mind that these are provincial average figures and there may be considerable variations in the growth of agricultural employment in different parts of the Province.

GLOSSARY OF TERMS

Active flood plain:	A strip of land beside a river or stream which is flooded at least once during most years, and is capable of reworking, subject to frequent deposition.
Aquifer:	A water bearing stratum of permeable rock, sand or gravel.
Area	
... assessed:	An area irrigated on which water rates are levied. Rates vary according to the cropping period.
... cultivated:	Land which has been under annual or perennial crop within the previous eighteen months.
... irrigated:	That part of the farmlands within an irrigation system on which water is applied during a cropping season.
Canal commanded ...:	The area which it is possible to irrigate by flow from a given outlet on a canal, whether the whole area is actually irrigated or not.
Culturable ... (CA):	The sum of the cultivated area plus the culturable wasteland.
Culturable commanded ... (CCA):	That portion of the culturable area which is commanded by canal irrigation.
Cropped ...:	The sum of areas under kharif and rabi crops plus twice the area under perennial crops.
Gross ... (GA):	The total area within extreme limits set by a project, system or canal.
Gross commanded ... (GCA):	That portion of the gross area which is commanded by canal irrigation. GCA includes villages, canals, roads, and some desert wasteland as well as CCA.
Perennial ...:	An area which has been designated to receive allocations of canal water throughout the year.
Authorized full supply (AFS):	The maximum discharge (usually the design capacity in cusecs) authorized for an irrigation channel.

Balanced recharge:	A term used in reference to groundwater pumping, meaning that the amount of water pumped out of the aquifer over a period is equal to the amount which seeps in.
Barani:	An Urdu term describing rainfed agriculture.
Barrage:	A gated diversion structure across a river. This structure is a part of the headworks of an irrigation canal.
Base load:	That part of the total power load at the base of the load curve which is continuous, as distinguished from that which fluctuates as the total system load changes from hour to hour or seasonally.
Bund:	A large artificial embankment which retains water, or protects agricultural lands from river floods. The term is also applied to small earth ridges separating two fields or sections of fields.
Canal capacity (irrigation):	Size of a canal, expressed as the volume of water that it can carry at any specified point.
Canal commanded area:	See under Area.
Capability (maximum):	The maximum demonstrated continuous dependable output of a generator under routine operating conditions, expressed in kilowatts or megawatts.
Critical water-year:	The year when the sum of flows from October through May of the Chenab, Indus and Jhelum Rivers measured at Marala, Attock and Mangla was minimum between 1922/23 and 1962/63. The critical water year was 1954/55.
Cropping intensity:	The cropped area expressed as a percentage of the CCA.
Cropping pattern:	The sequence in which crops are grown in any given area during a single year and the proportion of cropland devoted to each crop during the year.
Dead storage capacity:	That portion of the reservoir capacity which is not used for operational purposes. Dead storage means the corresponding volume of water.
Dead storage level:	The level of water in a reservoir below which the reservoir does not operate.

Delta:	Tract of alluvium formed at the mouth of a river.
Delta (irrigation):	The depth of water applied to cropland.
Demand (electrical):	The amount of electric power required (or delivered) at a given moment at any specified point or points in a system, usually expressed in kilowatts or megawatts. Often used in the report synonymously with maximum demand.
Design intensity:	The cropping intensity for which the irrigation system in an area is designed to provide adequate water supplies.
Discharge factor:	The outlet capacity from distributary and minor canals to watercourses expressed as cusecs per 1,000 acres of CCA, also known as water allowance.
Dispatching load:	The process of assigning generating plants to various positions on a load curve in order to indicate the amount of energy to be generated by each plant in a certain period.
Distributary (irrigation):	A canal of medium size, smaller than a branch canal and larger than a minor canal.
Distribution system (electric):	That portion of an electric system used to deliver electric energy from points on the transmission or bulk supply system to the consumers.
District:	Small territorial unit in West Pakistan for purposes of civil administration (about 50 in the Province).
Diversity:	That quality or characteristic by which individual maximum demands occur at different times. There is hourly, daily, weekly, monthly, and annual diversity.
Division:	Large territorial unit for purposes of civil administration (12 in Province).
Doab:	An Urdu term referring to the land between any two adjacent rivers in the Punjab.
Drawdown:	<u>In tubewells</u>: the difference between the static water level in a well and the stabilized water level attained after continuous pumping at a constant rate of discharge.

In reservoirs: the extent to which the water level of a reservoir is lowered when releases for irrigation and/or power exceed the inflow.

Electric system loss: Total electric energy loss in the electric system. It consists of transmission, transformation, and distribution losses, and unaccounted-for energy losses between sources of supply and points of delivery.

Evapo-transpiration: The amount of the water consumed in a given area during a specified time by transpiration from vegetation and evaporation from the soil.

Extra high voltage (EHV): Term applied to voltage levels of transmission lines which are higher than the voltage levels commonly used. Often used in the report as synonymous with either 380 kv or 500 kv.

Firm power: Power intended to have assured availability to the customer to meet all or any agreed-upon portion of his load requirements.

Full delta: The level of irrigation supplies at which crop yields reach the maximum attainable in the light of all the other circumstances of the agricultural regime. In the case of West Pakistan full delta supplies were in addition defined to include an allowance for the control of soil salinity.

Headworks: The works constructed at the off-take of a main canal. It includes the weir or barrage on the river as well as the control structure across the head of the canal.

Horizontal drainage: Tile, pipe or open channel land drainage or a combination of these.

Hydrological year: Year beginning towards the end of kharif, running from October 1 to September 30.

Impounding: Filling a reservoir with water.

Installed capacity: The total of the capacities as shown by the nameplates of apparatus such as generating units, turbines, synchronous condensers, transformers or other equipment in a station or system.

Interconnection: A transmission tie permitting a flow of energy between the facilities of two electric systems.

Interruptible load:	Electric power load which may be curtailed at the supplier's discretion, or in accordance with a contractual agreement.
Inundation canal:	Canal which is dependent upon the surface level of water in a river for its supplies and is therefore generally filled only at times of flood flow.
Kharif:	An Urdu term for the summer growing season, which includes the six months beginning April 15 and ending October 15.
Kharif-Rabi ratio:	Ratio of the areas cropped in the two growing seasons.
Leaching:	Washing down into the earth of salts in the top soil.
Leaching requirement:	The amount of water entering the soil that must pass through the root zone in order to prevent soil salinity from exceeding a specified value. It is used primarily under steady state or long-time average conditions.
Live storage capacity:	The reservoir capacity excluding dead storage capacity.
Load:	The amount of electric power required or delivered at a specific point, usually expressed in kilowatts or megawatts. (Also often loosely used all inclusively to designate demand and energy such as in Load Forecast.)
Load curve:	A curve indicating the amounts of energy required at different instantaneous loads over the course of a period.
Load factor:	The ratio in percent between the average load over a specified period and the maximum or peak load occurring during the period.
Lost and Unaccounted For (electric energy):	The calculated difference between energy sent out from generating stations and the sum of energy sales and energy accounted for but not sold.
Main canal:	A main irrigation supply canal off-taking from a river.
Maximum demand:	The greatest of all simultaneous demands on an installation or source of power supply within a specified time.

Mean water-year:	Average monthly or ten-day river flows over the 41-year period 1922/23 through 1962/63.
Mean-year flow:	See Mean water-year.
Median flow:	The values of flows such that half the recorded flows are above and half are below in amount.
Mining:	Extraction of groundwater beyond balanced recharge.
Nameplate rating:	The full-load continuous capability of a generator and its prime mover, in terms of megawatts, under specified conditions, as designated by the manufacturer.
Non-firm power:	Power supplied (or purchased) under an arrangement which does not have the continuous availability guarantee feature of firm power.
Non-perennial canal:	Canal designated to receive water supplies for a part of the year only, usually April 16 to October 15 (i.e. kharif) and fed from a permanent barrage spanning the source river. Control of river flow is the chief feature differentiating non-perennial and inundation canals.
Off-peak energy:	Energy supplied during periods of relatively low system demands.
On-peak energy:	Electric energy supplied during periods of relatively high system demands.
Overload capability:	The maximum load that a machine or device can carry for a specified period of time under specified conditions when operating beyond its normal rating but within safe limits predetermined.
Overpumping	See Mining (of groundwater).
Peak demand:	Demand at the instant of greatest load in a period.
Peaking capability:	The maximum output, specified in kilowatts or megawatts, that a generator or system can sustain for short periods of time.
Peak load:	The maximum load in a stated period of time.
Peak-load station:	A generating station which is normally operated only to provide capacity during peak-load periods.

Perennial canal:	Canal designated to receive water supplies all the year round and fed from a permanent barrage spanning the source river.
Persian wheel:	A mechanism powered by bullocks or camels used for lifting water from wells, canals, or streams.
Perspective Plan:	An outline of a plan for the economic development of Pakistan over the period 1965-85, prepared by the Pakistan Planning Commission.
Province:	West Pakistan.
Rabi:	An Urdu term for the winter growing season which includes the six months from October 15 to April 15.
Rated capacity:	See Nameplate rating.
Reactive power:	Power that does no work, measured in voltamperes reactive. (Vars or Kvar).
Recharge (groundwater):	The process whereby water, at or near the ground surface, percolates downwards into the store of groundwater thus replenishing water which was removed.
Regulated streamflow:	The controlled rate of flow at a given point resulting from reservoir operation.
Re-regulating dam:	A dam or barrier built in a stream below a main dam to provide supplemental storage in order to smooth water releases from the main dam.
Reserve (electrical):	The difference between generating capability and load on the generators at a specified time, generally loosely used in this report as the difference between peak capability and peak load.
Reservoir capacity:	The gross volume of water which can be stored in the reservoir.
Rim stations:	Stations established on main rivers, near where they enter the Indus plains, at which the flow is gauged.
Riverain area:	The active flood plain lands along main rivers.
Salinity:	A saline condition in soils or water which is detrimental to plant growth.
Scouring:	Removal of silt or other material by flow of water.

Sediment:	Matter carried by rivers which settles at the bottom of the reservoir.
Siltation:	The deposition of silt or sediment on the bottom and sides of a reservoir.
Sluicing:	Passing water through low level outlets or sluices at a dam or barrage, generally in an attempt to remove some of the sediment deposited.
Spillway:	Structure for discharging superfluous water flows at a reservoir or on a river.
Storage capacity (reservoir):	The gross volume of a reservoir available to store water.
Sub-surface drainage:	Water table control by either horizontal or vertical drainage facilities.
Superstorage capacity:	Storage capacity available in a reservoir between normal maximum water elevation (FSL) and maximum elevation to which water can safely be raised for short periods.
Surface drainage:	Removal of surface effluent water by use of open channels.
Tailwater level:	Level of water at foot of structure in a river, such as dam or barrage.
Tehsil:	Administrative subdivision of a district comprised of several Union Councils.
Tile drains:	Sub-surface horizontal drains lined with tiles.
Transpiration:	The process by which plants draw water into their roots for either building plant tissue or passing through the leaves into the atmosphere.
Tubewell:	A drilled well, cased and screened, usually gravel packed.
Turbine (hydraulic):	An enclosed rotary type of prime mover in which mechanical energy is produced by the force of water directed against blades fastened to a vertical or horizontal shaft.
Turbine (steam or gas):	An enclosed rotary type of prime mover in which heat energy in steam or gas is converted into mechanical energy by the force of a high velocity flow of steam or gases directed against successive rows of radial blades fastened to a central shaft.

Under watering:	The application of insufficient water to sustain the maximum yields which would be attainable in the light of all the other circumstances of the agricultural regime.
Union Council:	The smallest political subdivision composed of several villages.
Value added:	Output at factor cost, net of purchased inputs.
Vertical drainage:	Drainage by tubewell pumping.
Watercourse:	Farmers' channel, carrying water from a Government canal to the fields. Also used in reference to the area irrigated from such a channel.
Waterlogging:	State of the land with groundwater lying at or near the surface. The use of the term indicates that groundwater is so high that crop growth is precluded or crop yields lessened by it for at least part of the year.
Water table:	The height in the ground to which the earth is saturated with water.
Water year:	See Hydrological year.
Weir:	A structure across a river designed to pond water and thus raise its level for purposes of diversion into irrigation canals.

Names

ADB:	Agricultural Development Bank.
ADC:	Agricultural Development Corporation.
Agriculture Consultant:	International Land Development Consultants N.V., and Hunting Technical Services Ltd.
Bank Group:	A group of staff members of the International Bank for Reconstruction and Development assigned to assist Dr. Lieftinck in the execution of the Indus Special Study.
Binnie:	Binnie & Partners, Consultant to WAPDA.
Coode:	Coode & Partners, Consultant to WAPDA.
CSP:	Civil Service of Pakistan.

CTM:	Chas. T. Main International, Inc., Dam Sites Consultant to the Study.
Dam Sites Consultant:	Chas. T. Main International, Inc.
Gibb:	Sir Alexander Gibb & Partners, Irrigation Consultant and coordinator of consultants to the Study.
GOP:	Government of Pakistan.
Harza:	Harza Engineering Company, International, general engineering Consultant to WAPDA.
HTS:	Hunting Technical Services Limited, Agricultural Consultant to the Study.
IACA:	Irrigation and Agriculture Consultants Association.
IBRD:	International Bank for Reconstruction and Development. (World Bank).
IGC:	Indus Gas Company, which distributes Sui gas in the Sind (Sukkur, Hyderabad, etc.).
ILACO:	International Land Development Consultants N.V., Agricultural Consultant to the Study.
Irrigation Consultant:	Sir Alexander Gibb & Partners.
KESC:	Karachi Electric Supply Corporation, Ltd.
KGC:	Karachi Gas Company, which distributes Sui gas in the Karachi area.
LIP:	Lower Indus Project: regional study carried out by Hunting Technical Services Limited and Sir Murdoch Macdonald & Partners.
LWDB:	Land and Water Development Board.
MESCO:	The Multan Electric Supply Company, Ltd.
NEMA:	National Electrical Manufacturers Association.
PMS:	Power Market Survey Organization.
Power Consultant:	Stone & Webster Overseas Consultants, Inc., Power Consultant to the Study.
REPCO:	The Rawalpindi Electric Power Company, Ltd.

SCARP: Salinity Control and Reclamation Project.

SGTC: Sui Gas Transmission Company, responsible for transmitting gas from Sui to the South.

SNGPL: Sui Northern Gas Pipelines, Ltd., responsible for transmitting Sui gas to the North and distributing it and the gas from Dhulian field there.

S & W: Stone & Webster Overseas Consultants, Inc.

TAMS: Tippets-Abbett-McCarthy-Stratton International Corporation, Consultants to WAPDA on Tarbela Dam.

T & K: Tipton and Kalmbach, Inc., Consultant to WAPDA.

WAPDA: Water and Power Development Authority of West Pakistan.

WASID: Water and Soils Investigation Division (of WAPDA).

Units of Weights, Measures, Currency, etc.

Acre-foot (AF): A measure of volume of water, corresponding to 43,560 cubic feet, the volumetric equivalent of one acre covered to a depth of one foot.

Ampere: Unit of measurement of the intensity of electric current, being that produced by one volt acting through a resistance of one ohm.

Animal Unit (AU): Livestock expressed in terms of units determined by their respective feed requirements compared with the requirements of a standard bullock. The standard bullock is taken to equal one animal unit.

Bale (cotton): 1 bale = 392 pounds.

Btu: British thermal unit, the standard unit for measuring quantity of heat energy such as heat content of fuel. 1 Btu = 0.29307 watt-hours.

cfs: Cubic feet per second.

cfs/month: 1 cfs/month = 59.45 AF (30-day month) or 61.43 AF (31-day month).

Cusec (cfs):	One cubic foot per second, used to describe the rate of flow of water.
Cusec-hour:	At one cubic foot per second, the volume of water for one hour would be 3,600 cubic feet or 0.086 acre-foot.
cy:	Cubic yard.
Fps:	Feet per second.
FSL:	Full supply level.
GPV:	Gross production value (output x prices).
Horsepower (HP):	Unit of mechanical power equivalent to 550 foot-pounds of work per second; 33,000 foot-pounds per minute. 1 horsepower-hour = 0.7457 kwh.
Kilovars:	1,000 reactive volt-amperes.
Kilovolt (kv):	1,000 volts.
Kilovolt-ampere (kva):	1,000 volt-amperes.
Kilowatt (kw):	1,000 watts.
Kilowatt-hour (kwh):	Unit of electrical work; work done by one kilowatt of power in one hour. 1 kwh = 1,000 watt-hours.
Mac:	Million acres.
MAF:	Million acre-feet.
MAF/month:	1 MAF/month = 16,850 cfs.
Maund:	A Pakistani unit of weight equal to 82.28 lbs.
Mcf:	Thousand cubic feet (gas measurement).
Megawatt (mw):	Unit of electric power equivalent to 1,000 kilowatts.
Megawatt-hour (mwh):	Unit of electrical work; work done by 1,000 kilowatts of power in one hour.
MMcf:	Million cubic feet (gas measurement).
NPV:	Net production value (GPV less input costs).

Ohm:	Unit of electrical resistance.
Paisa:	One hundredth of a Rupee.
Pcf:	Pounds per cubic foot.
Ppm:	Parts per million.
PRs:	Pakistani Rupees (see Rs).
Rs:	Pakistani Rupees. Official rate is Rs 4.76 = US$1 or 1 Rupee = $0.21.
SPD:	Standard Pakistan Datum (based on mean sea level at Karachi).
TDN:	Total digestible nutrients which are the sum of all digestible organic nutrients, viz. protein crude fiber, nitrogen-free extract and fat. TDN represents the approximate heat energy value of a feed.
Ton (long):	2,240 pounds.
Trillion:	10^{12}.
volt:	Unit of electromotive force (or electric pressure analogous to water pressure) being that which when coupled to a conductor with a resistance of one ohm will produce a current of one ampere.
Watt:	Rate of energy transfer equivalent to one ampere flowing under the pressure of one volt at unity power factor.
Watt-hour:	Work done in an hour at the steady rate of one watt.