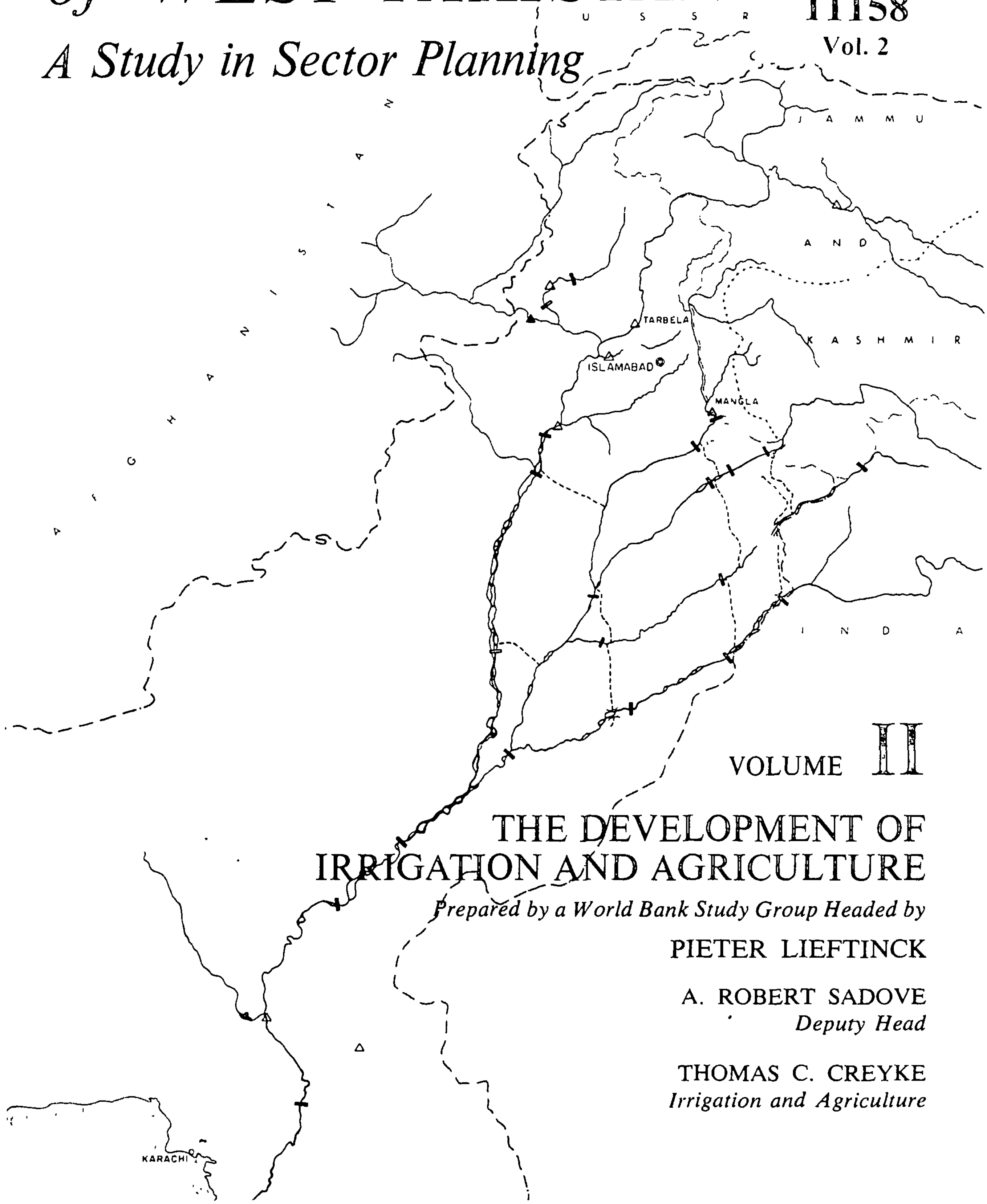
Water and Power Resources of WEST PAKISTAN

A Study in Sector Planning



VOLUME II

THE DEVELOPMENT OF IRRIGATION AND AGRICULTURE

Prepared by a World Bank Study Group Headed by

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Irrigation and Agriculture

WATER AND POWER RESOURCES OF WEST PAKISTAN

A Study in Sector Planning

Volume I: The Main Report $10.00

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Prepared by a World Bank Study Group Headed by Pieter Lieftinck; A. Robert Sadove, Deputy Head; Thomas C. Creyke, Irrigation and Agriculture.

Without doubt, the greatest single co-ordinated development operation in which the World Bank has been involved is the massive program for development of the Indus Basin. This pioneering study is an integral part of that project and is unique both in its conceptualization and its comprehensiveness. It demonstrates the feasibility of a new and more rigorous approach to resource planning and development and will serve as an indispensible model for engineers, economists, and planners for years to come.

Focal points of the Study are the Indus River, which runs the length of West Pakistan, several of its tributaries, and a huge natural underground reservoir. In developing a realistic investment program for water and power, the Bank's Study Group had to consider a host of interrelated factors: the objective of maximizing economic returns, the competition for scarce resources, all aspects of agricultural production, alternate sources of water for irrigation, the country's projected electricity requirements, and the coordination of decisions regarding power generation and agriculture.

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Introduction

At the beginning of this Indus Special Study, the general lines of procedure for agricultural studies, terms of reference and the principle of full cooperation were established between the Bank Study Group,[1] its consultants[2] and the Government of Pakistan (GOP), including its agencies and consultants. This cooperation was maintained formally through an irrigation and agricultural coordinating committee, which met on eight occasions, but to a much greater extent cooperation was secured through a continuous exchange of views and information between all concerned.

This Volume is based on IACA's work and findings. Over a period of two years, the consultants made a detailed study of the basic resources, the farming conditions and prospects, the existing and potential water resources, and the most practical means of developing agricultural production in keeping with the needs of West Pakistan's economy. Their findings, together with a vast amount of data, supporting information, reasoning, conclusions and recommendations, are contained in a Comprehensive Report[3] supported by 22 volumes of annexures and a map supplement.

In reviewing the consultants' report, the Study Group has been influenced by the views expressed by the GOP on the consultants' findings, by their own experience in Pakistan and to some extent by developments and information which has become available since the consultants completed their field work early in 1966 and their report in October 1966. No attempt has been made to reproduce supporting data beyond what is necessary for an understanding of the conclusions and recommendations. In a study of this complexity, where judgment must play such an important part in the interpretation of data and analyses, it is not surprising that—while there is a great measure of general agreement—the Study Group's conclusions differ in some important respects from those of its consultants.

The Study Group's report on irrigation and agriculture, in accordance with the objective of the Indus Special Study, concentrates on the determination of a feasible Action Program capable of achieving levels of agricultural production

[1] See Director's Foreword, Volume One.

[2] Irrigation and Agriculture: Sir Alexander Gibb and Partners, London; International Land Development Consultants N.V. (ILACO), Arnhem, Holland; and Hunting Technical Services Limited, London. For the duration of the Indus Special Study, these consultants formed the "Irrigation and Agriculture Consultants Association" (IACA) under the general coordination of Sir Alexander Gibb and Partners.

[3] International Bank for Reconstruction and Development; Program for the Development of Irrigation and Agriculture in West Pakistan. Comprehensive Report, Sir Alexander Gibb and Partners, International Land Development Consultants, N.V., Hunting Technical Services Limited; London and Arnhem, May 1966.

commensurate with the resources and needs of the economy within the decade 1965 to 1975. To this end the report evaluates some 14 major water development projects to be undertaken in the Third and Fourth Plan periods in addition to the ongoing projects. These include the Tarbela Dam, 12 groundwater development projects formulated by IACA and one drainage project. Such a program, however, must be evolved within the context of longer term planning and its implications for future resource development have also been assessed in this report.

Attention has been concentrated on the canal commanded areas of the Indus Basin. These produce over 80 percent of present agricultural gross production and also offer the greatest scope for rapid further water and agricultural development. A detailed study of the irrigated land and the irrigation system by IACA preceded the establishment of priorities which make up the Action Program for 1965-75.

The Study Group considers the Action Program consistent with the resources likely to be available, the immediate needs of the country and sound future development. Also, the extensive studies carried out by IACA provide useful guidance for long term planning of water resource development. But it should be understood that this report is not intended to provide a master plan for water and agricultural development.

Throughout, but particularly for the period 1965-75, the Study Group has been concerned with what is practically achievable within the constraints that are likely to be operative, rather than with the technical potential. There is no doubt that with reference to West Pakistan's basic resources, higher levels of production than are predicted in this Report are technically feasible. It has been assumed that the development of irrigation and agriculture would receive a 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 must receive appropriate emphasis. 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 should go far towards meeting West Pakistan's most pressing needs in food and exports of agriculturally based commodities and would reflect great credit on those concerned.

I

Past and Present Performance of the Agricultural Sector

A. AGRICULTURE IN WEST PAKISTAN

West Pakistan covers a land area nearly equal to that of France and Germany combined. But over three-fourths of this large expanse remains agriculturally unproductive. According to the 1960 Census of Agriculture, out of a total of nearly 200 million acres, only 37 million acres were actually under cultivation. Making allowance for sparse grazing over large additional areas, the agricultural sector thus rests on a much smaller land base than the vast size of the Province may at first imply.

A major characteristic of agriculture is the role played by irrigation. Because the area is semi-arid, the availability of water is of critical import to West Pakistan's agriculture. Most of the water used for irrigation is supplied through canals fed by the Indus River and its tributaries, and this elaborate canal system currently commands about 33.5 million acres. Only about 25 million of these acres actually receive irrigation, but this area comprises nearly 70 percent of the cultivated acreage, supplies approximately 80 percent of the foodstuffs produced in West Pakistan and nearly all the cash crops; there is also a high concentration of population, irrigation investment, infrastructure, and markets in the Indus Basin. Further extension of the canal system is constrained by salinity and topography, and ultimately governed by limitations to the future supply of irrigation water. In these circumstances, the more intensive use of the land already under irrigation is a strategic objective of efforts to bring about increases in agricultural production.

Within the constraints imposed by the natural resource base and the investment in agricultural infrastructure, the farmers of West Pakistan cultivate their fields under a two-season cycle—kharif crops are grown during mid-April to mid-October, and rabi crops are grown during mid-October to mid-April. Since the relative importance of different crops varies greatly with the regions of West Pakistan, these generalizations hold true only in the broadest sense. The major crops grown in the kharif season are cotton, rice, sorghum and millets. The major rabi crops are wheat and fodder. Gram, pulses, oilseeds, and fodder are grown in both seasons. Both sugarcane and fruits have been assuming greater importance as perennial crops. Livestock provide the main source of draft power in farm operations, and West Pakistan supports a large livestock population for this purpose. Milk, milk products, meat, and animal by-products also make a considerable contribution to total agricultural production. A more detailed description of West Pakistan's agricultural resource and development features is presented in Chapter II.

B. GROWTH OF AGRICULTURAL PRODUCTION

Pattern and Magnitude of Growth

From the time of Independence in 1947 to the start of the Second Five Year Plan in 1960, the agricultural sector as a whole failed to exhibit any signs of sustained growth. There were year-to-year fluctuations in output owing to weather conditions, but the gross value added by agricultural production[1] rose at an annual average rate of only 1.6 percent between 1949/50 and 1959/60. This trend continued into the first year of the Second Plan period, but changed markedly thereafter. Over the five years of the Second Plan period (1959/60 to 1964/65), the growth rate was at 3.8 percent per annum on average, or substantially higher than for any other comparable period since Independence.

The increased production of crops was particularly striking during these most recent years. Their gross value added grew at an annual rate of 4.7 percent over the Second Plan period. In contrast to this, the remaining components in the agricultural sector (livestock, forestry, and fishing) had a growth rate of 2.1 percent. It should be added, however, that the data concerning livestock are particularly uncertain, and are possibly subject to rather wide margins of error. Forestry and fishing did register sizeable increases during the Second Plan period, but they constitute small shares of the sectoral total, and are completely dominated in comparisons such as this by the livestock component.

Expressing the most recent level of output in monetary terms at 1959/60 prices, the official estimate of gross value added of agricultural production was Rs. 9,276 million in 1964/65.[2] This, in turn, consisted of Rs. 6,018 million from crops (about 65 percent of the total) and Rs. 3,258 million from livestock, forestry, and fishing combined (about 35 percent of the total). Forestry and fishing, however, accounted for less than 1.5 percent of total value added. The orders of magnitude and rates of growth over the period 1949/50 and 1964/65 are shown in Table 1-1.

The small amount of growth which occurred up to the 1960's came primarily as a result of sustained increases in the acreage under cultivation. The combined acreage under the major crops of wheat, cotton, rice, sugarcane, gram, oilseeds, and maize rose at an annual rate of about 2 percent over the decade 1949/50 to 1959/60, although rice and sugarcane acreage actually expanded at faster rates. Growth of crop yields was more disappointing and for most crops, yields either fell or remained relatively static during the same period. Continuous land and water development supported this acreage trend and this was also a time when refugees were being resettled in the aftermath of Partition and when land reforms

[1] Data from official GOP sources, expressed in constant (1959/60) prices.
[2] For years covered in IACA's analysis official estimates of value added magnitudes differ from IACA's estimates because IACA used its own assumptions for farm costs, farm prices, livestock production, acreage cropped and volume of production. In analyzing the implications of the IACA Comprehensive Report, the Study Group has worked mainly from IACA estimates.

TABLE 1-1
GROWTH OF WEST PAKISTAN AGRICULTURAL SECTOR AND CONTRIBUTION TO GROSS PROVINCIAL PRODUCTION 1949/50 TO 1964/65
(Rs. million at constant 1959/60 prices)

	1949/50	1954/55	Average Rate of Growth 1950–55	1959/60	Average Rate of Growth 1955–60	1964/65[a]	Average Rate of Growth 1960/65
Crops	4,250	4,320	0.3	4,775	2.0	6,018	4.7
Others	2,345	2,628	2.3	2,936	2.2	3,258	2.1
Total Agriculture	6,595	6,948	1.0	7,711	2.1	9,276	3.8
Agriculture's Percentage of GPP	54.4	48.8		46.3		42.4	

[a] These official estimates of recent production differ from IACA's estimates of GPV and value added because IACA has used its own assumptions for farm costs, farm prices, livestock production, acreage cropped and volume of production. The Study Group worked mainly from IACA estimates.
Source: Central Statistical Office.

were being initiated. These factors, plus natural population increase, undoubtedly had some impact on the area being cropped.

The experience since 1959/60 reveals a different set of forces at work. The shift to higher levels of production and more rapid growth which characterized most of the Second Plan period came about as a result of both increases in the acreage cropped and improved yields. For example, six of the seven major crops cited above showed some increase in acreage over the period 1959/60 and 1964/65, but they also showed greater proportionate increases in production in most of those same years. Climatic factors in different years caused some variation in yields, but the sizeable increase in production during the Second Plan period, which is not explained by acreage increase, suggests that factors other than weather had begun to exercise a significant influence on West Pakistan's agriculture. Recent acreage and production indices for major crops in all West Pakistan are shown in Table 1-2.

The recent yield trends for four of the most important crops in West Pakistan show the order of magnitude of some of the yield increases, as well as the variation in yield improvement as between different crops. Performance in wheat, for example, has lagged behind yield growth in cotton, rice, and sugarcane. Despite the favorable picture of yield improvement (Table 1-3), it should be borne in mind that yields in 1959/60 were generally at about the levels of the 1947/1948-1952/53 averages, or below. Sugarcane, for example, did not exhibit significant yield increases beyond the earlier levels until midway in the Second Plan period, and 1964/65 wheat yields were still at about the level of the 1947/48-1952/53 average.

Table 1-4 provides a more comprehensive view of the performance by major crops in terms of acreage, production, and yields for selected intervals between 1947/48 and 1964/65, and the implicit annual growth rates. Comparison of the growth rates for the earlier and latest period indicates that a break of some kind has been made with the past. Increases in production seem less dependent on expansion of acreage than previously, again leaving the inference that yield improvements have begun to play a more important part in agricultural growth than before.

TABLE 1–2
ACREAGE AND PRODUCTION TRENDS
(1959/60 = 100)

	Cotton		Wheat		Rice		Sugarcane		Gram		Oilseeds[a]		Maize	
	Acreage	Prod.	Acreage	Prod.	Acreage	Prod.	Acreage	Prod.	Acreage	Prod.	Acreage	Prod.	Acreage	Prod.
1947/48–1952/53 Av.	91	80	84	88	74	78	52	61	84	92	80	74	80	79
1959/60	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1960/61	96	103	95	98	98	104	98	109	97	100	98	91	99	91
1961/62	104	111	101	103	101	113	112	135	105	102	80	87	98	102
1962/63	102	126	103	107	99	110	134	173	107	112	89	113	95	102
1963/64	110	141	103	107	107	120	120	151	98	100	84	91	104	111
1964/65	109	127	109	118	113	136	127	175	106	110	86	91	101	111

[a] Rape and Mustard Seed only.
Source: Computed from acreage and production data given in "Handbook of Agricultural Statistics," Planning Commission (1959/60–1962/63) and "Statistical Bulletin," February 1966 (1963/64 and 1964/65).

TABLE 1-3
YIELD TRENDS DURING THE PERIOD 1959/60–1964/65
(1959/60 = 100)

Crop Year	Cotton	Rice	Sugarcane	Wheat
Average 1947/48–1952/53	88	106	117	105
1959/60	100	100	100	100
1960/61	107	105	112	103
1961/62	107	112	120	102
1962/63	123	112	129	104
1963/64	129	112	126	103
1964/65	116	121	138	108

Sources: Handbook of Agricultural Statistics, June 1964; Statistical Bulletin, February 1966.

The two kinds of trend data given here show that sugarcane, a high value crop, had the largest proportionate acreage and yield increases among the major crops since 1959/60. On these counts it therefore made a substantial contribution to overall growth in the agricultural sector, probably accounting for nearly 40 per cent of the increase in gross production value of major crops between 1959/60 and 1964/65. Wheat accounted for about one-third of the increase in gross production value. This was due mainly to the fact that wheat is the largest single crop in terms of both acreage sown and gross value. Although neither wheat yields nor wheat acreage increased vary greatly, its dominant position in the cropping pattern gives it an important weight in the total increase in production. Rice was the third largest influence among major crops, and recorded increases in both yields and acreage in the most recent years. Cotton yield improvements were among the highest, but cotton production increases contributed less to total production than the other three crops. Altogether, sugarcane, wheat, and rice probably provided over 85 percent of the increased gross production value over the Second Plan period. Viewed in this perspective, another aspect of the pattern of recent agricultural growth was that production increases in a very small number of major crops provided the bulk of the production on which growth is measured.

Sources of Growth

Efforts to identify the specific contribution of individual productive inputs to agriculture have not been convincing, but the increase in production has been accompanied by a general increase in the use of inputs of several kinds. One major influence has certainly been the impact of additional water supplies from public and private sources. The GOP investment policy in water resource development has been designed to expand the water supplies available to farmers, and about 5.5 million acre feet (MAF) were added to existing supplies during the Second Plan period. Approximately 3 MAF of this resulted from improvements in surface water supplies and the balance of 2.5 MAF came from public tubewell installations. The striking element, however, was the surprising surge in private investment in tubewells and the sustained momentum of this investment throughout the Second Plan period. The probable additional contribution of private tubewells was nearly 6 MAF, or a volume of water about the same as provided by the public programs. Available data indicate that the number of private tubewells has increased at a rate of about 15 percent per annum during the Second Plan period.

TABLE 1-4

GROWTH OF PRODUCTION OF MAJOR CROPS (EXCLUDING FODDER)

Averages for Representative Periods

	Wheat	Gram	Rice	Sugar	Cotton	Maize	Millet	Oilseeds
Quantities:								
Average over 1947/48–1952/53								
Acreage (mill. acres cropped)	10.2	2.4	2.2	0.5	3.1	1.0	3.4	1.1
Production (mill. tons)	3.5	0.6	0.8	0.6	1.3[a]	0.4	0.6	0.2
Yield (mds. per acre)	9.20	6.70	9.74	32.16	2.00	10.72	4.73	4.87
Average over 1957/58–1962/63								
Acreage (mill. acres cropped)	11.9	2.9	2.9	1.1	3.4	1.1	3.1	1.3
Production (mill. tons)	3.8	0.6	1.0	1.3	1.8[a]	0.5	0.6	0.2
Yield (mds. per acre)	8.75	5.85	9.43	32.78	2.43	11.03	4.92	4.87
For 1964/65								
Acreage (mill. acres cropped)	13.1	3.0	3.4	1.2	3.6	1.2	3.7	1.2
Production (mill. tons)	4.5	0.7	1.3	1.8	2.1[a]	0.5	0.7	0.2
Yields (mds. per acre)	9.15	6.25	10.25	40.20	2.78	11.17	5.07	4.47
Growth Rates (percent per annum):								
1947/48–1952/53 to 1957/58–1962/63								
(a) acreage	1.6	1.9	2.8	8.2	0.9	1.0	(−)0.9	1.7
(b) production	0.8	—	2.3	8.0	3.3	2.3	—	—
(c) yields	(−)0.5	(−)0.5	(−)0.4	0.2	2.0	0.3	0.4	—
1947/48–1952/53 to 1964/65								
(a) acreage	1.5	1.5	3.0	6.2	1.1	1.2	0.6	0.6
(b) production	1.5	1.0	3.3	7.8	1.1	1.5	1.1	—
(c) yields	—	(−)0.5	0.3	1.6	3.3	0.3	0.5	(−)0.6
1957/58–1962/63 to 1964/65								
(a) acreage	2.4	0.8	4.1	2.2	1.4	2.2	4.5	(−)2.0
(b) production	4.3	3.9	6.7	8.5	3.9	—	3.9	—
(c) yields	1.1	1.7	2.1	5.2	3.4	0.3	0.8	(−)2.2

Source: Handbook of Agricultural Statistics, June 1964; Statistical Bulletin, February 1966.

[a] In million bales.

TABLE 1-5
ESTIMATE OF PRIVATE TUBEWELLS IN OPERATION

	1963		1964		1965	
	Number	MAF	Number	MAF	Number	MAF
Private Tubewells	17,390	3.47	23,700	4.74	26,650	4.7
Private Tubewells supported by Department of Agriculture	1,109	0.22	1,475	0.29	7,350[a]	1.3
Total	18,499	3.69	25,175	5.03	34,000[b]	6.0
Rate of Growth			36%		35%	

[a] Source: Agriculture in Pakistan, USAID, Karachi, 1966.
[b] Exceeds IACA's estimate by about 2,000 wells allowing for recent findings of survey in the Northern Zone.

In 1964 and 1965 the annual increase averaged above 30 percent. The most recent figures on private tubewells are shown in Table 1-5. An important factor in spreading private tubewell development has been the Department of Agriculture's drilling activity on behalf of farmers.

A second important input was chemical fertilizers. Use of these, and particularly nitrogenous fertilizers, began to grow rapidly during the Second Plan period. The increase during the First Plan period (1954/55–1959/60) was a modest one of only 5,000 nutrient tons. Thereafter, the rise was more spectacular, as shown in Table 1-6. 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, offtake 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. The availability of additional water must have been an important stimulus to fertilizer sales because the geographical distribution of the largest increase in fertilizer use tended to coincide with the areas where rapid growth in private tubewell installation took place, i.e. the northern parts of the Indus Plains. Though still small in absolute terms, the rapid rise in fertilizer use must have made an important contribution to the growth of cash crops on which applications have been concentrated.

An increase in the use of other inputs may have made some marginal contribution to growth, but these effects are difficult to trace and do not begin to rank with water and fertilizer in importance. Plant protection measures were carried out on an additional four to five million acres during the Second Plan period, but results are uncertain. This is because the effectiveness of plant protection activities depends on the timeliness of their application and other factors as much, or more, than the acreage covered, and no comprehensive assessment of the program in these qualitative terms has yet been made. The distribution of improved seed has been hampered by administrative difficulties and a lack of good foundation stock. 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 equally effective in all areas. Major efforts have now been launched to produce and distribute improved wheat varieties, but these started too late to have an impact on production during the Second Plan period.

TABLE 1-6
FERTILIZER USE DURING THE SECOND PLAN PERIOD

Year	Nitrogen (N)	Phosphate (P_2O_5)	Total	Annual Increase (%)
	—(tons of nutrient)—			
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

Source: Planning Commission.

Better farming methods, e.g. proper seed bed preparation, effective weeding, row planting, and the like, depend in part on the institutions responsible for the dissemination of relevant information, and the agricultural supporting services in West Pakistan suffer from a variety of deficiencies which limit their capacity to perform this function. Operators of some of the larger farms have begun to express keen interest in new ways to improve husbandry practices, and the watercourse studies carried out by IACA have shown that the most progressive farmers are already achieving excellent yields under existing conditions. The average farmer, however, seems little affected thus far by the efforts of the research and extension services, and he continues to cultivate his land in the traditional manner and with generally poor results.

The varied experience with respect to crop production and the use of inputs does not detract from the fact that many farmers have begun to make positive, albeit selective, efforts to improve their yields and to adopt a more commercial type of agriculture. This implies that economic incentives were present and important in the stimulation of investment in new inputs, and led to a higher proportion of cash crops. Examination of the domestic terms of trade confirms that such incentives did, in fact, prevail. The terms of trade were unfavorable toward agriculture in the early and mid-1950's as a result of a range of Government policies designed to stimulate industrial growth. But this situation underwent substantial change starting in the early 1960's. More favorable price policies toward agriculture (for both exported and domestically consumed commodities), and a rapid growth in supplies of manufactured goods from the expanding Pakistan industrial sector combined to improve the situation of agriculture. This shift is illustrated by the movement in the terms of trade indices shown in Table 1-7. The changes shown, starting in 1958-61, should have provided incentives for farmers to increase their production, and also made it more possible to invest in the kinds of inputs which promote growth in production.

A final element affecting growth was the level of resources invested in agricultural and water development. Government planning has been directed toward a structural transformation of the economy to reduce its dependence on agriculture and increase the proportionate shares of the nonagricultural sectors, but it has not intended to curtail the contribution which agriculture can make to economic growth. The West Pakistan allocations to public sector expenditures on agriculture and water in the Second Plan period were 16.9 and 15.1 percent of the total Provincial allocation, respectively, or a total of Rs. 2,527 million. Weakness in the

TABLE 1-7
SUMMARY OF DOMESTIC TERMS OF TRADE FOR THE MANUFACTURING AND AGRICULTURAL SECTORS[a]

Year	Manufacturing	Agriculture
1951–54	108.6	97.4
1954–57	112.0	91.4
1957–60	102.6	99.4
1958–61	98.1	103.1
1959–62	95.3	106.4
1960–63	94.8	108.3
1961–64	96.1	107.8

[a] Based on three-year moving averages. The indices measure the wholesale prices of goods that a sector sells relative to the wholesale prices of goods it buys. The weights for manufacturing are the values added in each industry in 1959/60, and the weights for agriculture are the estimated purchases of agricultural goods by the nonagricultural sector in 1959/60. Stephen R. Lewis, Jr. and S. Mushtaq Hussain, "Relative Price Changes and Industrialization in Pakistan, 1951–64," Memorandum No. 5, Center for International Affairs, Harvard University, Cambridge, Mass.

administrative organization resulted in a failure to utilize more than two-thirds of the allocation to agriculture. Public investment in water development exceeded the Plan allocation by nearly 20 percent, although physical targets were not always achieved. There was thus a net shortfall in expenditures, amounting to about 9 percent of the total, for the agriculture and water sectors combined, but in comparison with the First Plan and earlier periods there was still a substantial increase in both the volume of resources invested and the proportion of the total allocation actually utilized by agriculture and water. Allowance should be made for the fact that much of this expenditure would not be productive during the Second Plan period but would be significant to growth during the Third Plan period. In addition to the above figures, Rs. 2,185 million were spent in the Second Plan period on the Indus Basin Plan Works.

C. CONTRIBUTION OF AGRICULTURE

Contribution to the National Economy

The agricultural sector in West Pakistan, although still the single most important sector in the Provincial economy in terms of value added, has been providing a declining share of Gross Provincial Product (GPP) since 1949/50, from 54.4 percent in 1949/50 the proportion had been reduced to 42.4 percent by 1964/65. Even the recent improvement in agriculture's growth rate during the Second Plan period failed to alter this trend, for other sectors of the Provincial economy continued to develop at a faster pace than agriculture.

When considered in the context of the national economy, the agricultural sector for the whole of Pakistan has been contributing about half the Gross National Product (GNP). The sector also exhibits a similar tendency to decline as a proportion of GNP, although the drop is less pronounced than in the case of West Pakistan alone. The structural transformation of the economy from agriculture

TABLE 1-8
PUBLIC SECTOR EXPENDITURE ON AGRICULTURE IN WEST PAKISTAN DURING THE SECOND FIVE-YEAR PLAN (1959/60–1964/65)

Sector	Allocation (Rs. mill.)	Allocation (percent)	Actual Expenditure (Rs. mill.)	Shortfall (percent)
Agriculture	1,336	16.9	890	−33.3
Water	1,191	15.1	1,413	+19.1
Total Agriculture	2,527	32.0	2,303	− 9.0
Total Plan	7,878	100.0		

Source: IACA Comprehensive Report, Volume 1, page 7.

toward a more diversified industrial base, which has been an objective of Pakistan's economic planning, has thus gone much further in West Pakistan than for the national economy as a whole. Even so, West Pakistan agriculture is still contributing more than one-fifth of Pakistan's GNP. It may also be noted that although the sectoral contribution of West Pakistan's agriculture has declined in the above sense, West Pakistan's share in the total agricultural sector for all Pakistan has increased slightly. This reflects the fact that West Pakistan's agricultural growth has been more vigorous than East Pakistan's during the Second Plan period. Table 1-9 summarizes these different relationships. The table indicates that over the five year period of the Second Plan GNP grew at about 4.3 percent per annum while the all Pakistan agricultural sector grew at about 2.7 percent per annum only. The agricultural growth in West Pakistan at 3.8 percent per annum was thus considerably above that of the total sector and fairly close to that of total GNP.

Employment and Per Capita Income

Agriculture's most direct contribution is the livelihood it provides to the people engaged in it, and this still involves a large majority of the population of West Pakistan. Out of a total population estimated to be 51.2 million in 1965, about 35 million or roughly 70 percent are directly dependent on agriculture. An additional three million people live in rural areas, but are only indirectly dependent on agriculture in the sense that they are employed as traders, artisans, in transport, or in other service occupations. Assuming the rural population was 38.1 million persons in 1964/65, and using only the agricultural sector total as a base, per capita GPP in that year for this population segment was Rs. 243. This compares with Rs. 962 per capita if the nonrural population is assumed to share in all sectors of the GPP exclusive of agriculture, and Rs. 428 for the total population and the West Pakistan economy as a whole. A similar disparity would be evident if the comparisons were made on the basis of GPP per worker employed in agriculture as against other sectors. Admitting the imprecision of the data on which such measures of per capita production rest, it nevertheless seems clear that the much larger agricultural population receives disproportionately small rewards.

Current estimates of population growth in West Pakistan assume a growth rate of about 2.6 percent per annum, and this rate has also been used to estimate the population in prior years back to 1959/60. Comparison of this rate with the growth rate for agriculture, and particularly for crops, over the period 1949/50

TABLE 1-9
AGRICULTURE'S CONTRIBUTION TO GROSS NATIONAL PRODUCT
(at constant 1959/60 prices)

	1959/60	1960/61	1961/62	1962/63	1963/64	1964/65 [a]
Gross National Product (Rs. mill.)	31,439	32,992	34,884	36,062	38,881	40,679
Agricultural Sector (Rs. mill.)	16,753	17,285	18,183	18,272	19,405	19,753
Agricultural Sector as percentage of GNP (%)	53.3	52.4	52.1	50.7	49.9	48.6
West Pakistan Agricultural Sector (Rs. mill.)	7,711	7,695	8,171	8,597	8,813	9,276
West Pakistan Agricultural Sector as percentage of GNP (%)	24.5	23.3	23.4	23.8	22.7	22.8
West Pakistan Agricultural Sector as percentage of all Pakistan Agriculture (%)	46.0	44.5	44.9	47.1	45.4	47.0

Source: Planning Commission.
[a] Provisional.

and 1959/60 indicates that agriculture failed to keep pace with an expanding population. This has been most evident in the case of wheat, the major foodgrain for the Province. West Pakistan had been a marginal exporter of wheat in years prior to 1950, but since that time the Province has absorbed increasing quantities of imported wheat. IACA has estimated that during 1950–54 average annual imports of wheat were 330,000 tons, equal to around 10 percent of Provincial production. This quantity and proportion had risen to an annual average of over one million tons, or 22 percent of Provincial production, by 1960–64. Wheat imports were brought in under concessional terms available through the U.S. foreign aid PL 480 program and therefore did not constitute a heavy foreign exchange expenditure, but their growing size does serve as one measure of performance during recent years. Other foodstuffs have not been imported to a similar extent, but IACA's estimates of apparent consumption from domestically produced supplies point to a conclusion that the typical diet in West Pakistan is deficient in calories and protein, does not include sufficient fruit and vegetables, and is unusually dependent on milk as a source of animal protein and calories.

This general picture can be shown in another way. Per capita foodgrain production, computed for four reference years between 1949/50 and 1964/65, was at its highest level in 1949/50. It declined quite seriously by the mid-1950's and had not fully recovered the 1949/50 level by 1964/65, in spite of the growth which took place during the Second Plan period. The same pattern emerges from per capita estimates of income for the agricultural population, again relating the rural population to the agricultural sector of the GPP. An important part of the most recent growth has, therefore, been devoted to regaining lost ground, and it appears that at present the rural population as a whole is probably little better off than it was 15 years ago. Looked at from this perspective of a longer time period, agriculture's contribution to the people engaged in it has not provided the basis for much, if any, improvement in economic status. Estimates for per capita income and production are summarized in the following Table 1-10. The maintenance of an acceptable per capita income in agriculture carries important implications for the economy at large. Economic growth involves movement of labor from agriculture into other sectors provided these have sufficient capacity to absorb additional labor. Absorption of labor by nonagricultural sectors, however, is largely dependent on agriculture as a market for industrial production. The maintenance of socially acceptable incomes in agriculture is thus important from two points of view: (a) it should prevent excessive movement of labor, and (b) it should generate sufficient purchasing power to create adequate markets to support domestic industrial growth. The disparity between per capita income in agriculture and other sectors shown above would suggest that this balance has not yet been reached.

Export and Import of Agricultural Products

Despite the fact that agricultural production has not grown as rapidly as the population during much of the period since 1949/50, agriculture has continued to be the major source of foreign exchange earnings. Furthermore, increases in output achieved during the Second Plan period, and changes in the composition of the crops which are grown, have raised the foreign exchange contribution in absolute terms. Agriculture, as measured by raw commodities and manufactures from cotton and animal products, provided about 74 percent of all exports from West Pakistan in 1964/65, and nearly Rs. 850 million in foreign exchange. This may be seen from Table 1-11. The major components in this export performance were cotton and fine rice, both of which have shown their largest growth during the Second Plan period. There has been an import substitution effect because West Pakistan textile manufacturers using domestic fibers now supply the bulk of cotton textiles used in Pakistan, but there have been direct effects as well, now that textile exports have begun to increase. Raw cotton exports declined somewhat during the early 1960's as the expansion of Pakistan's manufacturing capacity took place and local demand for the fiber grew, but raw cotton exports have again risen to the levels of previous years. Fine rice varieties from West Pakistan have been well received in Middle East markets, and export earnings from this source have increased more than threefold since 1954/55. Quantities and values of other agricultural exports, however, have changed less.

TABLE 1–10

PER CAPITA PRODUCTION AND INCOME

(at constant 1959/60 prices)

	1949/50	1954/55	1959/60	1964/65
Per capita—total population				
Income[a] (Rs.)	342	354	366	428
Foodgrains production (kgs)[b]	188	144	151	153
Total agricultural production[c]—(Rs.)	187	174	171	181
Per capita—rural population				
Income[c]	238	222	215	243
Foodgrains production (kgs)[b]	239	182	189	206
Population (millions)				
Total	25.3	39.9	45.0	51.2
Rural	27.7	31.5	35.8	38.1

[a] GPP factor cost.

[b] Taken from *Pakistan* Handbook of Agricultural Statistics, with same allowance for undercounting used by IACA.

[c] Agricultural sector of GPP.

TABLE 1-11
AGRICULTURE'S SHARE OF FOREIGN EXCHANGE EARNINGS DURING THE SECOND PLAN PERIOD[a]

	1959/60	1960/61	1961/62	1962/63	1963/64	1964/65[b]
			(Rs. million: fob)			
Total Exports West Pakistan	763	540	543	998	1.075	1,152
Agricultural Exports West Pakistan	593	431	392	792	781	849
Agricultural Exports West Pakistan as percent of West Pakistan Exports	78%	80%	72%	79%	73%	74%
Rate of Growth of Agricultural Exports from West Pakistan	—	(−)27%	(−)9%	(+)102%	(−)1%	(+)9%

[a] Compiled on the basis of Pakistan Statistical Yearbook 1964 Karachi 1966, pages 194 to 201 and Preliminary Evaluation of Progress during Second Five Year Plan, Karachi 1965, page 117; IBRD Report No. AS-112 and Annexure 1 of IACA Report.
[b] Estimates.

In the context of earlier observations concerning the need to import wheat for domestic consumption, it should be noted that West Pakistan's agriculture, as a sector, has contributed more to export earnings than has been required for the import of agricultural commodities (either as raw material or as manufactured goods based on agricultural commodities). It has, therefore, been more than self-sufficient on this basis and, in fact, has made a net contribution toward the importation of goods and services into Pakistan for consumption or investment in new development activities. Table 1-12 illustrates this aspect of agriculture's performance. Note that calendar year figures are shown in the table, whereas fiscal year figures were used in Table 1-11.

D. MAIN ASPECTS OF PRODUCTION POLICIES TOWARD AGRICULTURE

Policy Framework and Application

The foregoing brief review has attempted to describe the pattern of agricultural growth in West Pakistan and the factors most directly related to it. Behind these factors, however, lies a background of policy actions and policy attitudes which combine to stimulate or discourage responses in the agricultural sector. Some of the important parts of this background can be broadly outlined here, although the account necessarily will be incomplete and lacking in detail.

Government development strategy has been to provide the agricultural sector with adequate resources to achieve the agriculture production targets, while the nonagricultural sectors have been regarded as the major sources of long term economic growth. Within agriculture, an important share of the resources allocated have gone to provide physical inputs such as fertilizers and plant protection materials, while the supporting services have generally operated under some financial stringency in their efforts to improve the quality and quantity of such services. Because West Pakistan agriculture depends so heavily on irrigation, and because the implementing agency for water development has demonstrated a greater capacity to absorb the investment resources allocated to it, an increasing share of the resources for agriculture has been diverted to the water sector.

TABLE 1–12
EXPORTS AND IMPORTS OF AGRICULTURAL COMMODITIES, 1956–1963
(Rs. million)

	1956	1957	1958	1959	1960	1961	1962	1963
Exports (raw materials and manufactures based on agricultural commodities)	548.2	557.9	332.3	419.6	581.0	411.8	499.1	620.2
Imports (raw materials and manufactures based on agricultural commodities)	218.9	375.3	310.3	349.3	525.5	375.7	335.3	477.5
Export Balance	329.3	182.6	22.0	70.3	55.5	36.1	163.8	142.7

Source: Computed from data provided in Statistical Handbook of West Pakistan, 1964, pages 408–11.

Within Pakistan's comprehensive planning effort, however, and a public investment program which still dominates Pakistan's development activities, there is increasing evidence of a pragmatic willingness to afford wide opportunity for private initiative and private investment in all fields, especially since the start of the Second Plan period. This must be credited as an important environmental factor influencing the significant volume of private investment which has recently been going into tubewells. Although Government did relatively little consciously to stimulate such private investment, aside from a certain amount of contract drilling by the Department of Agriculture and electrification of some rural areas, the general attitude of Government did not impose obstacles which discouraged or dampened the vigor of the private sector. Now that the private tubewells' contribution to agriculture has been clearly demonstrated, Government has moved to provide more positive support. The Agricultural Development Bank (ADB), operating with an International Development Association (IDA) credit, has been increasing its loans for tubewell installation and mechanization since the latter part of 1965. The Government of West Pakistan has also adopted a formal policy position that public tubewell programs should not be carried out in areas where substantial private tubewell development is in progress, except in those places where public programs have already begun. Further indication of Government's recognition of the importance of private investment, including tubewells, is the projection that 31 percent of Third Plan expenditures on agriculture will come from the private sector—a proportion more than double the projection made for the Second Plan.

Policies affecting prices have shaped the favorable movements in the domestic terms of trade, cited earlier. Government has used its imports of wheat under PL 480 to stabilize the price of this staple foodgrain. Maintaining favorable prices in the urban areas was a part of Government efforts to stimulate the industrial sector, but at the same time the maintenance of relatively stable prices throughout the year may have also encouraged farmers to emphasize cash crops in place of subsistence production. Procurement prices for fine rice, reflecting to some degree the premium received for its export, have apparently had a promotional effect on this crop, and sugarcane production has increased under the combined incentives of a high procurement price for cane and heavy duties on imported sugar. These policies are in marked contrast to those which prevailed prior to 1960, at which time rationing of foodgrains and Government control over the intra-Provincial movement of foodgrains generated disincentives to farmers and disorganized normal marketing channels.

Prices of some farm inputs, notably fertilizers and plant protection, have been set at levels which provide incentives to use them. Fertilizers were sold to farmers at fixed retail prices which reflected a subsidy of about half the supply cost. When a reduction of this subsidy (accompanied by a corresponding increase in the price to farmers) coincided with a drop in the rate of fertilizer sales expansion in 1961-63, the original subsidy level was reinstated and fertilizer sales rose briskly in subsequent years. The subsidy has recently been again reduced, but the prices paid by farmers are still below costs of procurement, transportation and handling. Plant protection materials and service are provided without charge to the farmers. While the value of the current plant protection program is uncertain, for reasons briefly touched upon earlier, the intention is clearly to provide the strongest possible price incentive (i.e. a free good) during a time when plant protection is being introduced to farmers. Subsidies have also been present to some extent in the charges for rental of tractor services and for Agriculture Department well-drilling, and charges for canal irrigation water have not been raised commensurately with the increase in farmers' incomes and in operation and maintenance costs on the canals.

Production of certain crops, e.g. fine rice, dried and fresh fruits, oilcakes and oilseeds, has been stimulated by the issuance of bonus vouchers against their export. The bonus improves their competitive position in world markets, and domestic procurement prices are strengthened by the increased demand from foreign buyers. Cotton, however, has been subject to an export tax, designed originally as a revenue-producing levy. Government became increasingly aware that the export tax had the unfortunate side effect of depressing the price to farmers, and from 1958 the tax on cotton has been steadily reduced until it is now only a nominal amount. This has strengthened the prices farmers receive and has undoubtedly been a factor in the recent growth of cotton production.

Government has also made an attempt to alter the land tenure system in favor of the small landowner and the farm tenant. Land in West Pakistan is very unevenly distributed—IACA estimates that 49 percent of the farms are of five acres or less and account for 10 percent of the culturable area, while 8 percent of the farms are 25 acres or more and account for 40 percent of the culturable area. The average farm size is about 10 acres and therefore relatively small. Land reform legislation has sought to reverse this situation in two ways: one limits the right to subdivide land below a minimum size designated as an "economic holding," and the second requires the largest landowners (those with more than 500 acres of irrigated land or 1,000 acres of nonirrigated land) to divest themselves of land in excess of the legal limits. Both kinds of measures have had only limited success in achieving their objectives, but the former strong bargaining position of the larger landlords may have been partially weakened in the process. Efforts to consolidate landholdings which are fragmented have proceeded very slowly, although IACA finds that consolidation schemes are more favored by the large commercial farmers than the smallholders. It is difficult to relate any of 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 landholdings. 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.

There has been limited improvement in the agricultural marketing system in the Province. Market places have been established at convenient points, but malpractices persist and the farmer is generally at a disadvantage in his dealings with market middlemen. It seems probable, therefore, that marketing arrangements have had little positive influence on recent trends in agriculture and in their present form may create disincentives to increase production, particularly for the small farmer. Transportation is closely related to marketing and here Government has allocated resources under the Rural Works Program to stimulate local participation in the creation of rural infrastructure. In recognition of the importance of rural farm-to-market roads, Government stipulated that half the funds earmarked for Rural Works in 1964/65 had to be spent on local roads construction, but actual performance fell short of this. Aside from this, however, Government investment in transportation under the Plans has been for major highways and railway improvements. Weaknesses in both these respects emerged during the Second Plan period when transport facilities were severely strained by the increased movement of both agricultural and nonagricultural commodities. Improvement in these major arteries of transport, though not a direct link for much of the rural area, will nevertheless provide the basic transport capacity on which an expanding agricultural sector will depend for the movement of the goods it requires and the goods it produces.

Institutional Support

In addition to the general policies affecting agriculture, briefly sketched above, Government has sought to improve the efficiency of the direct flow of investment and services to agriculturists through a variety of institutional arrangements. Some of these are well-established, such as the Departments of Agriculture (responsible for agricultural research and extension) and Irrigation, and the Board of Revenue (responsible for land reform, colonization, land utilization, and revenue collection). Other agencies have been organized more recently to carry out certain development activities not generally provided for within the framework of the traditional administrative structure. Included in this latter group would be the Water and Power Development Authority (WAPDA), The Agricultural Development Corporation (ADC), The Land and Water Development Board (LWDB), The Agricultural Development Bank (ADB), and the Cooperative Development Board. Responsibility for overall planning and coordination (agricultural and nonagricultural sectors) rests with the Planning and Development Department of the Government of West Pakistan.[1] More recently, as further evidence of the priority Government attaches to the agricultural sector, a high level Agriculture Committee has been established, with the Governor of West Pakistan as Chairman. This listing of the organizations indicates the range of activities and the Government's willingness to support administrative innovations where development needs seem to require them.

The effectiveness of these institutional arrangements has not been uniform, however, although broad generalizations are both inadequate and probably unfair

[1] A description of the status, function, and composition of these Departments and agencies is given in IACA's Comprehensive Report, Volume 8, Annexure 11.

in some respects. Nevertheless, some comments can be made on the basis of experience to date. The most pervasive problem has arisen from the fact that institutions dealing with agriculture have frequently had overlapping responsibilities, or at a minimum have had jurisdictional limits which were sufficiently vague to permit differing interpretations by different Government bodies. Strong and purposive coordination is essential in such situations, but this has been difficult to attain at times in West Pakistan. Problems have arisen in efforts to relate research to extension, development of water resources to water distribution and utilization, project implementation to project management, and input supplies to credit availability, to cite some examples. Where coordination has been weak, there has been some tendency to protect or expand narrowly construed institutional interests, rather than to focus efforts on the main task of promoting agricultural development. An outcome of this nature may be inevitable whenever new institutions are created since it takes time for any new organization to fall into a workable relationship with the already existing administrative structure. The point remains, however, that there is, at present, need for better coordination and careful delineation of areas of responsibility. Further, the difficulties encountered in providing coordination in the past should receive heavy weight when considering proposals to increase further the number of institutions to be coordinated.

A second area affecting institutional performance concerns the quality of the available staff in the various agencies. Lack of skilled and experienced personnel is, of course, a constraining factor in any large and rapid development effort, and its elimination is one of the objectives of policy. Personnel deficiencies with respect to skill and experience retard the capacities of development-oriented agencies to fullfill their functions adequately. Agricultural institutions in West Pakistan have been subject to this weakness, and all could benefit substantially from significant additions of well-qualified staff in a wide range of specialties. The availability of such personnel depends, in part, on improvement in the education facilities at all levels. It also requires pay scales and career opportunities (in fields related to agriculture) that are attractive to promising young people at the secondary levels of education.

To illustrate something of the magnitude of this problem the institutions concerned with water development programs (WAPDA and the Irrigation Department) will require large numbers of graduate engineers. Current estimates indicate that against Third Plan total requirements in all fields for about 7,000 new engineers, only 3,800 new graduates are expected to come from the engineering colleges. The IACA water development program alone will need about 1,000 engineers for planning and construction and 300 for supervision and operation of tubewell projects. The number of graduates of agricultural colleges may be more adequate when compared with expected needs, but it is difficult to predict whether they will be adequate in terms of the quality of training received, or whether certain critical fields of specialization (e.g. in research) can be sufficiently staffed. The shortage of field assistants, to work with farmers in extension activities, is particularly severe. IACA has estimated that the agricultural institutions will require about double their present field staff by 1975, and nearly three times as many by 1985. Present training facilities cannot produce these numbers and, at the same time, the process of providing qualitative and quantitative staff improvement for agricultural institutions requires support and planning from levels of Government outside the institutions themselves.

TABLE 2-1
LAND AREA AND PRESENT LAND USE

	Land Area (mill. acres)	Land Area (percent)
Culturable Commanded Area (CCA)		
Designated for Perennial Irrigation	20.3	
Designated for Nonperennial Irrigation	13.2	
Subtotal	33.5[a]	16.8
Other Cultivated Area		
Irrigated (from Wells, Streams, Tanks, etc.)	1.6	
Rainfed (Barani)	8.0	
Riverain	2.9	
Subtotal	12.5	6.3
Culturable Waste and Forest		
Culturable Waste	24.0	
Estimated Forest Area	3.0	
Subtotal	27.0	13.6
Total Suitable for Agriculture and Forestry	73.0	36.7
Unsuitable for Agriculture and Forestry		
Mountains and Deserts	100.0	
Unrecorded, Towns, Water Area, etc.	26.0	
Total Unsuitable for Agriculture and Forestry	126.0	63.3
TOTAL AREA—West Pakistan	199.0	100.0

[a] Out of a culturable commanded area of 33.5 million acres, only 25.0 million acres currently receive surface water supplies. The balance of 8.5 million acres is classified as culturable commanded waste.

duction. If forests (which are included in the agricultural sector) and culturable waste outside the canal commands are added to this present land base, the maximum agricultural land potential rises to 73 million acres, or about 37 percent of the total area of West Pakistan. The distribution among different categories of land is shown in Table 2-1.

Although the Indus Plains are well suited to irrigated agriculture and can be productive, a lack of water for proper crop growth has imposed a rather rigorous obstacle to increased intensification of cropping by West Pakistan's farmers. Current estimates are that about 39 million[1] acres are being cropped annually, of which 26.5 million[1] acres are within the canal commanded areas. Despite an apparent land base for agriculture much larger than this, the shortage of past and current surface water supplies relative to the total culturable area commanded by the canal system has been an important factor inhibiting the growth in cropped acreage.

[1] Perennial crops counted once only.

TABLE 2–2
AGRICULTURAL ZONES

Region		Agricultural Zones	Approximate Acres in Millions: CCA	Approximate Acres in Millions: Cropped	Present Cropping Intensity[a]
Peshawar	I	Peshawar Vale	0.7	0.9	135
Punjab	II	Punjab Rice Area	3.1	3.3	107
	III	Punjab Cotton Area	13.0	13.2	102
	IV	Punjab Development Area	3.6	2.3	64
		Punjab Regional Totals	19.7	18.8	96
Sind	V	Sind Cotton Area	5.2	4.5	87
	VI	Gudu and Sukkur (perennial rice area)	1.0	1.1	106
	VII	Gudu and Sukkur (nonperennial rice area)	1.4	1.9	138
	VIII	Ghulam Mohammed (nonperennial rice area)	1.0	1.1	104
	IX	Ghulam Mohammed (perennial rice area)	0.3	0.1	54
		Sind Regional Totals	8.9	8.7	98
(A)		All Regions—Canal Commanded	29.3	28.4	97
(B)		Noncommanded (outside areas)	—	12.4	—
		Total Cropped Area of West Pakistan		40.8[b]	

[a] Cropping intensity is defined as the sum of the areas under kharif and rabi crops plus twice the area under perennial crops expressed as a percentage of the CCA.
[b] Perennial crops counted twice.

Distinct regional differences between the agriculturally important parts of West Pakistan have led to different cropping emphases based on prevailing climate, soil, and rainfall characteristics, as well as the pace and extent of past and present investments in irrigation facilities. IACA has adopted a breakdown which identifies nine such regional distinctions, using a classification system which groups together areas with similar crop distributions.[2] The boundaries of these nine agricultural zones have been drawn across canal commands where necessary because the basis of classification is agricultural similarity, rather than the particular canal command which provides water for irrigation. Since an important part of the acreage cropped during the rabi season is devoted to wheat and fodder in all zones, with the exception of those located in the Ghulam Mohammed Barrage area, these crops do not afford a basis on which to distinguish one zone from another. IACA has chosen instead to use the important kharif and perennial crops as identifying features for the nine zones. These zones, together with the CCA and present cropping intensity in each, are listed in Table 2-2 above and in Map 2. It will be noted that the CCA totals 29.3 million acres, which is the area IACA has recommended for further development. The higher intensities achieved in some nonperennial zones reflect the cultivation of crops using residual water from the kharif season (dubari cropping), a single watering at the start of autumn (bosi cropping), or the growing influence of private tubewell installations.

[2] See Map 2.

TABLE 2-3
PRESENT AREA AND GPV OF CROPS (1964/65)

Food Crops	Area (mill. acres)	Percent of Cropped Area	GPV (Rs. mill.)	Percent of GPV
Wheat	12.71	32.5	1,635	30.4
Coarse Grains	3.01	7.7	205	3.8
Pulses, Oilseed	3.02	7.7	390	7.3
Rice	3.52	9.0	589	11.0
Maize	2.16	5.6	251	4.7
Gram	2.93	7.5	277	5.1
Sugar	1.21	3.1	721	13.4
Fruit, Vegetables	0.41	1.0	391	7.3
Others (including Tobacco)	0.25	0.6	34	0.6
	29.22	74.7	4,493	83.6
Nonfood Crops				
Fodder	6.19	15.8	—	—
Cotton	3.71	9.5	880	16.4
Grand Total Cropped	39.12	100.0	5,373	100.0

Source: IACA Comprehensive Report, Volume 7, page 106.

Rice and cotton are the distinguishing kharif crops in seven of the nine agricultural zones, and are important sources of cash income to farmers. Sugarcane is another important cash crop, although the area devoted to it is smaller than the areas covered by the other two. This is mainly a reflection of demand but it is also because sugarcane is more dependent on regularity in the perennial water supplies, and cane exercises a high demand on available water because of greater water requirements. Further perspective on the acreage devoted to different crops may be gained from summary figures for all of West Pakistan, which are presented in Table 2-3. The weight accorded to the production of food crops emerges clearly, for they ocupy nearly three-quarters of the cropped acreage. Wheat alone accounts for nearly one-third of the cropped acreage. The disproportionately greater Gross Production Value (GPV) for sugarcane and cotton, and to some extent for rice, reflects their role as cash crops. Taking both acreage and value into account, the dominant crops in West Pakistan are thus wheat, fodder,[1] cotton, rice, and sugarcane which together contributed more than 70 percent of the 1964/65 GPV.

Soils

Two general conclusions emerge from studying the findings of the several soil surveys carried out in West Pakistan. These are that soils of the irrigated plains provide a satisfactory medium for plant growth, and that soils, as such, do not impose a serious constraint on future development of agriculture. Soils were surveyed under a Colombo Plan Cooperative Project in 1954/55 and by the Water and Soil Investigation Division (WASID) under assistance from the US Inter-

[1] Fodder is the most important crop after wheat in terms of acreage, but in the IACA analysis it does not receive any valuation in calculating the GPV of crops. Fodder, grazing, and crop residues consumed by work animals are accounted for as negative cost elements in the farm production costs. Fodder consumed by production animals is reflected in the GPV for livestock from milk, meat, and animal products.

national Cooperation Administration, also in 1954. The Lower Indus Project (LIP) carried out soil surveys at a later stage, concentrating on the Sind and former Khairpur State. A UN Special Fund Soil Survey project has been under way since 1964, but will not be completed until 1968 or later. Finally, IACA has done some further soil investigation in connection with the study of 20 individual watercourses and a semi-detailed soil survey of two of the sample areas amounting to 240,000 acres. Although strict comparison of the results of these studies has not been possible, for a variety of reasons, some generalizations about the soils appear valid and relevant to development planning.

The physical properties of the soils, though generally favorable, do create some problems. The majority of the soils have favorable textures and a high potential productivity. Over most of the area they have characteristics favorable for irrigated farming, and even the lighter textured soils have relatively good moisture retention capacity. Soil texture tends to vary from loams to silty clays, with the heavier textured soils becoming more evident in the downstream areas of the doabs. Heavier textured soils are also more common in the Sind than in the Punjab. Where fine silts are present, weakly developed soil structure in the top layer (due to a lack of organic material in the soil) results in the formation of a crust which interferes with water infiltration, and therefore with seedling emergence. Proper preparation of the seedbed thus becomes extremely important for future plant growth and this would require more attention to the necessary cultural practices than most farmers in the Indus Basin typically devote to such activities at present. Failure in this regard appears to be one reason for the observed low plant populations and associated low yields in many areas, and particularly in the Sind.

With respect to the fertility aspects determined by mineralogical and chemical composition, the soils of the Indus Plains are characteristically deficient in nitrogen and organic matter, and many are also deficient in phosphate. There seems no widespread evidence of primary deficiency of trace elements. There is considerable information on the response to fertilizers, one important source being the Rapid Soil Fertility Survey carried out under FAO guidance between 1958 and 1963. Although the results varied from crop to crop and region to region, nitrogen applications on current varieties in the irrigated areas of the Punjab and the Sind appear to give satisfactory response at the level of 30 to 40 pounds per acre. Requirements in some parts of the Punjab, however, are twice this much. Phosphate application at the level of 30 to 40 pounds per acre in the Punjab also gives satisfactory response when used in combination with nitrogen, but smaller applications seem to be required in the Sind. The need for potash is less clearly established, although some areas (e.g. Sialkot) did show economic response to its application. The available evidence thus suggests there is great scope for increased and continuing use of nitrogenous and phosphatic fertilizers to raise and maintain the high fertility necessary for high crop yields. The more widespread use of new, higher yielding varieties, such as those derived from the introduction of Mexican short-stemmed wheats, would require higher levels of application than present varieties. This factor also supports the belief that there would be high demand for fertilizers in the years ahead.

Salinity in the soil has been a major concern in West Pakistan. This condition arises from the upward capillary action of moisture which contains salts, and the evaporation of this moisture at or near the soil surface. Capillary action of this type is most likely to occur in areas where the groundwater level is high. The common practice of underwatering, or spreading the available surface irrigation supplies over too wide an area, further aggravates the situation because the soil does not receive enough water to leach out the accumulating salts. The use of unirrigated fallow periods also promotes salinity because it permits more rapid evaporation and precludes the leaching action of added irrigation water. Although some crops are more sensitive to salinity than others, or are more sensitive at some stages of plant growth than others, wherever salinity occurs it has adverse effects on the output of major crops grown in West Pakistan.

Current assessments of the full extent of salinity largely rest on annual surveys undertaken by the Directorate of Land Reclamation, Irrigation and Power Department, when each canal patwari is required to estimate the extent of visible salinity in his irrigation unit. This survey methodology results in findings which reflect the subjective judgment of those making the reports, but it does provide some rough measure of the extent of the salinity problem. WASID salinity investigations are more restricted, and relate only to the Punjab and the former Bahawalpur State. The various salinity surveys suggest that about 15 percent of the area surveyed is visibly affected. Since the area included in the surveys is not identical with areas used in other contexts (i.e., the total CCA of the canal commands or the total cultivated acreage), it is difficult to translate survey results into more meaningful terms. Under these circumstances, the most significant information provided by the surveys relates to the changes which appear to be occurring from year to year. During the recent period of 1961/62 to 1963/64, the percentage of saline area appears to have remained relatively unchanged at about the 15 percent level noted above. Moreover, about a third of the area classified as saline has never been under cultivation, and nearly half of it is still under cultivation. The balance is made up by land which has gone out of cultivation due to excessive salinity.

While salinity thus constitutes an important problem for agriculture, there is little evidence that it is a growing threat, and it should be susceptible to control. Current reclamation efforts may be already restoring as much land to productive use as is annually lost to agriculture because of salinity.[1] Future efforts to reduce the groundwater level should serve to reduce the capillary action which is responsible for the deposit of salts, and an increase in irrigation supplies should provide farmers with the water needed to leach out the past accumulations. Less land would be left in fallow if more irrigation water is available, because it would permit a more intensive use of the land than at present. This view is not intended to imply that the task would be easy, or that there would be few complications. In some areas, for example, the groundwater is too saline for use as irrigation water (over 3,000 ppm TDS), even when mixed with fresh surface water, and any lowering of the groundwater level would require costly special drainage facilities. Nevertheless, the presence of salinity in West Pakistan does represent a solvable problem. The means to achieve a solution are known, and to a great extent could be feasibly employed. From the point of view of bringing about rapid agricultural growth, salinity does not appear to warrant the high priority previously accorded to it.

A problem related to salinity, which may become more important in the future and requires special attention, concerns the continuing presence of alkalinity in the

[1] IACA's Comprehensive Report, Volume 1: Comparative study of aerial photographs taken in 1954 and in 1964/65.

soils after soluble salts have been leached away.[1] There has been relatively little attention given to this possibility, although recent monitoring of reclamation procedures provides an indication that "non-saline alkalinity," or "residual alkalinity," is a more important factor than previously thought in Pakistan. The presence of residual alkalinity causes physical soil conditions to deteriorate with reduction in permeability which impedes the reclamation process. High sodium levels in the soils also adversely affect plant growth and development. Further careful monitoring and continuing research are needed to identify the full extent of alkalinity as a residual problem following simple leaching. IACA has concluded that it is a fairly common occurrence in the Punjab, but had insufficient data on which to base any firm opinion about the incidence in the Sind. It is generally believed, however, that alkalinity is relatively rare in the Sind.

IACA has recommended the application of gypsum to reduce the hazard of alkalinity during the reclamation process. Specific recommendations would differ under various circumstances and in different areas, but IACA proposes a general level of application of about two tons of gypsum per acre every five years.[2] The Study Group does not question the technical validity of this suggestion, but does feel that the transport and application of the volume of gypsum required to implement this recommendation would create major organizational problems were this to be adopted as a widespread reclamation measure under West Pakistan conditions. Localized initiative may be able to implement these reclamation practices on a limited scale, however, and such efforts should receive every encouragement.

The productive capacity of West Pakistan's soils has been summarized by IACA as being a function of many factors. Although soils are basic to agriculture's performance, the availability of irrigation water and drainage facilities, the skill of the farmer, the preparation given the land, and the quality of seed used, to cite some of the important influences, can upset expectations based on analysis of soil quality alone.

Climate

Three principal climatic factors in West Pakistan—day length, temperature, and evaporation—are consistent with the temperate tropical climate generally found in the latitudinal range of 24-34 degrees North. The exception to this generalization is with respect to rainfall, for the precipitation pattern provides a more arid climate than is found in many areas at comparable latitudes. Altitude also modifies the climate in the north and northwest parts of the Province, where climatic characteristics more closely approach those associated with the subtropics.

Day length tends to vary from 10 hours in January to 14 hours in June, but because most of the crops grown in West Pakistan are neutral with respect to photo-periodicity this factor exercises little critical influence. This is not necessarily true for all varieties of these crops, however, and it is therefore important that the sensitivity to day length of new varieties be carefully examined before they are widely introduced.

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 during June and July. While it is generally true that

[1] IACA's Comprehensive Report, Volume 4, Annexure 5.
[2] Ibid., Volume 4, Annexure 6.

this range of temperature *per se* does not hamper agriculture and, in fact, the range permits year-round cropping over the entire Province, temperature does exercise an influence on the cropping patterns. For example, the lower winter temperatures in the north slow down early crop growth and, despite its widespread distribution there, are not favorable for the cultivation of sugarcane. Temperature also comes into play with respect to wheat grown at higher altitudes, because low temperatures arrive earlier in those locations and the best wheat yields are obtained when wheat is sown before the minimum temperatures occur. The diurnal temperature range, or the variation within a single day, is important for cotton production. The best boll development of cotton takes place when the diurnal range is greatest, which is usually during October and November. To meet this condition, it is necessary to sow cotton no later than June.

The factor of evaporation is strongly related to the water requirements of crops. Its measurement is extremely complex, and any evaluation of evaporation in connection with irrigation requirements must take into consideration both the irrigation water and probable precipitation. Some of the substantial differences in evaporation which take place in different parts of the Indus Basin may be seen in Table 2-4 and in Map 1. The data there show the range of variation on the basis of both geographical location and season of the year.

The significance of the relationship of rainfall to evaporation is demonstrated by Table 2-5. The higher irrigation requirements, including a modest addition to permit leaching of accumulated salts and to offset seepage losses, in the southern Punjab and the Sind reflect the combined effect of higher evaporation and lower rainfall although for the purpose of this comparison all areas selected were assumed to be under cultivation at a cropping intensity of 150 percent. Allowance has been made for the portion of rainfall making an effective contribution to plant growth. The implications of evaporation and rainfall factors for development thus stand out clearly, for the higher irrigation requirements at watercourse head in the Sind mean larger water supplies than in northern areas to achieve a comparable cropping intensity on a given CCA.

The pattern of rainfall in West Pakistan is highly variable, both with respect to its distribution over the Province and its timing. The southeast monsoon moves up the Indo-Gangetic Plain in July to September, but is quite unpredictable in terms of rain it produces because it is nearing the end of its travel when it reaches the Punjab Plains. The southwest monsoon is more reliable in this sense, but is weaker at its source and produces less rain for the lower parts of the Indus Basin which it touches. The range of mean annual rainfall extends from less than four inches in the Sind to more than 30 inches in the foothills of the northern mountains. Although

TABLE 2-4

COMPUTED EVAPORATION AND RAINFALL, BY REGION AND SEASON OF THE YEAR

(rainfall in parentheses)

	North (in inches)	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)

TABLE 2-5
IRRIGATION REQUIREMENTS AT WATERCOURSE HEAD FOR CROPPING INTENSITY OF 150 PERCENT

	Acre-Feet Per Acre of CCA
Northern Punjab	3.9
Southern Punjab	4.7
Sind	5.6

the latter amount is apparently quite adequate for agriculture, most of this comes during the monsoon period, and then frequently in torrential showers. Much of the summer rain may therefore not be available for agriculture because of rapid run-off and is not effective in meeting the crop water requirements. Moreover, the intensity of the rainstorms in the northern catchment areas of the rivers of West Pakistan results in sudden rises in the river discharges, with consequent breaching and/or overtopping of protective bunds. This is most likely to occur at the time of heaviest rainfall in the Indus Basin itself, when inadequate drainage prolongs the period of inundation and increases the probability of serious damage. At other times, showers may be so light that the precipitation evaporates before the water can penetrate to the root zone of the crops. In general terms, therefore, over large areas rainfall is either so meager, or so unreliable, or some combination of these characteristics, that it constitutes a distinct constraint on agricultural production in the absence of assured irrigation supplies.

People

Reference has been made earlier to the size and rapid rate of growth of population in West Pakistan. This population is predominately rural, largely dependent on the land for direct subsistence, and concentrated in its geographical distribution. Table 2-6 shows that over three-quarters of West Pakistan's people live in the Peshawar and Punjab regions, and that this proportion is not expected to change significantly by 1985. This reflects, in turn, the attraction of areas where the climate and conditions are more favorable and where irrigation was installed earlier, with the result that irrigated agriculture has become more advanced.

TABLE 2-6
IACA'S POPULATION ESTIMATES

	1965		1985	
Region	Millions	Percent	Millions	Percent
Peshawar	14	27	22	25
Punjab	26	50	43	50
Sind and Karachi	10	20	19	22
Rest of Province	1	3	3	3
Total West Pakistan	51	100	87	100
Rural	38	74	50	57
Urban	13	26	37	43

Source: IACA's Comprehensive Report, Volume 1, page 5.

Estimates of the size of the labor force available to the agricultural sector generally assume that it consists of about one-third of the rural population dependent on agriculture. This would total between 11 and 12 million people in 1965, using an estimate of 35 million people as the rural population dependent on agriculture. On the other hand, the Planning Commission estimates that a labor force of only 8.1 million man-years is required for the agricultural sector. Direct comparison of these two estimates indicates a likelihood that there is considerable underemployment in the sector. While this is a somewhat tenuous basis for generalization, especially in the absence of widespread mechanization, there is undoubtedly a certain amount of seasonal unemployment. There are, however, also times of the year when labor requirements may equal, or exceed, the number of persons available to work, as, for example, when the harvesting of one crop and the preparation for planting another must be completed within a very short time interval. At such periods there may be localized labor shortages. This is not to deny the possibility of generalized underemployment, but it does argue for caution against easy acceptance of the view that abundant labor is always available. Although the rural population proportion is likely to decline, present projections show an increase in absolute numbers up to 1985 and beyond. Further, IACA's projections anticipate that the rural labor force and the cropped acreage will increase at about the same rates up to 1985. To the extent that underemployment, and particularly seasonal underemployment, exists at present, it may continue in the future. On this basis the factor of labor does not appear to pose a serious development constraint. With a larger cropped acreage and increased output of commodities, however, seasonal labor shortages may become increasingly critical. IACA's projection of greater mechanization of farming—to cover about 25 percent of the irrigated farm area by 1985—therefore seems realistic, and could be consistent with the expectation that a sizeable portion of the agricultural labor force may be underemployed for several months out of the year.

Although the typical farm size in West Pakistan is generally categorized as "small," and the land as equally divided between owner-operators and tenants, this tends to obscure the variation which exists in land tenure arrangements throughout the Province. The average farm holding, for example, is 10.1 acres (with an average cultivated area of 7.7 acres), but the range extends from an average of 5.5 acres in Peshawar Division to a high of 35.9 acres in Kalat Division.

The 1960 Pakistan Census of Agriculture shows that 49 percent of the farms are under five acres, but these only contain some 10 percent of the culturable farm area. By contrast, 8 percent of the farms which are over 25 acres contain 40 percent of the culturable farm area.[1] Land ownership patterns, shown in Table 2-7, indicate that nearly two-thirds of all ownership units are smaller than five acres, but that these small units account for only 15 percent of the farm area. It also shows that over 30 percent of the total area owned falls within the limits of large-scale units above 100 acres in size. This suggests there may be considerable scope for private investment in agriculture by operators of commercial-scale farm units. In general terms, farms are smaller in the more productive, irrigated areas of the Punjab and Peshawar Vale than elsewhere. There is also variation in the proportion of land which is owner-operated. Owner-operated farms account for nearly half the acreage in three Divisions of the Punjab, but the proportion drops to

[1] IACA's Comprehensive Report, Volume 7, Annexure 9, page 13.

TABLE 2–7
LAND OWNERSHIP PATTERN

	Up to 5 acres	5–25 acres	25–100 acres	More than 100 acres	Total
Number of owners (thousands)	3,266	1,452	286	63	5,067
Percent of owners	64	29	6	1	100
Area owned (thousand acres)	7,427	15,438	10,616	15,161	48,641
Percent of area owned	15	32	22	31	100

Source: IACA's Comprehensive Report, Volume 8, page 8.

about a third in Khairpur Division in 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.

In its watercourse studies, IACA has attempted to assess the prospects for innovation and the exercise of initiative among the farmers in relation to the land tenure system. These studies found evidence of willingness amongst farmers to accept new ideas and new methods in examples such as the widespread use of improved sowing material and the increasing demand for chemical fertilizers, though these are more apparent on larger farms than smaller ones. In general, however, IACA has found no significant differences in farm productivity between tenant farmers and the owner-operators of small farms, indicating that tenant status apparently does not generate additional productivity-depressing influences at the level of smallest farm size. The large investment made in private tubewells during the Second Plan period is further evidence of the exercise of initiative at the farm level, but the costs involved have tended to restrict this development mainly to owner-operators of the medium and larger farm units.

Experience such as this supports the generalization that conservatism and resistance to change should not prove to be insurmountable obstacles to future development efforts. It is nevertheless probable that adoption of new methods and ideas will be more rapid among the owner-operators of the larger farms than among tenants or the smallest owner-operators. Not only would the owner-operators of larger farms be in a better economic position to make investments to increase productivity, but there would be greater incentives for them to do so than in the case of tenants who retain a much smaller share of total output. This would mean a somewhat uneven pattern of improvement, with a slower rate of increase in real living standards among the majority of farmers who fall in the smallest farm-size categories. An uneven pattern need not imply any greater innate unwillingness to accept change on the part of those who would, by force of past circumstances, be in a less advantageous position to adopt the means of change, nor may it necessarily curtail the rate of growth in production if the required support and incentive is provided.

B. PRINCIPAL FEATURES OF DEVELOPMENT

Introduction

The above description indicates that West Pakistan's agriculture is endowed with the basic resources sufficient to realize production levels many times greater than the level achieved at the present time. In planning for this development, however, there tends to be a preoccupation with material inputs of various kinds which sustain a production effort—a preoccupation that, at times, may obscure the fundamental importance of the farmers themselves. It is essential to remain aware that farmers are involved and that they themselves will determine what is done on the land. They must be assisted to acquire the knowledge and equipment necessary to employ material inputs and farming skills in a manner which results in increased production. There must also be assurance they would be rewarded adequately for the additional effort, risk, skill, and investment involved. This underlying frame of reference should be borne in mind when considering the succeeding sections of this report, which necessarily devotes considerable attention to the material input element and its relevance to development planning.

To obtain detailed information on all aspects of production at the farm level field studies were carried out on 20 watercourses in the Punjab by IACA and on 60 watercourses in the Sind by the Lower Indus Project (LIP), consultants for WAPDA. The areas chosen for these watercourse studies were intended to represent all the main geographical features of the irrigated areas and the major canal commands. Data of agricultural activities, land use, costs, cropping, and other statistics were recorded over a period of four seasons in the Sind and one complete summer and two partial winter seasons in the Punjab. The comprehensive and detailed information emerging from these important studies has influenced IACA's assumptions and projections over the whole field of irrigation and agriculture and undoubtedly will be of great value to the Government of West Pakistan in future planning. A full account of the watercourse studies is given in IACA's Comprehensive Report and supporting documents[1] and is briefly summarized in Annex 1.

The need to increase agricultural production in Pakistan is a basic need for the foreseeable future. Estimates of future demand for agricultural commodities show the large and widening gap which has to be closed between the present level of production and future demand (see Chapter VIII, B). There is no doubt that it is technically feasible to meet the anticipated demand, but achievement of this goal will require much higher standards of farming than presently prevail, and a high rate of growth in agricultural production which has seldom been attained over a sustained period except in relatively small countries. Data for agricultural production of a number of countries were used to estimate compound annual growth over the eight-year period ending 1964/65, and are shown in Table 2-8. To achieve a breakthrough in the growth of agricultural production there must be a major effort to provide the incentives, the physical resources, and the technology for developing the necessary farming skills, and a determined attempt to make judicious use of the market mechanism.

The IACA's Comprehensive Report attempts to provide guidance for West Pakistan's agricultural development. It proposes large public and private investments to supplement the irrigation supplies, examines the need for complementary efforts (such as drainage works and canal remodelling), estimates the scope for applying other agricultural inputs, and discusses the role to be played by agricultural institutions of various kinds. The Study Group's review of IACA's development proposals is presented in some detail in the succeeding chapters. But first it is necessary to consider some of the fundamental factors which underlie agricultural development. This section emphasizes the need for more water and other inputs,

[1] IACA's Comprehensive Report, Volume 10, Annexure 14 and supporting documents.

TABLE 2-8
GROWTH IN VOLUME OF AGRICULTURAL PRODUCTION FOR SELECTED COUNTRIES, WITH ARABLE AREA AND TOTAL POPULATION
(base for 1952/53 to 1956/57 = 100)[a]

	Arable Area (million ha.)	Population (millions)	Compound Growth of Agricultural Production Over 8 Years to 1964/65[b]
India	163	472	3.0
Pakistan	26	101	3.5
Japan	6	97	2.8
Brazil	19	79	3.7
France	21	48	4.0
Mexico	24	40	6.0
Thailand	11	30	7.4
Australia	33	11	4.7
Israel	½	2½	11.0
U.S.A.	185	192	2.1

[a] Source of Data: FAO Production Year Book 1965.
[b] Compound Growth from regression coefficient.

but examines their relative importance and interrelationship within a framework of improved farming, higher cropping intensities, higher yields and increased livestock production.

Dependence on Irrigation

The semi-arid conditions which prevail over much of West Pakistan are generally unfavorable for rainfed cropping; where rainfed cropping does occur, it tends to be a hazardous undertaking. The parts of the Province which depend on rainfall alone provide an important annual contribution to the agricultural output, but it is also true that climate and the amount and pattern of rainfall impose a severe constraint on efforts to promote a more productive agriculture in such areas. Even in the areas currently receiving irrigation, it is difficult to foresee much increase in the intensity of land use, or significant new additions to the acreage cropped, without further improvements in the irrigation system. Recognition of this dependence on irrigation underlies the priority which has been and continues to be accorded to water resource development.

To illustrate the degree to which agriculture in West Pakistan depends on irrigation, canal irrigation water is now being provided annually to about 27 million cropped acres. Together with a small, but important, lift-irrigated area of about 1.6 million acres, irrigation covers over 70 percent of the total cropped area. Production of three of the important crops grown in the Province—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 canal irrigated areas. Fodder is not included in this accounting because its contribution is reflected in the separate valuation of livestock production, but its importance should not be overlooked in assessing the benefits of irrigation. Farmers clearly recognize the need for small water supplements, to minimize crop risk and to ensure the supply of fodder for their livestock, as demonstrated by the popularity of Persian wheels and (more recently) private tubewells for this use.

TABLE 2-9
CROPPED ACREAGE AND GPV FOR CANAL IRRIGATED AND OTHER AREAS (1965)

	Canal Irrigated		Remainder		West Pakistan	
	Area in Acres	GPV Rs.	Area in Acres	GPV Rs.	Area in Acres	GPV Rs.
			(million)			
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

Source: Computed from data provided in IACA's Comprehensive Report, Volume 7, Annexure 9, page 106.

The rainfed (barani) areas in contrast to this are both less extensive and less productive. They are located primarily in the Peshawar region, the northern part of the Lahore region, and in Quetta and Kalat, and altogether comprise about ten million cropped acres. Their major contribution to agricultural production is in foodgrains, of which they provide 25 percent of the wheat, 49 percent of the maize, and 67 percent of the millets currently (1965 figures) produced in West Pakistan. Production in the rainfed areas is characterized at present by low levels of agricultural inputs and correspondingly lower yields than elsewhere. The relative position of the irrigated and rainfed areas, in terms of cropped acreage and contributions to the GPV of crops, is given in Table 2-9. On the basis of the figures cited above, the canal irrigated areas now provide 79 percent of the GPV from food crops on 62 percent of the cropped acreage under food crops, which summarizes the relative importance of these areas in terms of extent and productivity. For all crops canal irrigated areas supply 82 percent of the total GPV of crops from 68 percent of the total cropped area.

The canal system which supplies the bulk of the irrigation water used in West Pakistan was originally designed for a low intensity of cropping.[1] These design intensities range from a low of 60 percent to a high of 81 percent, but a majority of the canal commands would fall in the upper portions of this range. In actual practice most of the commands are currently being farmed at average cropping intensities above the design level, and only a few development commands have not yet reached the design level. The achievement of average cropping intensities above the design level is partly due to the presence of private tubewells and Persian wheels, but after making a suitable allowance, these intensities are still indicative of widespread underwatering. Whatever the underlying explanation in a given situation, the comparison of actual with design intensities provides evidence that

[1] Cropping intensity is defined as the sum of the acreage cropped in the kharif and rabi seasons plus twice the perennial cropped acreage, all expressed as a percentage of the CCA.

there is considerable scope for effective use of additional water supplies. Future development of agricultural production is thus dependent on irrigation for thc extension of acreage as well as for the increase in yields through higher irrigation application per acre cropped.

Irrigation Application

IACA has assessed water requirements and, with minor exceptions before 1975, all yield and intensity projections are made on the basis of "full delta irrigation." "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 requirements at watercourse head, IACA has totalled items (a), (b) and (c) above and adjusted this sum upward by assuming that item (d) involves a general loss of 37 percent, including conveyance losses in the watercourses. It should be noted that full delta, as defined by IACA, provides water in excess of the consumptive use of water by crops at the ultimate (year 2000) stage of development. The irrigation requirements at watercourse head, based on full delta irrigation, are shown in Table 2-10 for an assumed cropping intensity of 150 percent, and these water requirements are compared with the current status in various parts of the Indus Basin. In contrast to the earlier grouping of variations in agricultural specialization by zones, Table 2-10 shows the irrigation pattern in terms of canal commands grouped by regions. This is because data on irrigation flows and cropping intensity are collected on the basis of canal commands and not for agricultural zones. Because the zones, as identified by IACA, can include more than one canal command, any conversion of canal command data to a zonal base would involve some arbitrary allocation of acreages and water supplies. To avoid this, the canal commands have been retained by IACA as the basic units in their analyses.

TABLE 2-10

CCA, CROPPING INTENSITIES, WATERCOURSE DELIVERIES[a] AND WATER APPLICATION

			Current (1965) Status		For Full Delta At 150% Intensity	
Region	CCA (mill. of acres)	Cropping Intensity (%)	Annual Water-course Supplies (MAF)	Acre-Feet Per Cropped Acre	Annual Water-course Supplies (MAF)	Acre-Feet Per Cropped Acre
Peshawar and Swat	0.7	135	1.7	1.8	2.8	2.3
Bari Doab	5.8	102	12.1	2.0	26.0	3.0
Rechna Doab	4.7	106	11.2	2.3	18.0	2.6
Chaj Doab	2.0	104	3.8	1.8	8.0	2.6
Sutlej/Panjnad L.B.	3.5	92	7.0	2.2	18.0	3.4
Thal/Indus R.B.	3.6	64	6.3	2.7	15.0	2.8
Sind	13.2	67	25.6	2.9	47.0	3.5
	33.5[b]		67.7		134.8	

[a] Includes surface and groundwater deliveries.

[b] Only 25 million acres currently receive canal supply.

The table shows that a gross area of 33.5 million acres CCA (of which 25 million acres are irrigated) now receive 68 million acre-feet (MAF) annually. If the same CCA were to be cropped at an intensity of 150 percent with full delta irrigation, the water requirements at watercourse head would rise to 135 million acre-feet. The table was drawn on the assumption that the cropping pattern would remain the same, but at a higher intensity of cropping. A comparison of the current water applications (in acre-feet per cropped acre) and at full delta gives some indication of the present degrees of underirrigation by comparison with the ultimate level required when new varieties, adequate inputs and full delta irrigation are employed. IACA has estimated that the prevailing overall average degree of underwatering is about 20 percent below ultimate full delta requirement, but this varies considerably between and within canal commands, and between seasons and years.

While there is no doubt that the average applications of irrigation water per cropped acre are below the full delta requirements, there is evidence that farmers exercise some judgment in scheduling their use of available water. Important crops, and cash crops in particular, probably receive close to present crop water requirements, while other crops are underirrigated to a greater extent than indicated by the overall average estimates of underirrigation. This is important in considering the scope for increasing production under prevailing conditions through the application of better husbandry and agricultural inputs other than irrigation water.

The Relationship between Crop Yields, Irrigation Application and Nonwater Inputs

IACA and the Study Group have examined available data on crop yields and application of water and other inputs to assess the nature of the relationship which exists among them. Appreciation of this relationship is necessary for evaluation of the probable contribution of agricultural inputs at different levels of water application. One source of information for this review was the Revelle Report,[1] which contained an extrapolation of expected relationships. A second source was the Watercourse Studies,[2] which reported the field results for wheat yields under different irrigation applications in the Punjab, and had the advantage of reflecting actual results under West Pakistan conditions.

The relationship between yields and irrigation applications was strikingly similar in both sets of data (see Figure 2.1). Yields decline as the degree of underirrigation increases, but the rate of decline in yield is disproportionately smaller than the rate of decline in water application. A greater increase in production in the short run would therefore be expected if a given quantity of irrigation water were used to expand cropped acreage, rather than using it on the acreage implied by IACA's full delta requirements. Data to illustrate this point are given in Table 2-11. The table indicates that under prevailing farming conditions production could be maximized by increasing intensities with proportionate reduction in irrigation application. IACA estimates that the present water availability is on average equivalent to about 80 percent of its full delta requirements. This prevailing level of water availability—subject to the necessary qualifications regarding its timely distribution—exceeds the 80 percent of crop water requirements shown in Table 2-11,

[1] Report on Land and Water Development in the Indus Plains, The White House Panel, Washington, D. C., January 1964, pages 417-29.
[2] IACA's Comprehensive Report, Volume 10, Annexure 14.

since it includes a leaching allowance. Full delta would therefore be adequate to support the 125 percent intensity at the 80 percent level of underwatering. Although yields would be 10 percent lower than optimum, the larger acreage would produce 13.5 percent more wheat.

VOLUME II
FIGURE 2.1

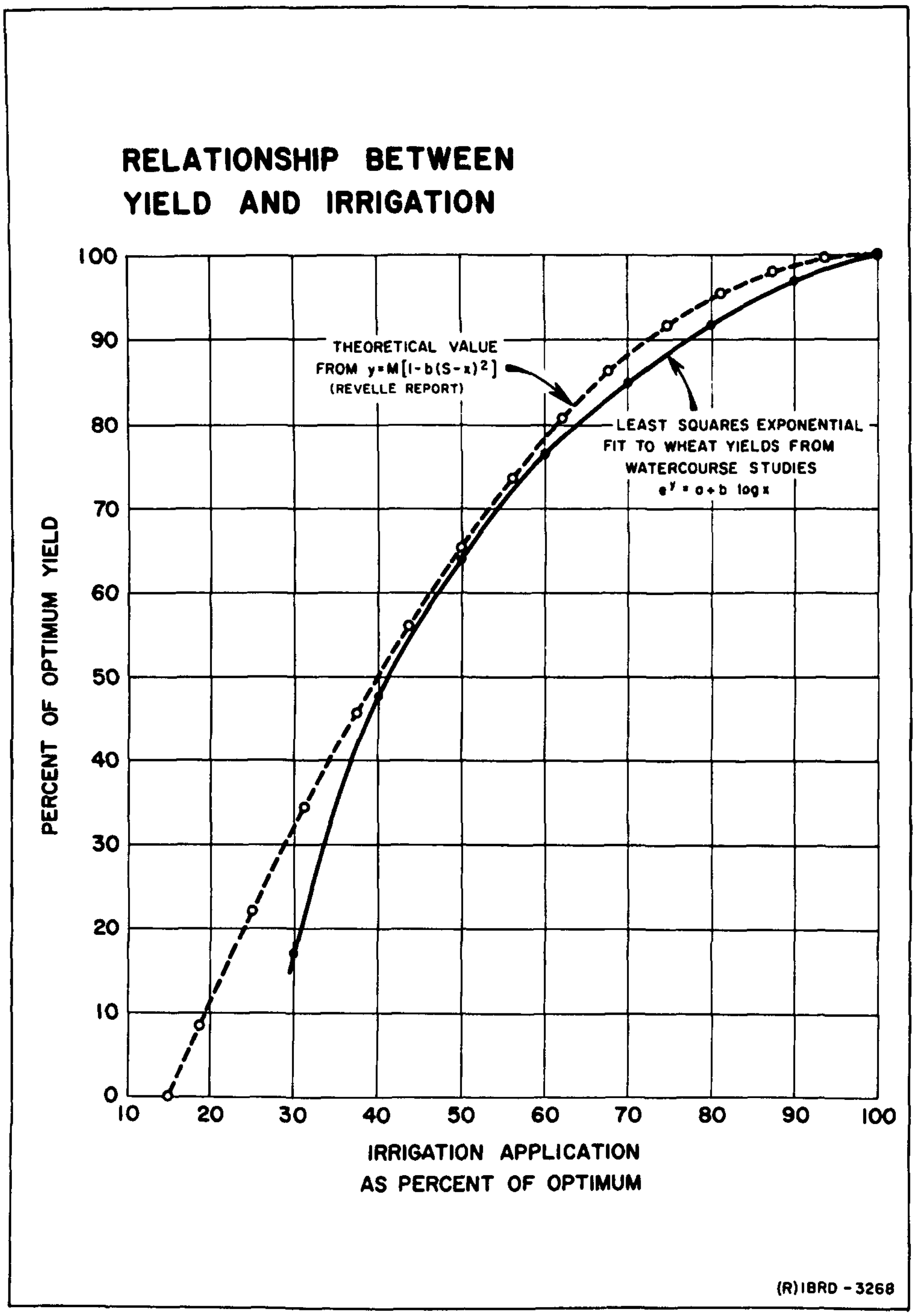


TABLE 2-11
RELATIONSHIP BETWEEN IRRIGATION APPLICATION AND WHEAT YIELDS

Irrigation[a] Application	Yield at Irrigation Application	Cropping Intensity at Respective Irrigation Application	Production From Area and Yield
	(percent)		
100	100.0	100.0	100.0
90	96.0	111.1	106.7
80	90.8	125.0	113.5
70	84.2	143.0	120.4
60	76.3	166.7	127.2

Source: Computed from data presented in Watercourse Studies, IACA's Comprehensive Report, Volume 10, Annexure 14, page 179.

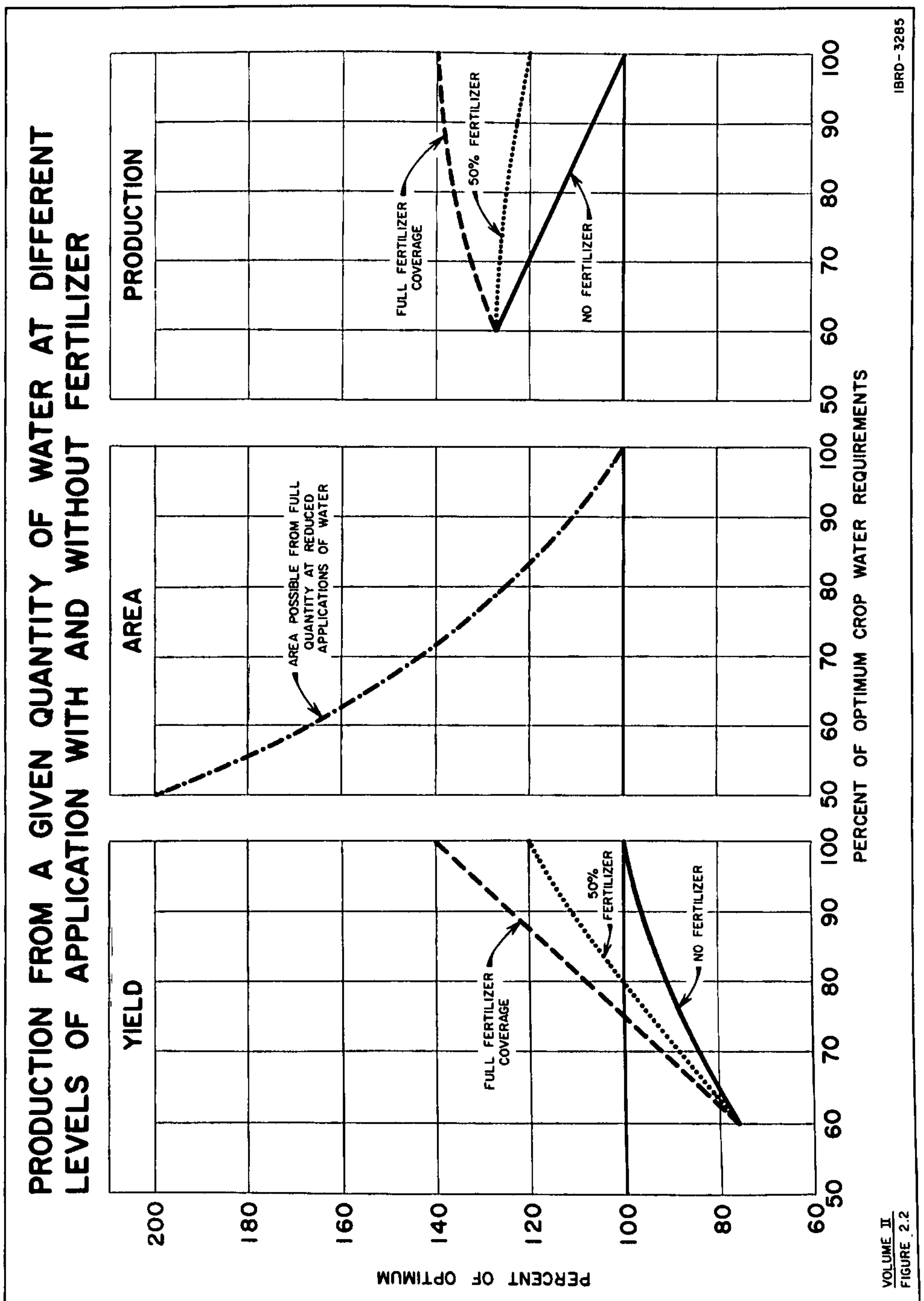
[a] Expressed as percentage of crop water requirement, not IACA's full delta requirement which refers to ultimate state of development and includes an allowance for leaching and losses.

The relationship described above would hold generally true for all crops, subject to some qualification because of special characteristics associated with certain crops. Cotton, for example, is distinguished by its boll-shedding tendency because of its extreme sensitivity to water strain, and slight water deviations as a result of field conditions would lead to greater crop loss in cotton than in the case of wheat.

These relationships between irrigation application, yields, acreage cropped, and consequently productivity are of considerable significance in present circumstances and are likely to continue to be of importance for some time to come. Under the prevailing standards of farming and use of inputs, and measured purely in terms of production, the relationships imply a diminishing rate of return to water at the higher levels of application. This implicit relationship supports farmers' present practice and the widespread belief that, in the short term, underwatering is advantageous to the farmer in conditions of scarce water and so long as farming standards and crop yields remain at their current levels.

As farming standards improve and yield levels increase as the result of better crop husbandry and a greater use of inputs, this bias in favor of underwatering and extended acreage would disappear. At higher yield levels, there is some evidence that the use of a given increment of water to increase delta should, in most circumstances, result in more production than an extension of acreage at the existing degree of underwatering. (These relationships are illustrated in Figure 2.2.) The influence on yields and productivity of water and other inputs are thus inextricably linked. Each supports the other, so consideration of the effects of one must be set in a frame which includes reference to the related use of the others. All factors must be kept in proper balance to avoid one particular ingredient of the input mix becoming the limiting factor or, alternatively, being applied in excess of requirement.

As stated previously, all IACA's projections of water requirements, yields, intensity and consequently productivity are based on full delta irrigation commensurate with the ultimate (year 2000) state of development and yields. Such levels of water application would be in excess of the consumptive use of crops even at the stage of full development and much more so at prevailing levels of farming with suboptimal inputs, plant populations and varieties. In these circumstances, where water is the constraint, to limit increase in intensity and yield response to inputs to the equivalent of the full delta acreage, as IACA does, may well be understating the potentiality (and the probable actual production increase) during the transitional period of development by comparison with what could be obtained with modest underwatering on an extended acreage.



In the opinion of the Study Group, if timely availability of water could be assured by improved operation and regulation, the prevailing level of water application (around 80 percent of IACA's full delta requirements) would in many areas be adequate to support as high a level of farm inputs as is likely to be generally available for use in the next few years. If this is the case, the choice between moving to full delta (as IACA does with all water increments) or extending the cropped acreage at a lower level requires very careful consideration and the decision should be properly related to particular circumstances (i.e., a move to full delta should only be made where water is, in fact, the limiting factor). Support for the view that water alone is not universally the principal limiting factor is to be found in IACA's Watercourse Studies.[1]

In recognition of the fact that farmers in general are not likely to reduce their existing cropped acreage to that which would correspond with water availability at full delta application, IACA has assumed a continuation of some underwatering up to 1975. In IACA's production calculations, however, all cropped acreages have been reduced to "full delta equivalent acreage" and IACA's full delta yield growth has been applied to this reduced acreage. To compensate to some extent for the additional production which would associate with the farmers' actual practice of underwatering (but is eliminated by IACA's process of calculation), IACA has made an addition to the resulting production of something like 10 percent in the case of minor crops (fodder, maize, millets, oilseed and gram). No such addition has been made in respect of major crops (wheat, rice, sugarcane, groundnuts and fruit). In the opinion of the Study Group, this method of projection must tend to understate the probable, and certainly the potential, level of production during the transitional period.

In the case of major crops, IACA makes the assumption that in conditions where underwatering prevails additional water made available would give the same increase in production whether it was used to increase delta or to expand acreage at underwatering. In keeping with this assumption, in circumstances when additional water becomes available from surface storage, public tubewells or canal enlargement, IACA in their production calculations give almost instantaneous increase in yield equivalent to the degree of underwatering corrected, e.g. if the additional water is sufficient to raise the irrigation level from 80 percent to full delta this would, on IACA's assumptions, result in an automatic yield increase of 20 percent. In the opinion of the Study Group, this has the effect of overstating the immediate post-project productivity since in its view it would take considerable time to organize the required higher level of other inputs to match the increase in water. In practice, a gradual improvement in all respects, acreage as well as delta and inputs, would be more probable with neither moving up to the optimum except in proper balance. This implies for some time a larger cropped area at a lower level of production per cropped acre but higher overall production.

While the Study Group recognizes the need and supports the policy of adequate water application to meet both crop consumptive use and maintain the long term productive capacity of the soil, they are of the opinion that IACA's full delta concept has been too rigidly applied, particularly under the conditions likely to prevail during the early years of development. IACA's assumptions appear to have the effect of:

[1] IACA's Comprehensive Report, Volume 10, Annexure 14.

1. Understating the probable increase in crop production in the absence of improvement in water availability, by discounting the opportunity for increasing productivity through better farming and greater use of inputs under prevailing conditions of water availability.
2. Overstating the rate of agricultural growth of productivity in the immediate post-project period as a result of the instantaneous increase in yield in direct proportion to the additional water provided up to full delta.
3. And reducing the production potential, after more water becomes available, by limiting intensity growth to the acreage corresponding to full delta. This level of water application may be excessive in relation to the other ingredients in the production package likely to prevail in the early years of development.

Existing underirrigation and unreliability of water supplies undoubtedly have a substantial influence on the low yields presently obtained in West Pakistan, but the separate effects of these and other factors cannot be easily isolated. The IACA Comprehensive Report tends to approach this problem indirectly, largely from the standpoint of the sequential adoption of inputs. According to IACA, increases in water application up to full delta requirements would result in improvements in yields, but much of the full benefit in terms of production would arise because full delta irrigation would stimulate the use of, and increase the response to, other inputs such as fertilizers and improved varieties of seed.[1] It is important nevertheless to have some indication of the extent to which other inputs can increase yields, with underirrigation, because this practice is likely to continue for some time and until more adequate water supplies become generally available would represent the main opportunity to increase population. An assessment of the contribution of inputs other than water is also relevant to areas which depend on rainfall alone, where no additional irrigation supplies are anticipated, to determine the effect of better farming methods on yield improvement.

The Study Group has attempted to assess the contribution of fertilizers using data from both the IACA Comprehensive Report and the West Pakistan Department of Agriculture.[2] IACA used the yield responses to fertilizers for several crops as evaluated and reported by the Rapid Soil Fertility Testing Scheme in the Punjab and the Sind for the years 1960-63. These tests were not laid out as formal replicated experiments but were carried out on relatively large numbers of unreplicated plots. It seems appropriate to conclude, with IACA, that the reported average yields in the presence and absence of nitrogen and phosphate, under better than average irrigation conditions, probably represent yields which the better farmers in West Pakistan might achieve. Average yield response to 30 pounds of nitrogen was between 20 and 30 percent while with the addition of 30 pounds of phosphate the average yield increase was about 45 percent.

The fertilizer trials conducted by the Department of Agriculture during 1954-57 covered a large number of irrigated plots and a smaller (though sizeable) number of plots cultivated under rainfed conditions. Although precise data are lacking, for purposes of analysis it has been assumed that the irrigated plots received adequate crop water requirements and that the rainfed plots represented a degree of

[1] IACA has provided a wealth of valuable information on the responses to water and other inputs in Volume 10, Annexure 14, but in the absence of carefully designed long term experiments the consultants were hesitant to present firm conclusions on the precise effects of inputs other than water.

[2] A. Wahab, "Fertilizer Trials in Farmers' Fields," November 1965.

underirrigation equal to the discrepancy between the calculated crop water requirements and the average rainfall. In Peshawar, for example, a crop water requirement of 14 inches coupled with an average rainfall of eight inches would thus represent an equivalent of irrigation at 60 percent of crop water requirements. This method of estimation does not take into account the irregularity of supply inherent in dependence on rainfall, but it does give some indication of the yield improvement resulting from fertilizer application at low levels of water supply. Table 2-12 shows the average wheat yields in 131 field trials over a period of several years. Although these data are an inadequate basis for drawing general conclusions, they are the best available to the Study Group for providing some evidence of the magnitude of input effects. The rainfed plots (assumed to represent underirrigation) show an increase of 2.9 maunds per acre when treated at a rate of 30 pounds of nitrogen per acre. Irrigated plots, with nitrogen, show a greater increase over unfertilized rainfed plots than the additive effects of irrigation alone and nitrogen alone. With the qualifications noted above, the main inferences to be drawn from the table are therefore that nitrogen alone seems capable of raising wheat yields on rainfed lands by about 30 percent, and there is some beneficial interaction between additional water and nitrogen. With all the reservations necessary on such slender evidence, this would tend to support the view that there is a case for additional nitrogen even at relatively low levels of water availability but, due to the interaction effect, the advantage would be greater at higher levels of water application.

The data from the Rapid Soil Fertility Scheme and the Department of Agriculture trials were all based on results obtained in farmers' fields, and not on experimental farms. From the control yields cited, however, it appears likely that some selectivity was exercised in choosing the sites for the trial. Even so, it would be unrealistic to assume that the selection was done in a manner which avoided situations of underwatering, particularly for the trials on rainfed lands. It therefore still seems plausible to conclude that satisfactory responses to fertilizers can be obtained under conditions approximating the current degree of underirrigation. On this basis, the increase in yield due to nitrogen on rainfed plots (2.9 maunds per acre) would be equivalent to a conversion rate of eight pounds of wheat grain per pound of nitrogen. This compares with a conversion rate of ten to one when nitrogen is added to irrigated plots. Considering the present limited use of fertilizers, increased applications of nitrogen, even under conditions of underwatering, thus constitute an important potential for agricultural production in West Pakistan in the immediate future. It should be noted, however, that a response factor of 1:8 may not be achieved generally nor with all crops.

TABLE 2-12
WHEAT YIELDS ON IRRIGATED AND RAINFED PLOTS, WITH AND WITHOUT NITROGEN

	Yields and Percentage Response (Yield without fertilizers = 100 percent)					
	No Nitrogen		30 lbs. Nitrogen/acre		Increment	
	(maunds)	(%)	(maunds)	(%)	(maunds)	(%)
Rainfed	9.8	66	12.7	86	2.9	30
Irrigated	14.9	100	18.5	124	3.6	24

To summarize, the available evidence suggests that at present farming levels there are decided production benefits if farmers spread the available irrigation water over a large cropped acreage, and correspondingly apply less than full delta irrigation (as defined by IACA) to the cropped areas. This is understandable, in part, because full delta irrigation includes allowances for pre-planting, for seepage and leaching out accumulating salts and for run-off losses. Underirrigation as defined by IACA in comparison with its full delta requirement, may give close to the quantities required by plants alone. The benefits to farmers from underwatering may be short-run benefits, however, because as IACA has rightly stressed continued underwatering brings with it the danger of increasing salinity and its associated depressing effect on yields. The application of either additional water (up to full delta irrigation) or fertilizer appears to bring favorable responses when the starting point is some degree of underwatering, and there are no grounds for asserting that one must precede the other. On balance, as yields begin to rise there appear to be advantages in a shift from underirrigation of larger acreages to full delta irrigation of smaller acreages. This is in addition to the longer term benefit of preventing undesirable salt accumulations.

The Choice between Water and Other Agricultural Inputs

With considerable development of water resources already accomplished—80 percent of full delta, which may be approaching the crop water requirements under prevailing conditions—the question arises whether future emphasis should be on further water development or on the measures required to get full use of other inputs. Water development has been a major source of agricultural growth in the semi-arid conditions of West Pakistan, and farmers and Government agricultural agencies have come to regard water as the element most strategic to the expansion of agricultural production. There is little reluctance among farmers to accept more water. Rather, the major constraint has been the rate at which additional timely water resources can be developed with the capacities available. It therefore seems necessary that any development strategy take into account the familiarity with irrigation, and the rate at which additional water can be made available.

In contrast to irrigation, farmers are less familiar with the advantages from inputs such as fertilizers, improved seeds, plant protection, mechanization, and other supporting services. This is partly due to lack of knowledge about them, but it is also related to the problems of availability in adequate quantities, regularity of supply, and the manner in which these inputs and services have been introduced to farmers. Further, benefits from some inputs may not be attained without more assured water supplies than farmers are currently receiving.

A strategy which emphasizes the increased use of inputs other than water may therefore be more difficult to implement in West Pakistan than one which offers more irrigation water. It would require a re-orientation of habitual attitudes toward agriculture, and also an expansion and improvement of the institutional base which supplies the new inputs. Both of these would be time-consuming efforts. The difficulties would be further compounded by the risk of uncertain irrigation supplies, the virtual absence of river regulation, and the currently limited development of groundwater resources. Despite practical problems such as these, inputs other than water can make a very important contribution to agricultural growth. In economic terms and without taking account of behavioral patterns, a strategy which emphasizes the nonwater inputs might be superior to a strategy of water development alone at this stage. This is, however, too rigid a formulation of the alternatives, for both water and other inputs fill vital gaps in West Pakistan's current agricultural practice. Emphasis should be on balanced provision of these inputs to obtain the added advantages of interaction, and it is important to avoid thinking of development inputs in mutually exclusive terms.

For purposes of comparison individual canal commands with similar crop distribution have been grouped by IACA into nine specific agricultural zones. Locations are shown on Map 2. The summary of these data was employed by the Study Group in an attempt to attribute growth of GPV to water alone, other inputs, and the combination. Table 2-13 shows estimated increments of GPV over the 35 years from 1965 to 2000. Since 1965 prices have been used (with minor exceptions), the increment in GPV between any two reference years reflects increases in acreage plus the increase in yields. The separate effect of acreage was derived by employing IACA's estimated acreage expansion for the reference years, at the fixed GPV per acre for 1965, i.e. no increase in yield. Similarly, an estimate of yield effect was derived by using IACA's estimate of yield advances, but at fixed 1965 acreage, i.e. no increase in area. Production values are strictly those of IACA. While this method is somewhat arbitrary, since IACA's yield growth incorporates some improvement in delta, this contribution of yield is still indicative of the order of magnitude although it is subject to some margin of error. The acreage effect would be the most directly measurable effect of more irrigation water alone, and would be a first approximation of what would result from a strategy which concentrates on supplying additional water without improving other inputs. The "input effect" is less clearly defined. It consists of the increment in GPV due to increased inputs of all kinds—i.e. increased delta and more nonwater inputs—on the fixed 1965 cropped acreage. The "input effect" effectively measures what would happen if no water were used to expand acreage, but additional irrigation water, merely to increase delta, were combined with increased application of other inputs as proposed by IACA. This would be a rough approximation of the results of a strategy which concentrated on providing new inputs and only sufficient water to improve the delta on the existing cropped acreage. The "combined effect" is the additional increment in GPV projected under the IACA program when there is sufficient water to increase acreage cropped and apply full delta irrigation to match the level of nonwater inputs IACA has assumed in the different reference years. The "residual or interaction" is the difference between the sum of "acreage effect" and "input effect" from the "combined effect," and can only be loosely ascribed to the beneficial interaction between water and inputs not already contained in the "input effect."

The table shows that the "acreage effect" is important, but that it accounts for a much smaller proportion of total increment in GPV than the "input effect" would provide. Moreover, the relative importance of the "acreage effect" would decline as cropping intensities approach practical limits. The "input effect" would also decline slightly over time, but less sharply than the "acreage effect." The relative decline in the "input effect" would occur because the potential GPV in any year is based on acreage expansion and additional inputs (water and nonwater) over the entire acreage. There would thus be an increasing "residual effect" as the cropped acreage increases because the "input effect" is measured on the 1965 acreage and is thus based on a declining proportion of the increased cropped

TABLE 2–13
ESTIMATED INCREMENTS OF GPV ATTRIBUTED TO WATER AND OTHER INPUTS
(totals of GPV in Rs. billions)

		1965–1975			1975–1985			1985–2000		
	1965 Present GPV	GPV 1975	Increment over 1965	% of Increment	GPV 1985	Increment over 1975	% of Increment	GPV 2000	Increment over 1985	% of Increment
Due to										
Combined Water and Other Inputs	6.8	10.5	3.7	100	19.0	8.4	100	31.9	12.9	100
Of Which										
(1) Acreage Effect[a] (Water Alone)	6.8	8.0	1.2	31.7	9.6	1.6	19.0	11.7	2.2	17.0
(2) Input Effect[b] (Yield Alone)	6.8	8.9	2.1	56.4	13.5	4.6	54.9	18.9	5.4	42.2
Residual or Interaction			0.4	11.9		2.2	26.1		5.3	40.8

[a] Acreage expansion with yield held constant (water alone).
[b] Increased inputs with acreage held constant (effect of inputs).

acreage at successive reference years. The implications of this analysis appear consistent with the views expressed earlier, i.e. that emphasis should be on application of a combination of all inputs and that water resource development and provision of material inputs are not real alternatives.

In considering further agricultural development, it is important to keep in mind the interdependent nature of all measures relating to agricultural production. For instance, the application of fertilizers has reduced effects unless the land is watered properly. Proper water applications would not have the desirable results unless adequate drainage is provided. In saline areas the use of better seeds would have little effect without measures for desalinization of the soil. The full impact of land and water improvement measures would be felt only when followed by the use of better seeds and the application of fertilizers. It thus becomes apparent that few improvement measures can be taken in isolation, and that maximum benefits are obtained only from an integrated approach. Some measures may have to precede others, but there should be an integrated plan that calls upon all to play their proper roles at the appropriate time.

The development strategy implicit in IACA's program is based on a time horizon of 35 years (1965-2000), and assumes specific scarcities as well as some substitutability. It must therefore be considered in the context of a feasible rate of implementation of either choice, as well as the possibilities for combination. Because of higher risks and the large degree of uncertainty surrounding the possible future use of nonwater inputs, it would appear advisable to continue a strategy of accelerated water development in the short run. Because, however, of the large potential contained in further emphasis on nonwater inputs, it is of the utmost importance that water development be supplemented by a vigorous program of introduction and supply of nonwater inputs. As irrigation supplies become more reliable the emphasis should gradually shift more and more toward nonwater inputs in the medium term run. Thereafter, water development would mainly consist of replacement and additional re-regulation and distribution, while the main source of further agricultural growth would be expected to come from the growth of yields, e.g. better farming practices and increasing use of nonwater inputs.

The main strategy elements arising out of these considerations are thus as follows:

1. Water development should retain relative priority in the short run, say, up to 1975.
2. The relative priority of water development is based on considerations of risk, associated with unreliability of irrigation supplies, as well as the need for additional supplies to act as incentives for the use of nonwater inputs.
3. Because of "interaction effects," efficient use of existing as well as additional irrigation supplies is dependent upon the complementary use of nonwater inputs.
4. When assured water supply is established, emphasis should shift increasingly towards the accelerated use of nonwater inputs. To accomplish this it is imperative in the immediate future to develop the productive, administrative and organizational capacities for the supply and distribution of such inputs.

The Study Group thus agrees with IACA that the strategy of agricultural development to be adopted for West Pakistan should take into consideration the practical complementarity between water and other inputs. In the present circumstances, to the extent that the two modes of development are competitive, it appears necessary for water development to have priority in the strategy until such time as the irrigation system offers a degree of reliability which would largely eliminate the risks involved in the full use of nonwater inputs. This does not detract from the importance of increasing the use of other inputs without delay up to the level compatible with the prevailing level and reliability of water supply and institutional support.

Yields, Cropping Intensities, and Cropping Patterns

Yields and Yield Growth. With the background of the previous discussion on the influence of water and other inputs on crop yields, yield prospects can now be discussed in more generalized terms. Comparison of average yields of different crops in Pakistan with average yields in other countries shows that Pakistan's are among the lowest in the world. Such averages, however, hide remarkable differences in the range of performance. IACA watercourse studies have shown that the most progressive farmers in West Pakistan obtain average yields for rice, cotton, and wheat as high as the averages in countries specializing in these crops. During the period 1961-63, for example, only Japan and the United States had average rice yields higher than the average of the best farmers on the watercourses of West Pakistan. Similarly, only Israel had a higher average for cotton. The United States, with an average of 15.6 maunds of cotton per acre, was at the lower end of the progressive farmers' range of 15 to 20 maunds per acre. Only the Netherlands, with an average yield of 42 maunds, surpassed these farmers in wheat performance. Even Mexico, where new high yield varieties have been developed in recent years, did not, on average, do as well as the best Pakistani farmers.

These averages are, of course, national averages and are compared above with the performance of a small sample of very good farmers. Moreover, the national averages include both rainfed and irrigated acreages, whereas the Pakistani farmers in the comparison all benefited from irrigation. Nevertheless, it is valid to point out that much higher yields than the current average are quite possible in West

Pakistan—in fact, the better farmers are already obtaining them. The most urgent problem is therefore to raise the yield levels of the vast majority of the farmers whose productivity is so far below the leaders and who have been unable to achieve much more than bare subsistence thus far. This serves to emphasize the vital role to be played by extension and farmer services in the development effort.

Earlier discussion in this Chapter has emphasized the importance of irrigation water, in terms of both quantity and regularity of supply, and the yield-depressing effects of inadequacies in these respects. There are, however, many factors not directly associated with the availability of irrigation supplies which singularly, and in combination, keep yields low in West Pakistan. Problems of salinity and alkalinity are, of course, related to water supply. Poor farming practices—related to levelling, seedbed preparation, subsequent cultivations and weed control—affect yields adversely. The absence of effective plant protection measures may be a deterrent to farmers otherwise prepared to introduce inputs such as fertilizers. Improved varieties of seed may be known and actually be in circulation, but poor quality basic seed stock as well as inadequate quality control can lead to disappointing yields.

Yield constraints of these kinds can be reduced by corrective action. There appear to be no technical reasons why, over time, uniformly high yields cannot be obtained in most of the irrigated parts of West Pakistan. The speed with which this can be done would depend in large part on the research and extension services, and the degree to which such services become aware of and are responsive to practical farm problems. It would require more field experimentation oriented toward general improvement in farming methods, rather than basic technical research, and a heavy practical emphasis in the training given to extension personnel. 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.

IACA's analysis of yield potential is based on the assumption that unreliable and inadequate water supplies, waterlogging and salinity, limited use of fertilizers and pesticides, and poor quality seed are major constraining factors at present. To overcome these constraints, IACA stresses the importance of using a combination of agricultural inputs. While this would be the most desirable approach, it seems unlikely that it would occur rapidly over wide areas. The more probable sequence of events would be a gradual increase in the use of some inputs, or sporadic enthusiasm for one or two inputs at a time, building up to the full package as farmers become convinced of the advantages. Consequently, the widespread achievement of uniformly high yields would not come about rapidly. Increased irrigation supplies should act as something of a catalyst in the adoption of new inputs, but this again would be a relatively slow process determined by the pace of the water development program.

According to IACA's estimates of future agricultural production in West Pakistan, average crop yields per acre would go up by nearly three times their present levels over the period 1965-2000. IACA assumes that this may take place generally by cumulating contributions of the more important yield-increasing factors. This assumes that each additional factor builds on the yield level obtained from the introduction of preceding factors. The result is a cumulative growth in yield which is greater than the additive effects of the factors if taken separately, thus providing the interaction effect due to the combined application of different sources of yield growth. Table 2-14 shows IACA's supposition regarding the most important yield-improving factors. This should be regarded as a general indication of the possible cumulative effects rather than as experimentally based findings of actual contributions. This supposition is, of course, a gross oversimplification and, in practice, there would be wide variation in the response to different factors depending on the circumstances and the composition and balance of the package of inputs. The apparent contributions of factors would change with the sequence in which they were implemented. In practice the yield-improving factors would not be added in the discrete steps set out in the table. Rather, they would be adopted in various combinations and at various rates as development proceeds over the entire 35-year period. Since water is such a familiar input in West Pakistan, farmers probably would quickly take advantage of additional timely water supplies depending upon when they become available. Fertilizer is also in increasing demand and may reflect the stimulus which appears to follow added supplies. The sequence in Table 2-14 is therefore probably accurate to this extent.

The nearly threefold increase in yields over 35 years would constitute an annual compound yield growth rate of 3 percent, but the growth rates between different periods within this total time span would depend on the actual pace of the water development program, and the speed with which other inputs are available to, and accepted by, farmers. IACA has assumed, for instance, that proposed project areas and canal commands would not all receive adequate water supplies for full delta irrigation prior to 1975. The increase in yields would therefore continue at present rates between 1965 and the advent of additional water. As additional water becomes available under the program—mainly during 1965–85—the most rapid yield improvement is expected to occur. This reflects IACA's assumptions regarding the water/yield relationship and the assumption that elimination of underwatering would bring about an immediate proportionate increase in yields. IACA anticipates a Provincial growth rate in yield per acre of over 4 percent per annum for the ten-year period 1975-85, but with rates of around 4 to 8 percent in the irrigated areas. Yields are projected to grow at a slower rate thereafter averaging less than 3 percent per annum from 1985 to 2000 because the major yield improving inputs and farming practices would already have been adopted in

TABLE 2–14
IACA's Assumptions Regarding Contributions to Yield Growth from Selected Yield-Improving Factors over the Period 1965–2000

	Factor Contribution in Isolation	Cumulative Yield	Apparent Contribution in Combination
	(%)	(%)	(%)
Present Yield	—	100	—
Factors:			
Additional Water Supplies Alone	10	110	10
Removal of Waterlogging and Salinity	10	121	11
Application of Fertilizers	40	169	48
Disease and Pest Control	15	195	26
Improved Seedbed Preparation and Cultivation Practices	20	234	39
Improved Varieties	20	281	47

Source: Computed from data presented in IACA's Comprehensive Report, Volume 7, Annexure 9, pages 93 ff.

the earlier period. Also, at the higher yield levels projected for 1985, IACA assumes that further rapid improvement would become much more difficult to achieve.

The total effects of the various IACA assumptions affecting yield are reflected in the yields per acre and rates of growth in Table 2-15. The growth rates of yields for the crops included in the table strongly reflect the dominating influence of additional water supplies on yield levels implied in the IACA projections. This is particularly pronounced in the rapid growth during the 1970's and the early 1980's. Similarly, the projections reflect a less optimistic response to nonwater inputs at higher levels of application in those areas not receiving additional water supplies and by the modest yield growth projected for the period 1985 to 2000 (see Figure 2.3).

These yield levels appear feasible on purely technical grounds, but the Study Group has some reservations about the practical probability of the sustained high rates of yield growth projected for some crops. This applies particularly during the 1975-85 period and especially to cotton in the Punjab and all crops in the Sind. With respect to cotton yields, experience at the Convillepur Farm in the Punjab can be used as an example. On this large-scale, well-managed commercial farm, which employs irrigation and has continually adopted a variety of improved agricultural inputs over time, cotton yields have been increasing at an annual rate of 2.1 percent since 1915. Figure 2.4 shows the Convillepur (and Khanewal)[1]

[1] Khanewal is another large farm similar in all respects to Convillepur.

TABLE 2-15
DERIVED AVERAGE YIELDS FOR IMPORTANT CROPS IN THREE REGIONS APPLYING IACA ASSUMPTIONS AND ASSOCIATED COMPOUND ANNUAL GROWTH RATES

	1965	1975	Growth 1965–1975	1985	Growth 1975–1985	2000	Growth 1985–2000	Growth Overall
	(mds. per acre)		(percent per annum)	(mds. per acre)	(percent per annum)	(mds. per acre)	(percent per annum)	
Punjab (Irrigated)								
Rice	17.0	21.0	2.2	32.7	4.1	43.3	2.1	2.8
Cotton	8.3	10.4	2.3	16.8	5.0	21.8	1.7	2.8
Wheat	12.7	17.2	3.1	26.9	4.6	33.8	1.5	2.8
Sugar	34.5	42.8	2.2	63.2	4.0	78.6	1.5	2.4
Kharif Fodder	226.8	285.9	2.3	425.0	4.1	543.5	1.7	2.5
Rabi Fodder	522.7	596.1	1.3	800.4	3.0	957.5	1.3	1.8
Sind (Irrigated)								
Rice	2.2	15.3	2.3	29.2	6.7	44.9	2.9	3.8
Cotton	7.1	8.0	1.2	16.2	7.4	22.5	2.2	3.4
Wheat	10.6	13.5	2.4	24.6	6.2	34.2	2.2	3.4
Sugar	22.7	28.6	2.3	63.2	8.2	97.0	2.9	4.2
Kharif Fodder	172.2	218.7	2.4	365.8	5.5	513.9	2.1	3.1
Rabi Fodder	206.1	361.9	5.8	633.0	6.0	901.5	2.3	4.3
Outside Areas								
Jowar	6.0	7.7	2.5	9.0	1.6	10.9	1.3	1.7
Gram	6.0	7.6	2.4	8.8	1.5	10.6	1.3	1.6
Wheat	6.1	7.6	2.1	8.7	1.5	10.3	1.2	1.5
Maize	10.0	13.0	2.7	15.3	1.6	18.5	1.3	1.8
Kharif Fodder	120.1	154.6	2.6	181.7	1.6	219.1	1.3	1.7
Rabi Fodder	115.3	145.7	2.3	167.8	1.4	196.3	1.0	1.5

Source: Prepared from data given in IACA Comprehensive Report, Volume 7, Annexure 9, pages 106–8, and exclusive of dubari/bosi crops in the Sind.

experience and compares these with the IACA and Study Group projections for 12 project areas. The Convillepur Farm experience thus demonstrates that maintenance of sustained yield growth is quite possible but that about 2 percent growth per annum represents the best effort of a sophisticated farming enterprise in West Pakistan. Therefore, it would be difficult to sustain average yield growth rates for

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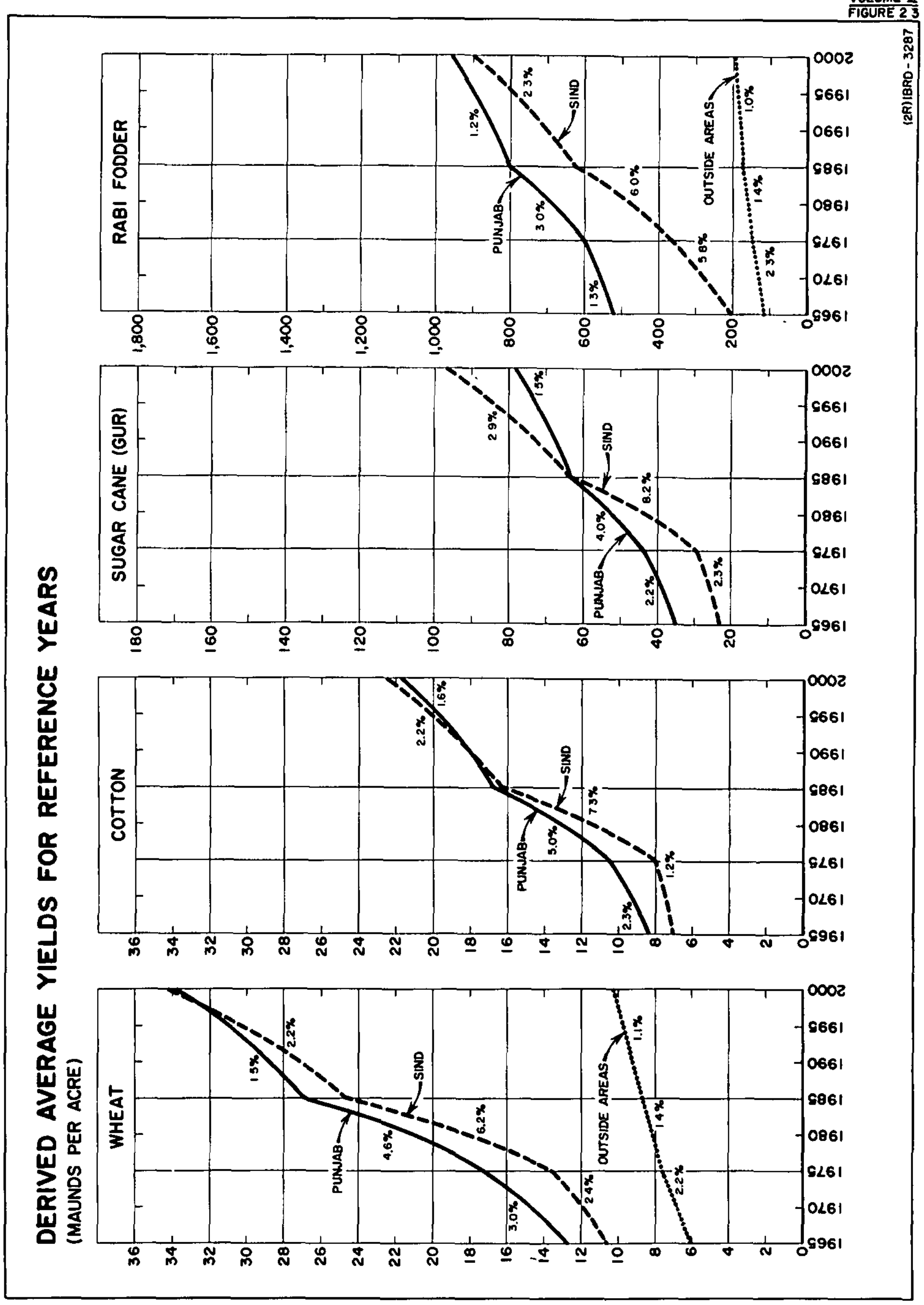
FIGURE 2 3



cotton of the order of 5 to 7 percent per annum as projected by IACA for 1975-85 over the whole cotton area.

The prospects for wheat also require special consideration since this is a critical crop both as regards acreage devoted to it and the role it plays in domestic consumption. In Pakistan, as elsewhere, great efforts have been made in recent

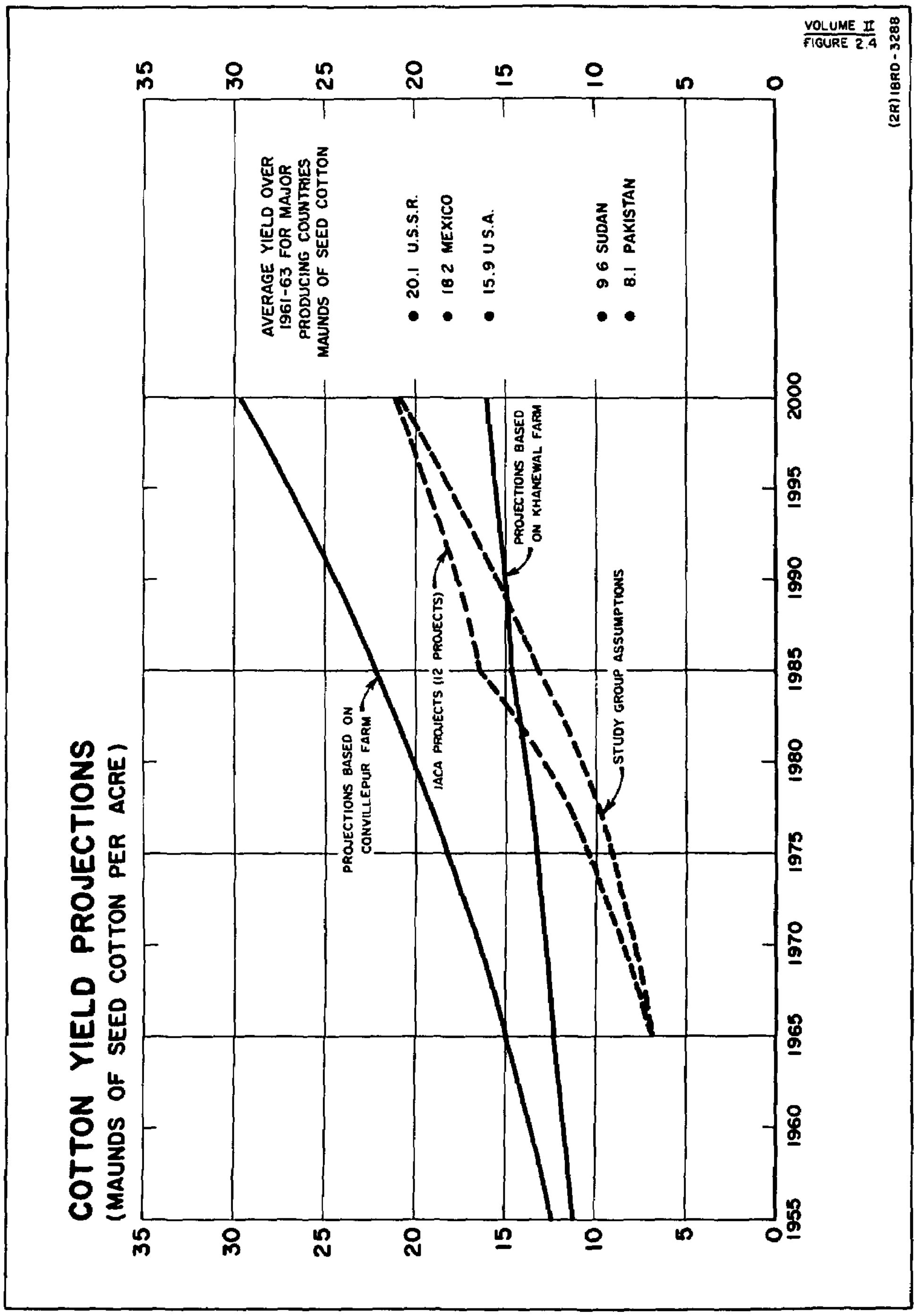


TABLE 2-16
IACA BASE FOR PROJECTION OF GROWTH IN CROPPING INTENSITIES
TIME REQUIRED TO REACH 150 PERCENT

Starting Intensity	Salinity Category[a] I	II	III
(percent)	(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.
Source: IACA's Comprehensive Report, Volume 7, page 215.

on the full CCA) may call for additional managerial skill, labor, and animal power which farmers are not in a position to provide. Reclamation of saline land can also be an expensive process and farmers, particularly those with smallholdings, may not be able to afford the costs of bringing this land under production, even where additional water supplies become available. There is the further fact that some of the CCA may have to be reserved for the use of livestock, so it would not always be practical to consider that all of the CCA would be available for cropping.

After taking factors such as these into account, IACA has concluded that an overall average cropping intensity of 150 percent is a reasonable indicative target for development in the Indus Basin. Two exceptions to this are: (a) Region I (Peshawar Vale) where maize, wheat and sugarcane occupy 82 percent of the cropped area and ultimate intensity may reach 173 percent, and (b) Region VIII (Ghulam Mohammed Barrage, nonperennial rice area) where a low rabi cropping associated with dubari/bosi conditions limits expectations to an ultimate cropping intensity of 130 percent.[1] IACA projects an ultimate cropping intensity for the 29.5 million acres of CCA of about 145 percent. IACA's projections for intensification assume that the principal controlling physical factors would be the starting intensity and the occurrence of salinity, and current variations in these respects are reflected in the projections. Table 2-16 gives the estimated average time required, in years, to raise present cropping intensities to the 150 percent level. To the extent that the occurrence of salinity would influence the growth of intensities, this is further broken down in the table to show the length of time required under three categories of salinity.

[1] This is based on the assumed command of the Ghulam Mohammed Barrage of about 1.3 million acres as against the original design of 2.8 million acres with a cropping intensity of about 75 percent.

The time estimates shown above have been applied by IACA to each area as it becomes scheduled to receive sufficient water to provide for expansion of cropped acreage at full delta, and include an allowance for reclamation. The estimates also include the assumption that intensities may increase fairly rapidly up to about 120 percent, but that advances beyond this point up to 150 percent will be slower because farm management constraints become increasingly operative.

By applying these generalized time estimates to the conditions prevailing in the major irrigated regions, IACA has provided a view of the cropped acreage, and cropping intensities, which might occur with the proposed water development. This is given in Table 2-17 which shows the cropped acreage in three regions for selected reference years. The table also shows the expected variations, by region, around the ultimate objective of 150 percent cropping intensity for the Indus Basin as a whole. The small contraction of cropped acreage in the Peshawar Vale as projected for 1975 is apparently a result of IACA's full delta calculations. In the absence of detailed investigations. IACA has projected no further water development in this region for the period 1965 to 1975. The slower expansion in the Sind reflects the later development there, and the continuation of some nonperennial water supplies up to the year 2000.

Recent experience with the SCARP I (Salinity Control and Reclamation Project) provides some check on the realism of the IACA projections. SCARP I is situated in an area where salinity was quite severe, and not unlike the conditions postulated for Salinity Category III (about 45 percent of the CCA requiring reclamation). In the first four years of operation in SCARP I, cropping intensity has increased from 89 percent to 110 percent. This compares with IACA's estimated increase, under Category III conditions, from 97 percent to 114 percent over a four year period. Table 2-18 illustrates this comparison. The close correspondence between the SCARP I experience and IACA's Category III projection tends to support the view that IACA's estimates represent feasible possibilities.

The IACA selection of an overall average of 150 percent intensity at full delta as the ultimate objective was influenced by a desire to provide the means by which small-scale farms could rise above the subsistence level and produce marketable surpluses. IACA concludes that if water supplies were made adequate for an

TABLE 2-17
GROWTH OF CROPPED ACREAGE AND CROPPING INTENSITIES IN IRRIGATED ZONES
(as projected by IACA)

	1965		1975		1985		2000	
	Cropped Acreage (mill. acres)	Cropping Intensity (percent)	Cropped Acreage (mill. acres)	Cropping Intensity (percent)	Cropped Acreage (mill. acres)	Cropping Intensity (percent)	Cropped Acreage (mill. acres)	Cropping Intensity (percent)
Peshawar	0.8	135	0.7	132	0.9	153	1.0	173
Punjab-Irrigated	17.5	95	21.3	114	24.2	131	27.7	150
Sind-Irrigated + Dubari/Bosi	8.5	90	9.3	100	10.6	115	12.5	137
	26.8		31.3		35.7		41.2	

Source: IACA's Comprehensive Report, Volume 7, Annexure 9, page 106.

TABLE 2-18
CROPPING INTENSITY INCREASES IN SCARP I
COMPARED WITH IACA PROJECTIONS

Time Period	SCARP I	Category III
	(percent)	
Start of Operation	78	80
1st year (1961/62)	89	97
2nd year (1962/63)	100	107
3rd year (1963/64)	108	111
4th year (1964/65)	110	114

ultimate intensity of only 130 percent (at full delta irrigation), farmers would continue to underwater, and expand their cropping to an operational limit of about 150 percent. Because of IACA's conviction that underwatering must be stopped as rapidly as possible in the interest of eliminating salinity in the long run, it has recommended a program which matches the farmers' desire to increase cropped acreage with a water supply which will enable them to preserve the productivity of their lands. The Study Group agrees that full delta irrigation is essential to West Pakistan's long term agricultural development. It also recognizes, however, as noted earlier, that there are short run advantages to the farmers from underirrigation at lower yield levels. The increase in intensity, but at less than full delta applications, may thus be more rapid than IACA has projected within the rigid set of assumptions it has used with respect to intensity growth.

With the overall intensity objectives determined on the grounds which have just been briefly indicated, IACA's estimated water requirements over time (in quantities and seasonal distribution) have been derived from the cropping patterns proposed to fit into an ultimate average intensity of 150 percent. In this context, the kharif/rabi ratio of the cropping pattern exerts considerable influence on the corresponding seasonal water requirements, and changes in this ratio could have quite large effects on the type of water development program which would be needed. In the early years of the development program, maximum emphasis is placed on increasing the rabi intensity consistent with the greater efficiency in water use, the importance of wheat, and in keeping with the constraints imposed by the existing system and the availability of resources. As intensities increase over time, other considerations, notably land occupation, distribution of the work load and the greater scope for canal remodelling begin to operate with greater force leading towards an equalization of rabi and kharif intensities as 150 percent is approached.

At the higher intensities the GPV of crops, whether related to total water requirements or to the cropped acreage, is relatively insensitive to changes in the kharif/rabi ratio. This is illustrated in Table 2-19, which contrasts three different crop rotations at the same cropping intensity of 150 percent. The water requirements at watercourse head are those for the Lower Chenab and Sidhnai Canal Commands, and the GPV of crops has been calculated on the basis of IACA's estimates of ultimate yields and constant farm-gate prices. The alternative use of present yields would not affect the results materially. Changes, however, in prime relationships would have a substantial impact. While no detailed assessment of the associated on-farm costs have been made, IACA's projections of future on-farm costs under varying conditions would indicate that on-farm expenditures would not materially change the above results.

TABLE 2-19
GPV FOR THREE ROTATIONS AT 150% CROPPING INTENSITY WITH DIFFERENT KHARIF/RABI RATIOS

	Rotation 1	Rotation 2	Rotation 3
	Lower Chenab	Sidhnai	Sidhnai
Kharif: Rabi Ratio	75:75	81:69	71:79
Major Crops (percent)			
Rice	11	Negligible	Negligible
Cotton	23	45	35
Wheat	26	28	38
Fodder	38	32	32
Irrigation Requirement at Watercourse Head (Acre-Feet per Acre)	4.90	4.95	4.75
GPV per Acre-Foot of Water (Rupees)	161	156	160
GPV per Cropped Acre (Rupees)	787	774	760

Source: Data from Lower Chenab and Sidhnai Canal Commands, IACA's Comprehensive Report, Volume 7, Annexure 9, pages 73 and 80.

In the light of the similarity of returns to land and water from different cropping patterns as seen in Table 2-19, the patterns can be expected to change over time in response to new opportunities to increase intensity, change technology, and markets for farm commodities. As farmers increasingly participate in the market economy, they are also likely to become more cost conscious. Thus, to promote a sustained efficient utilization of the irrigation system while simultaneously meeting production objectives, the cost-price relationships are likely to assume increasing importance over time.

Although IACA is aware that there is adequate flexibility to permit changes in cropping patterns and kharif/rabi ratios, the projections of cropping patterns given in the Comprehensive Report show a distribution of crops that is largely unchanged from the present. This results in estimates of foodgrain shortages in future years, and surpluses in fodder, cotton, sugarcane, and some other crops. The demand and supply projections are discussed further in Chapter VIII but it is noted here that on technical grounds it would be possible to adjust the cropping patterns so that surpluses and deficits are eliminated or greatly reduced, provided appropriate incentives are given to induce farmers to make such changes. This appears feasible without alteration in IACA's estimates of total water availability. For example, acreage could be changed from rabi fodder to wheat; this would reduce projected fodder surpluses without serious loss to food requirements for the projected livestock production and without major change in the water requirements. Acreage can also be switched easily from gram or oilseeds to wheat. Wheat can be sown later than the final date shown in IACA's cropping calendar (mid-November), which has been used in the projection of cropping patterns and water requirements. This would require water for a pre-irrigation, and late sowing would reduce yields, but despite these qualifications it is nonetheless true that additional wheat acreage could be obtained by planting after mid-November. In fact, recent experience in perennial canal commands in the Punjab, based on IACA's Watercourse Studies, shows that about 45 percent of the wheat acreage was planted in the second half of November or later. There is a pressing need for the agricultural research and extension services to pursue investigations to determine which new crops can be introduced with advantage in the future and to develop the necessary information on cultural practices, costs, and probable returns.

As previously explained, IACA's Comprehensive Report and this report tend to focus attention on the canal irrigated portions of the Indus Basin, but the future contribution from the sizeable uncommanded and mainly nonirrigated areas should not be overlooked. Where cropping depends on rainfall, or residual soil moisture from flooding, the concepts of cropping intensity and cropping pattern cannot be applied directly. Since the area involved is not fixed, as in a canal command, and the supply of water is uncertain from one year to the next, without private tubewell development there can be little planned change in land and water use. In those areas not served by private tubewells, farmers will have little choice but to adjust to the cropping opportunities presented by the play of natural forces. IACA's projections therefore indicate little change in the proportional allocation between crops on the nonirrigated land, but they do show a gradual increase in the area cropped. The latter is expected to come about as a result of private tubewell installation, improved technology, increasing pressure of population on the land, and because gradual farm mechanization may make timely sowing possible over a larger area than at present. Soil conservation and grazing protection programs may increase the output from livestock supported on grazing land, and IACA estimates that this would help to double the production of livestock nutrients from noncommanded lands. The Study Group believes that farmers in the noncommanded areas could improve production by private tubewell installation where conditions permit, and by better farm practices and increased use of agricultural inputs, but agrees with IACA that there are only limited opportunities to change the combination of crops which are grown on the nonirrigated areas.

Livestock Production Potential

At West Pakistan's present stage of development, draft animals are the main source of power for farm operations. While some of the larger farms have begun to employ tractors and other mechanized equipment, they are a very small minority among all farms. The agriculture sector's heavy dependence on animal power means that an important part of the available land, irrigated and nonirrigated, must be reserved for the support of the livestock population. Moreover, development planning must make provision for the animals needed for farm work in years to come. Farm mechanization would continue to spread, but the small size of so many farms in West Pakistan would limit their participation in this development and necessitate a substantial reliance on animal power. Development planning must also take into account the probable change in diet associated with rising per capita income levels in all sectors of the economy—a change which should bring higher per capita consumption of milk, dairy products, and meat. Whether speaking of work animals or production animals, qualitative improvement in livestock would require increased fodder intake per animal, either to increase draft power or production efficiency, and this aspect must also be included in planning estimates. For reasons such as these, the livestock portion of the agricultural sector would constitute an important component of total production and would absorb a significant portion of resources for development.

The IACA framework for projecting the livestock component starts with an estimate of the livestock population in 1965 derived from the Livestock Census of 1960 adjusted to allow for changes during 1960-65. These data on West Pakistan livestock, while admittedly of uncertain quality, have been used in the absence of any alternative that appeared more reliable. From this bench mark estimate, the size of the bullock herd, which would be the source of draft power on farms, is assumed to decline gradually to half its present number by the year 2000. In the early years between 1965-75, however, the herd may increase somewhat. This later declination would reflect a growing mechanization of West Pakistan farming but does not eliminate the current need for draft animals. A breeding herd for bullocks is also retained, but the size is scaled down in proportion to the decline in the number of working bullocks required. On the other hand, the number of livestock raised for milk production increases substantially, and more than offsets the reduced number of working bullocks. Table 2-20 illustrates these changes over the period 1965-2000. The totals are expressed in actual numbers and in terms of Animal Units (AU), a concept used by IACA as a common denominator to permit estimation of food needs for animals of different categories. The base for an AU is the annual fodder consumption of one bullock.

The figures in the table imply an increase of nearly 40 percent in the total number of Animal Units over the 35-year period. 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.

TABLE 2-20
PROJECTED LIVESTOCK POPULATION
(Actual Numbers and Animal Unit Equivalents)

	1965		1975		1985		2000	
	No. of Stock	Animal Units	No. of Stock	Animal Units	No. of Stock	Animal Units	No. of Stock	Animal Units
	(millions)							
Bovines								
Bulls and Adults	7.4	7.40	6.6	6.60	5.6	5.60	3.7	3.70
Milk Cow Adults	4.4	3.32	3.8	3.11	3.0	2.52	2.0	1.78
Male Followers	1.8	1.39	2.3	1.77	2.0	1.54	1.4	1.08
Female Followers	1.7	1.25	2.4	1.73	1.9	1.35	1.4	0.98
Milk Zebu and Followers	—	—	—	—	0.7	0.58	7.6	6.76
	15.3	13.36	15.1	13.21	13.2	11.59	16.1	14.30
Buffalos								
Bulls and Followers	3.1	3.19	6.4	6.08	10.9	19.92	8.4	7.22
Cows	5.4	6.53	6.9	9.35	9.6	12.97	7.0	10.74
	8.5	9.72	13.3	15.43	20.5	22.89	15.4	17.96
Other Work Animals								
Horses, Camels, etc.	2.4	1.20	2.1	1.05	1.8	0.90	1.0	0.50
Small Animals								
Sheep and Goats	17.0	2.77	20.1	3.16	24.7	3.82	27.2	4.15
Poultry								
Existing Desi Breed	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
GRAND TOTALS		27.18		33.04		39.55		37.69

Source: Prepared from data presented in IACA's Comprehensive Report, Volume 7, Annexure 9, page 110.

Anticipated improvements in pasture management and control would also help to supply some of the additional TDN consumed by the larger herds. Nevertheless, the IACA projections show that fodder production would double between 1965 and 2000. The consumption of TDN per AU of production animals would go from 1,035 kg. in 1965 to 1,395 kg. by the year 2000. Included in this would be enough digestible protein to ensure a reasonably balanced diet for the livestock.

While the method and assumptions employed in arriving at these projections seem appropriate to West Pakistan conditions, the resources employed to produce fodder would generate a surplus of TDN under the IACA demand assumptions. This may be seen from Table 2-21. As discussed in other parts of this report, the Study Group believes that pressures for foodgrain production would bring about some shift of cropped acreage from fodder to wheat and coarse grains.

An important special element in the IACA projections, obscured in the total figures of Table 2-21, is the assumed change in the kinds of the cattle to be raised for milk and meat production. Buffalos provide a major part of the milk production up to 1985, and the projections show an increasing herd size to that date, but a decline from 1985 to 2000 would be offset by increases in the number of dairy cattle from Zebu breeds such as the Sahiwal and Red Sindi. Present numbers of these cattle are small and, in fact, are expected to total only 0.7 million head by 1985. Between 1985 and 2000, however, this herd is estimated to grow to 7.6 million, or at an annual rate of 11.7 percent. This is obviously an extremely high rate of growth, and would be a difficult objective to achieve. Experience elsewhere has shown that a dairy herd can be doubled in 10 years' time, with good management and adequate feed, and this would be a growth rate of 7.2 percent. IACA counts heavily on very widespread use of artificial insemination and expects that the high growth rate can be attained if this is used on about four million cows and followers in the latter part of the 15-year period, 1985–2000. An extract giving a brief summary of IACA's proposals for the organization of Artificial Insemination is given in Annex 9. If an artificial insemination program can be organized to this extent, and particularly if it is introduced at an earlier stage than assumed by IACA, there seems to be no biological reason why the ultimate target of 7.6 million head cannot be reached. It normally requires long periods of time to bring about herd build-up to the extent envisaged here, and much would depend on the economic incentives operating in West Pakistan. While change on this scale may be technically feasible, the Study Group would doubt that its attainment can be realized in practice. Firmer judgment must be based on more detailed study as recommended later.

IACA has translated its projections of livestock development into value terms by concentrating on the milk and meat from production animals, plus an allowance

TABLE 2-21
IACA Projections of TDN Requirements and Supply

	1965		1975		1985		2000
			(million tons)				
Estimated Requirement	28.1		35.7		47.7		52.6
Estimated Availability	28.1		36.9		48.5		62.8
Annual Growth Rate		2.8%		2.8%		2.1%	

Source: Computed from data presented in IACA's Comprehensive Report, Volume 7, Annexure 9, pages 110 and 112.

for hides, skins, wool and other animal by-products. Produce from work animals has not been included in GPV because it is accounted for as a negative item in farm production costs. The value of fodder produced has also been excluded from crop GPV calculations on the grounds that this is later represented in the value estimates for livestock production. The contribution expected from livestock, which includes the value of fodder and crop residues fed to production animals, is shown in Table 2-22.

This table also indicates that conversion of TDN to milk and meat improves from 1965 to the year 2000. One exception to this general picture is the conversion rate for milk in 1975, which is lower than the rate in 1965. This slight drop in the quantity of milk per ton of TDN is because IACA assumes the period 1965-75 is a time of herd build-up when there would be a larger proportion of followers than at later stages. Other than this one case, the overall improvement in conversion rates reflects IACA's expectations that increasingly better-fed animals would be more efficient producers of milk and meat, and also that better breeding practices would result in overall upgrading of the basic stock.

The growth rates projected by IACA would constitute an impressive achievement. To a great extent, the growth of livestock appears to be an adjustment to the large volume of TDN which would be produced under the cropping patterns and cropping intensities assumed for future years, rather than a conscious production policy based on consideration of economic alternatives. Although the livestock projections make allowance for the biological constraints governing production and reproduction, they also depend implicitly on improvements in herd

TABLE 2-22
IACA PROJECTIONS OF AVAILABLE TDN, MILK AND MEAT PRODUCTION AND RESULTING GPV FROM PRODUCTION ANIMALS
(Excluding Draft Livestock)

	1965	1975	Growth Rate 1965–1975	1985	Growth Rate 1975–1985	2000	Growth Rate 1985–2000	Overall Growth Rate
			(% p.a.)		(% p.a.)		(% p.a.)	(% p.a.)
Available TDN:								
Amount (millions of tons)	17.8	26.9	4.2	38.8	3.7	55.5	2.4	3.3
Milk (kg) per ton of TDN	337	331		362		413		
Meat (kg) per ton of TDN	17.3	27.4		33.0		48.6		
Livestock Production:								
Milk (millions of tons)	6.01	8.94	4.0	14.04	4.6	22.91	3.3	3.9
Meat (millions of tons)	0.40	0.84	7.6	1.39	5.6	2.79	4.7	5.7
Gross Production Value:								
Milk (billions of rupees)[a]	2.66	3.95	4.0	6.20	4.6	10.13	3.3	3.9
Meat (billions of rupees)[a]	0.65	1.82	10.9	3.51	6.8	8.33	5.9	7.5
Total GPV (billions of rupees)[b]	3.31	5.77	5.7	9.71	5.3	18.46	4.3	5.1

[a] IACA (Volume 1, page 27) projects milk prices at 16.5 rupees per maund throughout. Data for GPV for meat, derived from IACA totals less milk, suggest a meat price range of Rs. 60 through Rs. 110 compared with IACA's stated range of Rs. 62 to Rs. 94 per maund.

[b] These projections represent the high growth path (Volume 1, page 84) from 1965 to 1975. At the lower path, resulting from 25 percent less TDN production, the 1975 figures would be 5.1 instead of 5.8 billion rupees, and would therefore represent 40 instead of 43 percent of the total GPV to agriculture.

management and selective breeding practices. The latter factors may impose more critical constraints than the availability of TDN. As previously stated, the livestock estimates appear technically feasible, but the Study Group considers them susceptible to downward adjustment in practice, particularly in light of the importance of managerial factors and if demand and marketing opportunities do not expand in accordance with IACA projections.

Livestock production and the growth projected for livestock production is an extremely important factor in agricultural production amounting to some 47 percent of the total GPV of agriculture by the year 2000. In the course of the Indus Special Study, examination of the problems of livestock development has of necessity been based on inadequate data; the discussion is intended to provide little more than a broad indication of what may be feasible and the steps required to bring about the performance projected. The Study Group considers that, in view of its importance and complexity, a special study of the livestock sector is urgently required to establish more accurately its present status, its potential, and to provide a better base for any detailed recommendations regarding the requirements for its development. Such a study should include production and marketing aspects and make more detailed recommendations on the appropriate measures required to bring about the desired improvement and growth.

III

Development of Water Resources

A. THE WATER RESOURCES

Introduction

The total water supplies available to agriculture within the Indus Basin derive from three sources: rainfall which occurs directly on the cropped areas, surface water from the River Indus and its tributaries, and usable groundwater from the aquifers underlying the Indus Plains. Rainfall alone is inadequate to sustain more than a very low level of agricultural production in the semi-arid conditions which prevail over most of West Pakistan. The increases in agricultural production over the past hundred years have been mainly dependent upon the provision and expansion of irrigation supplies which will remain the principal base for future development. This chapter is concerned essentially with the potential development of irrigation by surface water and groundwater within the Indus Plains. The present water budget for the canal commanded areas of the Indus Plains is illustrated diagrammatically in Figure 3-1.[1]

The supply of irrigation water in the Indus Basin can be increased in three ways: (a) by the development of the usable groundwater underlying a large proportion of the Plains; (b) by surface storage schemes that will store the surplus kharif water which flows into the sea; (c) by enlarging the canals to permit greater diversion of kharif river flows. According to the IACA projections and their water development program discussed in succeeding chapters, the relative use of the three water sources would increase as follows (flows measured at watercourse):

MAF

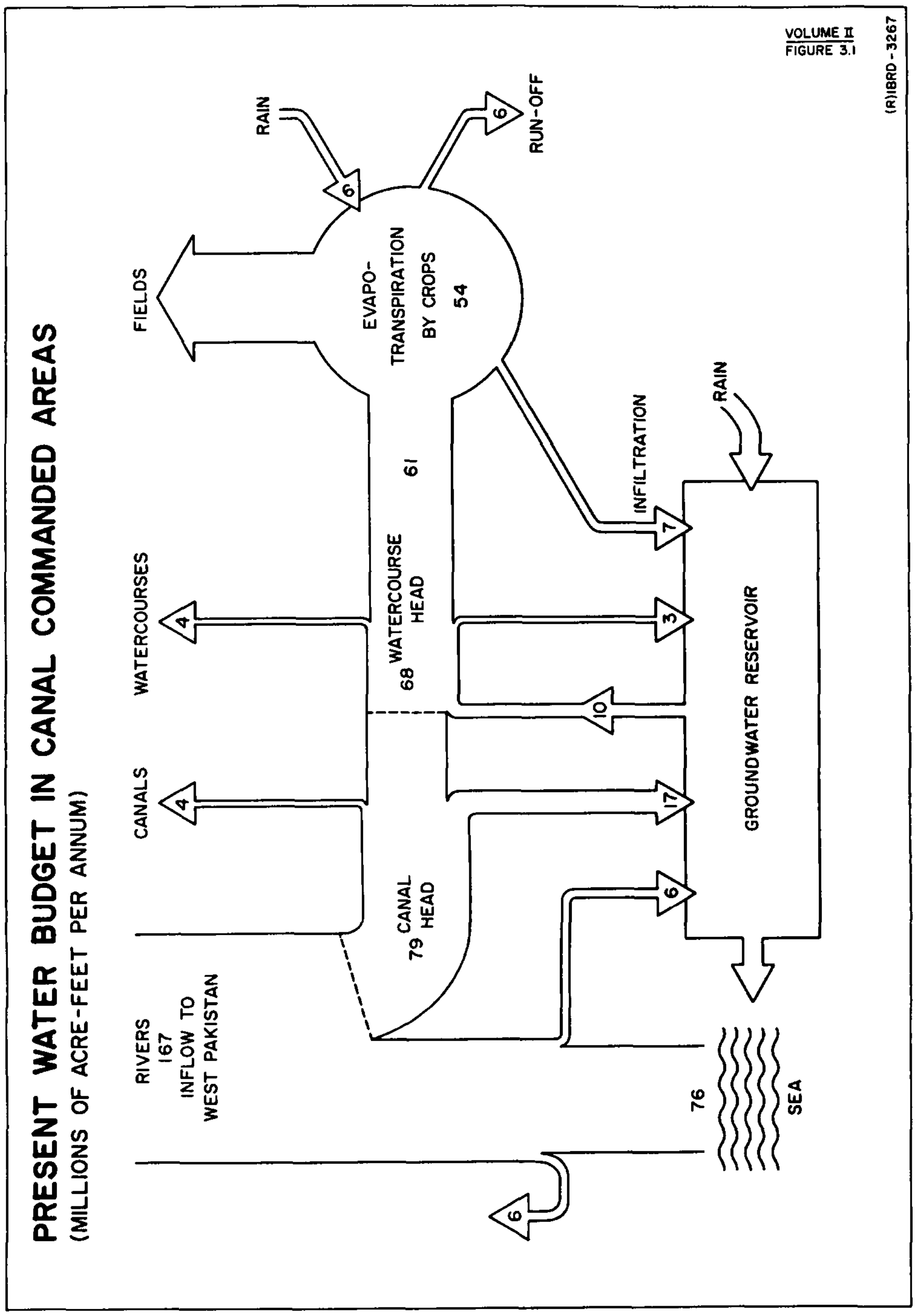
	Present	1975	1985	2000	Increase Percent
Rainfall	6	7	9	10	
Surface Water	58	63	77	91	50
Groundwater	10	30	40	44	340

The comparison shows that the surface water resource is and will remain the dominant contributor to irrigation supplies, but, over the period under review the groundwater resource can provide an increasing proportion of these supplies with the increment for the 1965–75 period exceeding that of surface water.

[1] The figures shown for river inflow and canal head diversions are known fairly accurately but those below canal head are less accurate and below watercourse head they are approximate estimates only.

Rainfall

The mean annual rainfall ranges from less than four inches in parts of the Lower Indus Region to more than 30 inches in the northern foothills (see Map 3). The effective annual rainfall which forms a useful and fairly reliable supplement to irrigation supplies is much less than the total; it ranges from only one inch up to



17 inches. The rainfall not used by crops seeps into the groundwater or is lost to evaporation and surface runoff. Most of the rainfall occurs in the monsoon season between July and September; it is in this period, particularly, that storm drains are required to prevent damage to crops.

The present contribution of rain to crops in the canal commanded areas is estimated at about 6 MAF which would rise to about 10 MAF as the cropped area increases in the course of development. Rain also represents the sole source of supply to much of the cultivated land outside the canal commands.

Surface Water

The rivers serving the Indus Plains are the Indus and its principal tributaries, the Kabul, Jhelum, Chenab, Ravi and Sutlej (Map 3). The rivers have individual flow characteristics but they all rise in the spring and early summer with the snowmelt and monsoon rainfall and have a combined peak discharge in July or August. In the winter flows are much lower. During the period November to February, the mean monthly flows are only about a tenth of those in the summer monsoon (illustrated by the hydrographs on Map 3).

The total annual mean discharge of the rivers entering the Indus Plains of Pakistan and India amounts to 175 MAF a year, of which about 167 MAF a year enters Pakistan. About 79 MAF is diverted into the canal system of West Pakistan and some 76 MAF discharges into the Arabian Sea, with the remainder lost to evaporation and seepage from the rivers. The discharge to the sea is largely concentrated in the summer period of high river flow between about June and September when the canals are already being operated near or at their full capacity levels.

After full implementation of the Indus Waters Treaty, in the early 1970's, India will be entitled to divert all flows of the eastern rivers, the Ravi and Sutlej, for her own use. As shown in Map 3, these two rivers have a combined average discharge of 33 MAF of which about 25 MAF flows into West Pakistan. By deducting this flow from the present available average flow of 167 MAF, the supply for future use in Pakistan will be about 142 MAF, made up as follows:

River	Mean Annual Discharge[1]
	(1922–62)
Indus (including Kabul)	93
Jhelum	23
Chenab	26
Total	142 MAF

[1] Measured at rim-stations—points of entry of the rivers to the Plains.

The median combined flow (exceeded in 50 percent of the years) of these three rivers is only slightly less than the mean, being 140 MAF a year. The lowest combined flow in the period of record was 116 MAF which occurred in 1961/62.

The flow in the Indus follows a more reliable pattern than that of the Jhelum or Chenab. The variation between the mean annual supply and the supply which would be exceeded in an average of three years out of four is only 6 percent for the Indus compared to 15 percent for the Jhelum and Chenab. On the same basis, the variation in monthly supplies extends up to 25 percent in the case of the Indus and up to 33 percent on the Jhelum and Chenab. The provision of storage on the Jhelum and later on the Indus would result in a considerable reduction in monthly variations downstream of the storage dams. The annual variability will also be alleviated over time with the expansion of tubewell fields and, at a much later stage of development, by over-year storage in surface reservoirs.

The storage of summer surplus flows will lead to a more efficient use of surface water resources but it is likely that some flows will still be passed to the sea at all stages of development. However, the principal river flows are supplemented by small tributaries entering the plains and by return flow from drainage effluent. Also the nonbeneficial losses from the rivers will eventually be reduced when plant growth is cleared and the river channels become more controlled. The mean discharge to the plains of 142 MAF a year is therefore considered to be a reasonable estimate of the surface water resource which is available for the development of irrigation. Domestic and industrial consumption is likely to remain relatively very small compared to the irrigation uses and has been allowed for by IACA in the calculation of system losses.

When compared with the present average canal head diversions of 79 MAF a year, the combined mean discharge of the Indus, Jhelum and Chenab of 142 MAF indicates the considerable potentiality that exists for future surface water conservation and use in West Pakistan.

The Indus and its tributaries carry large quantities of silt during the flood season and the average sediment transport is estimated at 700 million short tons a year which would have a deposited volume of about 0.4 MAF. Siltation would thus cause a significant rate of depletion in the volume of future reservoirs, particularly on the Indus main stem where the majority of the sediment flow occurs.

Groundwater

The Indus Plains, stretching from the foothills of the Himalayan Mountains to the Arabian Sea over a distance of nearly 1,000 miles, are composed of deep alluvial deposits which form an extensive groundwater aquifer of great potentiality covering a gross area of some 40 million acres. Before systematic irrigation was started, the groundwater table was well below the surface and the aquifer was in a state of hydrological equilibrium. The recharge to the aquifer from rivers and rainfall which probably amounted to some 10 MAF a year mainly in the north was balanced by outflow in various forms. When large-scale canal irrigation was introduced, percolation to the aquifer was greatly increased in the irrigated areas. Today the recharge is three- or fourfold that of the natural state with the result that the water table has risen to within 10 feet of the surface over almost half the canal commanded land. Furthermore, in about a sixth of the irrigated areas the groundwater table is estimated to have risen to within about five feet of the surface causing problems of waterlogging and soil salinity in some two million acres in these areas. Despite the problems of waterlogging the development of irrigation on the Plains has in this way created a valuable source of water with large potentialities that are discussed later in this chapter.

Outside the Indus Plains there are other opportunities for groundwater development, but they are on a relatively limited scale and at present little information is available on them. It is, however, clear that tubewell development outside the Plains would have to be restricted to small groups of wells and furthermore the potential yields of the scattered aquifers would be small on account of the arid conditions that exist over so much of the country. Areas of more significant potentialities appear to be the Bannu Basin, the Warsak-Peshawar area and the Potwar Plateau, but no general assessment of their resources has as yet been made.

Two basic factors in groundwater development are the physical characteristics of the aquifer and water quality. The physical characteristics of the alluvium of the Indus Plains are generally very favorable to tubewell development except in parts of the Lower Indus Region where some deposits of low permeability occur. The quality of the groundwater is more variable as may be seen from Map 3. It is, however, estimated that some 19 million acres of CCA lie over usable groundwater of which 14 million acres contain fresh water that may be used directly on the crops and the remaining five million acres has groundwater of intermediate salinity which requires mixing with fresh surface water to make it suitable for irrigation.

IACA has given particular attention to the requirements for quality of irrigation supplies in order to establish criteria for groundwater development.[1] An important conclusion reached was that water containing not more than 1,000 parts per million of total dissolved solids is suitable for direct use on the crops.

From a study of a large number of individual groundwater analyses, IACA has found that in most cases the 1,000 ppm TDS criterion embraces also an acceptable level for the other criteria and is therefore satisfactory for general planning purposes. Eventually it might be possible for water of higher salinity to be used directly on the crops but that would require an increased application of water and a degree of control which IACA does not regard as feasible at present or in the near future and which would require the assumption of lower yield levels and different cropping patterns.

IACA has considered the salinity of groundwater at a depth of 300 feet in order to classify the groundwater resource in terms of the following general zones:

Fresh groundwater zones, where tubewell water can be applied directly to the crops. Deep groundwater quality is less than 1,000 ppm TDS.

Mixing zones, where tubewell water has to be diluted by surface water before being used for irrigation. Deep groundwater quality is of intermediate salinity, being more than 1,000 ppm TDS but less than 3,000 ppm TDS in all areas except the Lower Indus Region where a limit of 2,000 ppm TDS is applied. The lower limit in the Lower Indus Region allows for the more rapid increase of salinity with depth of the aquifer than in the northern plains and for the higher salinity of the river water after it has received drainage effluent.

Saline groundwater zones, where the groundwater would not be used for irrigation. Deep groundwater quality is more than 3,000 ppm TDS in the northern areas and more than 2,000 ppm TDS for the Lower Indus.

It may eventually become feasible to employ skimming techniques in the saline groundwater zones to utilize the upper and less saline layers of the aquifer. However, this would require further investigations and careful control in actual operation. The proposed criteria for use of groundwater for irrigation are summarized below in Table 3-1.

[1] IACA considered that water with the following properties could be used directly for irrigation:

EC of less than 1.50 mmhos per cm. at 25°C, approximately equivalent to 1,000 ppm TDS. (EC is electrical conductivity which relates to the salinity hazard.)

SAR of less than 10. (SAR is sodium adsorption ratio which defines the alkali hazard.)

RSC of less than 2.5 m.e. per liter. (RSC is residual sodium carbonate and is an expression of the deleterious concentration of carbonates and bicarbonates.)

TABLE 3–1
PROPOSED MIXING RATIOS FOR OVERALL BASIN PLANNING

Groundwater Quality Zone	All Regions except Lower Indus: Deep Groundwater Quality (ppm TDS)	All Regions except Lower Indus: Average Mixing Requirements (Surface Water to Groundwater)	Lower Indus Region: Deep Groundwater Quality (ppm TDS)	Lower Indus Region: Average Mixing Requirements (Surface Water to Groundwater)
Fresh	Less than 1,000	No restriction	Less than 1,000	No restriction
Mixing	1,000–2,000	1:1	1,000–2,000	1:1
	2,000–3,000	2½:1		
Saline	More than 3,000	Not used	More than 2,000	Not used

The extent of areas of the different groundwater quality zones is shown below by regions in Table 3-2. The fresh groundwater and mixing zones together represent the usable groundwater and have a gross area of 18.8 million acres or over half the recorded CCA of the Basin and about two-thirds of the CCA included in IACA's development plan (see Chapter V). The physical characteristics of the aquifer are such that all the usable groundwater zones can be developed by well fields although the capacity of the well would be more restricted in the Lower Indus Region than in the northern plains. Well fields are also feasible for drainage of the saline groundwater zones except in parts of the Lower Indus Region.

The uppermost 100 feet of the usable groundwater in the irrigated area of the Plains stores about 300 MAF of usable water, equivalent to a latent resource of 400 MAF when reuse of the recharge from pumped groundwater is taken into account. The storage of groundwater is dependent on the inflow or recharge to the aquifer relative to the withdrawal or discharge from it. Recharge is derived from: (a) losses from rivers, canals and surface drainage channels; (b) irrigation losses from watercourses and fields; and (c) percolation of rain. Discharge is affected by: (a) natural agencies of evaporation, base flow to the rivers and basin discharge downstream; and (b) extraction by tubewells, Persian wheels and horizontal drains.

The recharge to the aquifer represents the main source of groundwater supply since it is being constantly renewed. The usable groundwater recharge is at present estimated at slightly over 30 MAF a year, of which about 10 MAF are pumped for irrigation. With full development of surface water resources and of the

TABLE 3–2
REGIONAL GROUNDWATER QUALITY ZONE AREAS

Region	Fresh	Mixing	Saline	Total
	(million acres of development CCA)			
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

canal system, the available usable recharge would rise to about 44 MAF a year. A further quantity of about 27 MAF a year would percolate to recharge in the saline groundwater areas and would require tubewells or tile drainage together with disposal works when the water table rises to near ground level.

The estimated recharge to the aquifer under the IACA projections for development would be as shown below (MAF)[1]:

	1975	1985	Full Development
To Usable Groundwater Zones	34	41	44
To Saline Groundwater Zones	15	18	27
Total Recharge:	49	59	71

[1] See also Figure 5.2.

B. THE IRRIGATION SYSTEM

Present Situation

The canal system was started in the nineteenth century when weirs and barrages were constructed so that the supply of irrigation water would be no longer so dependent on the natural variations in river level as it was in the old inundation canals. Since Independence in 1947, Pakistan has continued this extension of the canal system and almost all the areas previously served from inundation channels are now served from barrages. While barrages permit a more reliable command of the land they do not provide significant water storage.

The early weirs and barrages were mainly on the Indus tributaries in the Punjab and in the Peshawar area and more recently emphasis has been placed on the main Indus stem with Sukkur, Jinnah, Taunsa, Gudu and Ghulam Mohammed barrages (see Map 7).

The canal systems were generally designed to command as much land as possible, particularly crown waste, so that maximum returns would be obtained from the sale of project lands and from subsequent taxation. For this reason, the cropping intensities adopted for the designs were low and were often about half the intensities which the land would be capable of supporting. In the early stages canal systems were developed for perennial or year-round cropping but later, as the limited rabi supplies became fully committed, nonperennial systems were built essentially, though not exclusively, for summer crop production.

The irrigation system of the Indus Plains commands a gross area of about 38 million acres and comprises some 38 thousand miles of canals. By 1971, after completion of works under construction under the terms of the Indus Waters Treaty, the main and link canal headworks would be served from a major storage dam at Mangla, 16 barrages, three weirs and a hydroelectric power dam at Warsak (see Map 6).

The total irrigated area is covered essentially by 42 principal canal commands of which four are being partitioned by the link canals now under construction. The total CCA is officially stated to be 33.5 million acres, though in practice no more than about 25 million acres receive surface water supplies; the rest is classified as culturable waste and a large proportion of it is in the Lower Indus Region. About

20.3 million acres of the total CCA are at present designated for year-round perennial supplies of canal water and about 13.2 million acres designated for nonperennial supplies usually from mid-April to mid-October. Nonperennial areas do, however, receive occasional rabi water and some years fairly consistent deliveries reach the farmers, but not as a right and only when the river flows are surplus to the requirements of the perennial areas. With these irregular rabi supplies, supplemented by Persian wheel and tubewell water, rabi intensities often reach levels comparable with those in perennial areas.

The total area now remaining on the old inundation canal system is relatively small, amounting to about 100,000 acres.

Persian wheels, normally powered by animals, have always made an important contribution to irrigation in rabi, in perennial, nonperennial and noncommanded areas. It is estimated that there are about 200,000 Persian wheels in the Basin, but the discharge of even an efficient one is only about a tenth of a cusec and on average they are operated for only about 1,000 hours a year. Recently there has also been considerable activity by enterprising farmers in the installation of tubewells as a means of pumping groundwater for irrigation. IACA estimated that about 32,000 private tubewells with an average capacity of about one cusec each had been installed in the Indus Basin by 1965. More recent estimates of the 1965 situation indicate that the number of private tubewells in operation may be as high as 34,000. About one-third of the private tubewells are operated by electric power and the remainder by diesel engines.

A river barrage feeds one or more main or link canals. Many of the canals are very large indeed and practically all of them are unlined. Fifteen of them have capacities of between 10,000 and 22,000 cusecs. The main canals serve the irrigated areas whereas the links perform bulk transfers of water from the major sources on the western side of the former Punjab to the vast irrigated areas to the east. A main canal and its branches feed a number of distributaries or minor distributaries, with capacities of up to about 200 cusecs, and these in turn serve outlets to the farmers' watercourses. The watercourse area is generally between 150 and 600 acres in extent and the ratio between outlet capacity and watercourse area is determined for a given climatic zone by the originally assumed cropping pattern and intensity.

A feature of the canal system is the absence of intermediate regulators along the distributaries and minors. The latter are designed to run in a form of hydraulic equilibrium, maintaining sufficient head of water on each outlet to give it an almost constant discharge. For this reason they cannot be run at less than about three-quarters of full capacity without creating a very inequitable distribution to the irrigated lands they command. On the other hand, the main canals themselves have sufficient control structures to permit variations in flow down to about a third of full capacity.

Thus, the canal system has been designed to take variable flows from the rivers up to the limit of the canal capacity, yet deliver to the farmer a fairly constant flow. This necessitates a system of rotated closures of the distributaries during periods when less than full supply conditions are in operation owing to either reduced availability or reduced demand. Within the watercourse area a cultivator usually has a fixed time during which he is entitled to the whole of the flow in the watercourse channel.

The time allotted to a cultivator for the duration of his irrigation supply from a watercourse is directly proportional to the size of his holding in relation to the culturable area commanded by the watercourse. The schedule of cultivators' turn times, authorized by the Irrigation Department, is known as the "warabandi." When the cultivators decide the turn times themselves by joint agreement, the schedule is known as the "kacha warabandi," and is usually applied to watercourses with a small number of relatively large holdings. As the number of holdings per watercourse is rising and their size decreasing, it is becoming necessary for the number of watercourses operated by the warabandi system to be extended so as to ensure that the smallest landholder receives his proper share of the supply.

Once a warabandi has been drawn up it will stand indefinitely unless a successful petition for change is made to the District Canal Officer. In order to avoid indefinite night watering by some of the cultivators the warabandi is rephased by 12 hours annually. If, owing to canal closure, turns are missed there is no adjustment to compensate for the loss of water and the unfortunate cultivators must wait for their next established turn.

The water that is diverted into the canals has a sediment concentration approaching that of the river source, though every effort is made in the design and operation of the headworks to reduce the silt intake.

The canals are designed and built to such proportions that they would run without undue scouring or silting when operating under normal conditions of discharge but all problems of silting and scouring cannot be eliminated. Silting occurs at localized points, usually in the middle and tail reaches, and scouring is mainly experienced in the head reaches. Various devices are applied to the operation of the canals to rectify these occurrences but at times the canal design has to be modified. The farmers' watercourses are particularly subject to siltation and here the sediment is excavated by the farmers as part of the general maintenance.

Up to the present there has been virtually no development of surface storage to regulate the river flows. The only large dam, at Warsak on the River Kabul, is used primarily as a regulator for hydroelectric generation. The commissioning in 1967 of Mangla Dam on the River Jhelum, with an initial live capacity of 5.2 MAF,[1] would complete the first major storage scheme. The Mangla storage would, however, serve essentially as a replacement for the loss of flows from the Ravi and Sutlej Rivers. The raising of Chasma Barrage will provide additional storage of 0.3 MAF.

As with many irrigated areas developed in arid and semi-arid zones over the last century, there is very little drainage provided in the Indus Plains, either subsurface drainage to control the water table or surface drains to remove excessive runoff. The lack of subsurface drainage has gradually become a serious constraint on crop production and is being combatted by an ambitious series of salinity control and reclamation projects (SCARP's) the first of which was commenced in Rechna Doab in 1959. By 1965 some 2,500 public tubewells with capacities of between two and five cusecs each had been installed over an area of about 1.2 million acres in the whole of SCARP I, covering the central part of Rechna Doab, and the first part of SCARP II in Chaj Doab. These SCARP tube-

[1] IACA used a live storage capacity of 4.5 MAF based on a drawdown level of 1075 feet and the exclusion of the contents of the Jari Arm. Subsequently, WAPDA decided to abstract storage from the Jari Arm and to allow for drawdown to 1040 feet, thus providing 5.2 MAF.

wells have provided a valuable increment to irrigation supplies in the areas they serve.

The estimated irrigation deliveries to the watercourse from all sources under 1965 conditions are as follows:

		MAF/Year	
Surface Water:			
	Canals	58.0	58.0
Groundwater:			
	Public Tubewells	2.7	
	Private Tubewells	5.3	
	Persian Wheels	1.7	9.7
Total Watercourse Deliveries:			67.7

A further quality of about one MAF a year is estimated to be pumped by private tubewells and Persian wheels to cultivate land outside the canal commanded areas of the Indus Plains. The division of the present watercourse deliveries by regions is shown in Table 3-3. The Rechna and Bari Doabs, accounting for 32 percent of the total designated CCA of the Plains, receive nearly 80 percent of all groundwater supplies, 27 percent of surface supplies and 35 percent of all present watercourse deliveries. Since crop water requirements are slightly below average in these less arid regions, they thus receive a favorable proportion of the present water supplies. The Lower Indus Region receives a share of water which is proportionate to its designated CCA but in this case more than one-quarter of the CCA is in fact unused.

The practice of underwatering crops, as stated in Chapter II, is widespread and IACA estimates that more crops receive on average about 80 percent of full delta requirements. Exceptions occur in the developing commands on the Indus main stem where the intensities have not yet reached the design levels. This includes parts of the Lower Indus Region and the Thal. As would be expected, underwatering is most severely applied to crops grown in rabi in the nonperennial areas when some element of hazard must inevitably be accepted by the farmers.

TABLE 3-3
SUMMARY OF WATERCOURSE DELIVERIES BY REGIONS—1965 CONDITIONS
(MAF/year)

Region	Canal[a]	Public Tubewells	Private[b] Tubewells	Total	Feet Per Acre CCA
Vale of Peshawar	1.7	0.0	0.0	1.7	2.9
Thal Doab and Indus Right Bank	5.6	0.0	0.7	6.3	1.7
Chaj Doab	3.2	0.2	0.4	3.8	1.9
Rechna Doab	6.6	2.5	2.1	11.2	2.4
Bari Doab	9.0	0.0	3.1	12.1	2.1
Sutlej and Panjnad Left Bank	6.4	0.0	0.6	7.0	2.0
Lower Indus	25.5	0.0	0.1	25.6	2.9
Total Canal Commands	58.0	2.7	7.0	67.7	

[a] Based on recent average deliveries. [b] Including Persian wheels.

Main Characteristics and Constraints of the Present Irrigation System

The principal characteristics of the present Indus Basin irrigation system may be summarized as follows:

(a) Canal irrigation is dependent on natural river flows until major storage reservoirs come into operation.
(b) A large part of the irrigable land of the Punjab is on the eastern side whereas the preponderating water supplies are on the west.
(c) Almost throughout the Basin, the canal system has been designed for much lower cropping intensities than are presently required.
(d) The system is designed to deliver an almost fixed flow into the farmers' watercourses from distributaries that flow in hydraulic equilibrium without intermediate regulators. Flows below about three-quarters of full supply cannot be delivered through the system except by the rotation of distributary supplies.
(e) In many parts of the system a rapid advance is now being made towards the exploitation of the vast groundwater aquifer underlying the Plains.

Cropped acreage everywhere has almost expanded up to the limits of the present irrigation system, except in some of the still developing commands of the Indus served by Jinnah, Taunsa, Gudu and Ghulam Mohammed barrages. Over vast areas covered by the older parts of the system, the area cropped has gone beyond the water supplies based on the originally designed intensities, resulting in widespread underwatering.

The main deficiencies of the present system as they relate to present and future needs were found by IACA to be the following:

1. The amounts of water available to the cultivators in rabi and late and early kharif are too unrealiable and are inadequate to sustain optimum crop production.
2. In some areas, the canal capacities are inadequate to achieve optimum kharif intensities and this constraint will have an increasing impact as intensities rise.
3. In the longer term, distributary and watercourse flows will prove too inflexible for proper water economy.
4. Lack of subsurface drainage causes, directly or indirectly, adverse effects on crop growth.
5. Lack of surface drainage causes crop losses and yield reductions in the upper northern and lower southern regions.

These constraints and the works required to remove them over time are discussed in the following parts of this chapter and in Chapter V.

C. POTENTIAL DEVELOPMENT OF WATER RESOURCES

Introduction

In the next two decades there is no likely shortage of water resources. It is the feasible rate at which the water potential can be further exploited that will largely govern the rate at which irrigated agriculture can be intensified and extended. Subsequently, as cropping intensities rise, further development of irrigated agriculture in the Indus Basin will be increasingly constrained by water rather than land. IACA has demonstrated in the analyses of its projections, discussed in Chapter V, that even with full development of the total groundwater and surface water potentialities there is unlikely to be sufficient water to meet the crop water requirements at the estimated attainable cropping intensities over the whole of the presently designated CCA. As explained in Chapter V, IACA has, for this and other reasons, advocated a policy of intensification of existing irrigation rather than extension into new areas. Under the IACA proposals the present canal irrigated area of 25 million acres would be expanded to 29.5 million acres and brought to full intensity and full farming efficiency. This would leave some four million acres of the presently designated but partly uncultivated CCA of 33.5 million acres undeveloped. This is in accordance with the recommendation of the LIP consultants, who maintain that there is about 3.5 million acres of designated (but not developed) CCA in the Sind that is of very inferior quality and has been abandoned or is basically unsuitable for development in conditions of water shortage. A further 0.5 million acres will be required for roads, canals, dam sites, etc. Alternatively, if the full 33.5 million acres are to be developed it would have to be at a correspondingly lower cropping intensity with water used on inferior lands.

The rate at which water resources can be further exploited depends largely on the sources and mode of development. The most rapid progress can clearly be made with tubewell construction by both private and public undertakings because this method of supply can be applied progressively over the usable ground zones of the Plains and is not initially dependent upon other major works which might take time to build, thus hindering this early realization of benefits.

Enlargement of the irrigation canals, on the other hand, is not only a slow process in itself, owing to the complex land acquisition and other administrative and technical problems that it gives rise to, but little can be achieved without the associated enlargement of the feeder or link canals and, furthermore, most areas require drainage before the additional water from larger canals can be served onto the land. In general therefore canal enlargement would follow after tubewell installations and represents a longer term means of using more of the available surface water resources. Surface water storage in the Indus Basin again involves a long-term measure solely for the reason that it can be effected only through the construction of very large dams such as Tarbela and Mangla which take many years to plan and construct.

Groundwater

Objectives of Tubewell Development. The traditional function of Persian wheels and the recent trend to install private tubewells demonstrate that the concept of using groundwater for irrigation has long been accepted in West Pakistan and that the farmers are moving rapidly to the more advanced method of abstraction provided by the modern tubewell.

The main objectives of groundwater development are to increase agricultural production by provision of additional irrigation supplies and by control of the water table. As for additional supplies with more tubewells and with higher recharge to the aquifer from enlarged canals, but without depletion of the natural groundwater reservoir, IACA estimates that about 44 MAF of usable groundwater could be made available for irrigation each year, compared to the present total groundwater abstraction of about 10 MAF a year. The purpose of controlling the water table is to remove the ill effects of high groundwater on crop production; for this purpose, it is necessary to establish a means of control that will prevent the water table from remaining within about five feet of the surface except for short periods or in the rice areas. This control can be obtained by tubewells with the added advantage of additional irrigation water where they are placed in usable groundwater zones.

IACA expects the contribution of Persian wheels to dwindle to very small proportions over the next decade and to be replaced and greatly increased by the rapid expansion of tubewell installations under private and public control.

IACA has given particular attention to the respective rates of private and public tubewell development in the attainment of the above objectives. Although in the long term IACA foresees the need to bring groundwater abstraction under public control in order to integrate it efficiently with the already publicly controlled surface sources, and their whole water demand and distribution program is firmly based on this concept, their approach to planning for the next 10 to 15 years is more flexible and seeks to take best advantage of both public and private activity. By promoting private and public tubewell development in selected parts of the Indus Basin, it should prove possible to accelerate the rate of exploitation of groundwater resources.

In both cases IACA has assessed the likely rates of development, which are discussed in this Section below. Priorities for public development have been allocated to those areas where economic analyses indicated that a better rate of return and faster growth in production may be achieved by public rather than private wells. IACA's proposed policy would therefore emphasize the early development of usable groundwater zones, by allocating appropriate priorities in the case of public tubewells and by private initiative on the part of farmers who sink their own wells.

By 1975, according to the IACA program, private and public tubewells would extract some 85 percent of the current usable groundwater recharge. The program for groundwater development put forward by IACA would produce 32.8 MAF in 1975, 45 MAF in 1985 and 50.5 MAF in the year 2000. Details are given in Table 3-4. The relationship between groundwater exploitation, total water demand and distribution is discussed more fully in Chapter V.

Water Table Depth and Potential Groundwater Mining. Control of the water table by public tubewells allows some choice in the level at which the water table should be maintained. The need to maintain the water table sufficiently below the surface to avoid salinity and waterlogging is agreed by all who have examined the

TABLE 3-4
RATE OF GROUNDWATER DEVELOPMENT
(MAF/year)

	1965	1975	1985	2000
Private Tubewells (in CCA)	5.3	7.0	3.5	—
Public Tubewells	2.7	22.0	36.5	44.0
Persian Wheels	1.7	1.0	—	—
Total in CCA:	9.7	30.0	40.0	44.0
Private Tubewells Outside CCA	1.0	2.8	5.0	6.5
Total	10.7	32.8	45.0	50.5

problem, but expert opinions have diverged widely on the question of whether fresh groundwater should be continuously pumped to greater depths. IACA points out that the economic cost of mining[1] is substantially more than that of the immediate pumping involved since allowance must be included for the considerable extra cost of pumping normal recharge from a greater depth in perpetuity. The effective economic cost in terms of power alone to mine an acre-foot of water from an acre of the aquifer is calculated at Rs. 37 per acre-foot mined compared to Rs. 7.5 per acre-foot pumped with groundwater abstractions balanced by recharge at about 10 feet. If, however, mining were to form a part of policy for using groundwater resources, allowance would also have to be made for higher capital costs because of the need to penetrate to greater depth. The effective total economic cost of mining to a depth of about 100 feet over a period of 30 years is calculated at Rs. 63 per acre-foot mined, compared to a total cost of Rs. 17 per acre-foot pumped with groundwater abstractions balanced by recharge at a depth of 10 feet.[2]

The effective cost of mined water is therefore comparatively high and of the same order as surface storage water. However, IACA has stressed that mining cannot be considered in terms of economic costs alone and that there are a number of technical and operational factors which would require detailed analysis before mining could be accepted. The most important of these technical factors is the possible intrusion of saline groundwater, either from adjacent saline groundwater zones down the steep gradient which would have been introduced by mining in the fresh groundwater zones or from the underlying levels of the aquifer. The problem of intrusion from adjacent saline groundwater zones would result in curtailment of the areas of potential mining and most probably in a requirement for deep and expensive saline drainage wells to prevent intrusion. The problem of the increasing salinity of groundwater with depth means that the possibility of mining would have to be rejected throughout almost all the Lower Indus Region and probably in parts of the Bari Doab as well as possibly in certain other areas.

From the operational standpoint, mining would be of value only when it provides water at times of scarcity, e.g. during critical periods of the rabi season and early and late kharif. However, in a number of areas where mining might technically be considered, the pumping of normal recharge would be adequate to meet the requirements for scarce water of the projected cropping intensities. For mining to be valuable in such areas collector and conveyance channels would have to be constructed to transfer the mined water to other areas and this would add extra costs and would require works which would not be feasible within the proposed Action Program. As a possible alternative to surface storage mining is therefore limited primarily by its lack of flexibility in terms of the place at which the mined water could be provided and furthermore by a possible deterioration of water quality. Also, if considered as an alternative to surface storage, allowance would have to be made for the loss of normal recharge attributable to the storage water from losses in the rivers and canals. It is clear that examination of mining on a general basis in the Indus Plains would be misleading. Detailed studies of the characteristics of different areas would have to be undertaken in order to determine the potential for mining.

[1] Continuous overpumping of the groundwater reservoir without replacement is referred to as mining.

[2] See Annex 4 for IACA's estimates of the costs of groundwater mining and also Chapter IV for cost of recharge pumping.

Because of these economic, technical and operational considerations, no general case is foreseen at this stage for widespread mining of groundwater, although special cases could arise in particular areas. Rather it is concluded that the main emphasis on groundwater development in the Action Program should be on the installation of sufficient tubewells to enable the annual recharge to be extracted. There are, however, considerable advantages in temporary overpumping in order to meet demand at times of low surface water availability and in anticipation of surface storage projects. Additional pumping would lower the water table which would then be raised again at times of higher than normal surface water availability or with the introduction of new storage water. Deep pumping can also be justified in certain areas such as Upper Rechna Doab where Tipton and Kalmbach Inc.[1] have shown in the SCARP IV Project Report that a maximum equilibrium depth of 80 feet may ultimately be desirable near the center of the well field. In a similar way, deep pumping to induce additional recharge from the river might be a promising future development in an area such as Panjnad.

After the water table has reached an equilibrium level, abstractions from the aquifer should be balanced by recharge to the aquifer over a period of years, though not necessarily in any one year. IACA have indicated that a satisfactory average level of the water table would be about 10 to 15 feet below ground level, but it should be recognized that such a generalization could not be applied to all project areas. The actual level of the water table would depend on the degree of temporary overpumping required to meet temporary deficiencies in surface water supplies and also on the local topographical and hydrological conditions. The water table would sometimes thus be deeper than the average of 10 to 15 feet at times of temporary overpumping and at locations away from the sources of recharge such as rivers and canals.

Tubewell Planning and Design. The objectives of public tubewell fields and the policy for their siting in relation to provide tubewell areas, as proposed by IACA, call for certain changes in emphasis in what have hitherto been official lines of action.

Firstly, the main objective being to supply additional quantities of irrigation water, the previous emphasis on salinity control and reclamation is no longer appropriate. The latter becomes a secondary though not unimportant function of tubewell development. This does not, however, set aside the need to accord certain project priority to areas where waterlogging is now either prevalent or imminent; this will be discussed in due course.

Secondly, in order to derive the optimum combined benefits from both the public and private sectors, it will be necessary to depart from the concept of large development entities and adopt a plan that omits areas where private progress is favorable or can be expected to become so. This would result in smaller projects. It is, however, proposed that public tubewell projects should not be smaller than about 500 wells, unless exceptional circumstances exist, because units of lesser size would lead to constructional and administrative inefficiencies. Public tubewell projects should in general be designed to cover entire areas within which the development characteristics and constraints are as similar as possible and in so doing should embrace either whole canal commands or large parts of canal com-

[1] Consultants to WAPDA for Regional Planning in the Northern Zone.

mands in order to facilitate integration with surface water supplies. The smallest component of a project would be the area served by a distributary canal.

The first major tubewell field constructed in the Indus Plains, SCARP I, employs steel screens, some of which have within a few years of coming on flow suffered from corrosion, leading to a reported reduction of discharge in parts of the project area. This does not detract from the fact that SCARP I successfully fulfills its function in terms of the removal of waterlogging and the provision of the large quantities of groundwater which are abstracted annually. New well fields are now being constructed with fiber glass screens which are resistant to corrosion and there is every reason to believe that such material will give satisfactory service.

Public tubewells would be operated by electrically powered shaftdriven pumps as in the current SCARPs. The hydrological quality of the aquifer is high throughout most of the Indus Plains and its permeability is such that wells of about 300 to 350 feet in depth will give the favorable yield of between three and five cusecs. The present practice of discharging tubewells into the heads of watercourses or groups of watercourses is endorsed by IACA. In this way, canal enlargement as such would not be required but enlargement of the watercourses would be necessary.

Whereas the public well fields would completely cover large areas, private tubewells would be installed individually to serve a number of quite small areas. At present, private tubewells vary in quality of construction, in the area served, in capacity, and utilization. The construction, in some cases, is very crude and unreliable while in others it approaches the level of public tubewells. A typical private tubewell is of about one cusec capacity serving an area of about 100 acres and pumping from about 180 to 200 acre-feet of water a year (equal to a rate of utilization of around 27 percent).

Rate of Public Tubewell Development. The predominant factor in IACA's projected rate of development of groundwater resources over the next 10-15 years is the feasible rate at which tubewells—both public and private—can be installed.

The principal factors that determine the overall rate at which public tubewell projects can be installed are: investigations and detailed project preparation; the processes of decision making and administrative procedures, including contracting; the drilling and equipping of the wells; and the distribution of electric power. An additional factor which is associated with these technical considerations is the rate at which personnel can be trained in readiness for the staffing of the projects when they come into operation.

Before the construction of a tubewell project can proceed, the preliminary work necessary would include surveys to provide the latest information on watercourse locations and capacities and the culturable areas commanded and noncommanded, as well as to determine the aquifer conditions and groundwater quality zones where these are not already known. Studies of available soil data and land classification, possibly with supplementary surveys, will also be necessary in addition to seepage tests for the estimation of recharge. The analysis of the operational requirements and the design of the project would follow the receipt of this information, and it would normally take a year or more to carry out this work, depending upon the information already available and the extent and nature of the individual projects. After a detailed project report has been prepared, it would be advisable to allow a further six months for its consideration for financing to be arranged and for a decision to be reached to proceed with the project. The remaining preliminary stages leading to the construction contract could normally be expected to proceed as follows: finalization of project design and preparation of contract documents—six months; tendering period—three months; and review of tenders and award of contract—three months. The duration of preliminary activities from the commencement of field investigations to the start of project works can, therefore, be expected to be two-and-a-half years or more.

In the case of projects included in the Action Program (Chapter IV), the phasing of their construction is determined largely by the state of preparation of the field investigations. In some of the project areas concerned, such as Shorkot-Kamalia, and to a lesser extent Rohri North and Panjnad-Abbasia, the investigations are well advanced. In other areas, detailed field investigations have not yet been undertaken and due allowance has been made for the time required. Apart from projects scheduled for early implementation, however, there is no reason why the field surveys could not be carried out in the normal course of events with the technical resources available, and so permit the projects to be designed and the construction contracts to be formulated in accordance with the proposed program.

For the majority of projects formulated by IACA, covering the construction of 400 to 1,000 tubewells, IACA considers that a sufficient number of drilling rigs would be used so as to complete the drilling of wells in each project area in about three years. Although there would be a practical limit to the rate of well construction on each project, there would be no effective technical constraint on the total number of drilling rigs which could be used simultaneously on all projects under construction so that theoretically the rate of well drilling should not become a limiting factor in the public development of groundwater resources.

The rate of completion of projects is likely to be limited by the progress attainable on the electrification of tubewells. The Power Consultants[1] to the Study Group consider, and past experience supports the view, that a major constraint on installation would be the rate at which the electric distribution system can be expanded. They have estimated that during the Third Plan, 1965-70, electric service could be provided to not more than 8,000 newly installed public wells, and to 12,000 to 15,000 public wells in the Fourth Plan, 1970-75 provided that these were concentrated in reasonably large entities of land. Following this advice IACA has adopted tubewell installation rates which are within these rates of electrification. The electrification of wells and the completion of appurtenant works would be expected to follow within a year of drilling the wells. Although this is a longer interval than is desirable from the hydrological or economic standpoints, it is a delay which is likely to be associated with the constraint on tubewell electrification.

The elimination of the electric distribution constraint by the installation of diesel-engined public tubewells is not considered feasible owing to problems of operation and control and also because of the higher cost of pumping by this means.

The rate of training and supply of staff for the operation of tubewell projects, particularly with regard to the electrical and mechanical maintenance requirements, and agricultural supporting services, should match the rate of installation of the well fields. The provision of trained staff for tubewell projects will require a considerable increase in the establishment of the responsible departments and in order to derive the benefits that are attributed by IACA to the program, great efforts

[1] Stone & Webster Overseas Consultants Inc., "A Program for the Development of Power in West Pakistan," May 1966, Volume II, Annexure H.

will have to be made to ensure that the establishments are filled with staff of sound quality and training.

The available data on the first year of the Third Plan indicated disappointing progress in public tubewell development. Although about 1,000 wells were drilled, no more than about 140 were electrified and brought into operation in the year 1965/66. Special factors may have influenced progress, but the small number of public wells electrified does emphasize the presence of a serious constraint and defect in planning, and there is a need for a new and more vigorous approach if the levels proposed by IACA are to be achieved. The Study Group also places considerable emphasis on the problems of project operation to which IACA refers. In the view of the Study Group, failure to plan and train the required personnel for the efficient operation of the projects could seriously limit progress or drastically reduce the benefits.

Private Tubewells. The constraints that relate to public tubewell development do not for the most part apply to private development. It escapes some of the political and administrative problems that are associated with public tubewell construction and operation, and the electrification constraint is not as important because it is quite feasible for the farmers to use diesel power.

The widespread development of private tubewells in West Pakistan is of recent origin and for the most part has taken place over the past seven years. The most spectacular development has been in Bari and Rechna Doabs, the richer farming areas of the Punjab. In its initial stages it has been and continues to be stimulated by the Department of Agriculture and also to some extent by the availability of electricity supplies. It appears, however, that farmers are turning increasingly to diesel-driven wells because of the unreliability of power supplies. The success of these early private tubewells has led to an increasing awareness by farmers of the profitability of exploiting groundwater and, particularly in the past four years, farmers have installed a large number of diesel-powered pumps for private tubewells where electricity supplies are not available or are unreliable.

The main factors which appear to govern the rate of private tubewell installation relate essentially to the farmers' enterprise and financial resources and these, in turn, are related to farm size and to the form of tenure under which the farms are operated. The early initiative for private tubewell development has stemmed primarily from the large farmers and generally from the farmers with more than about 25 acres, a category which covers about 43 percent of the total farm area of West Pakistan. On the other hand, some 48 percent of the farm area is in units of 5-25 acres and 9 percent is in units of less than five acres. Thus, although small-scale family farming predominates, almost half the land area is within the farm size category which is demonstrating most readiness to invest in private tubewells. There are, however, other limitations imposed by land ownership. IACA, in its field surveys, found that the principle of forming partnerships between owners and tenants was not well understood, the tenant farmers being unwilling to make improvements such as the installation of tubewells and the planting of trees for fear of losing them to the landlords. Landowners on their side, on whom, in these circumstances, the initiative for tubewell installation must fall, often appear to be disinterested to make the necessary investment. There would thus be a considerable constraint in extending the level of activity shown recently in the owner-farmer category into the tenant-operated category. Taking again as a basis farms over 25 acres, about 26 percent of the land is owner-operated and 17 percent tenant-operated. From these statistics and the information gathered by IACA in the field it would be prudent to regard about one quarter of the land area in the usable groundwater zones as potentially best suited for private tubewell activity but at the same time making allowance for restrained extension of such activity into tenant-operated large farms and, by cooperative agreement, into some of the smaller tenant and owner-operated farms.

Finance does not seem to have been a major constraint in the early development of private tubewells. A feature of the impressive private tubewell development over the last five to six years has been that most farmers have financed their own tubewells either from their own resources or from noninstitutional sources of credit and so brought into productive use money which might otherwise have been used in consumption or nonagricultural activities. However, much of the farming in West Pakistan is at subsistence level and it is reasonable to presume that improved credit facilities must be provided if ownership of private tubewells is to spread to the smaller size farms. Considerable success has been achieved in the last two years by the Agricultural Development Bank (ADB) in financing private tubewell development, although loans so far have been mainly to the medium-sized farms of 12½ acres or larger.

IACA has considered these constraints and has analyzed in detail the reports on private tubewell installations since 1963 when the development of diesel as well as electrically driven tubewells became firmly established. From its analysis IACA has established general trends and has used the trends to estimate the future rates of installation and the number of tubewells which are likely to be installed in different areas in the absence of public tubewell projects.

IACA found that there are great variations in the quality of construction of private tubewells, in the area they serve and in the amount of water they pump. The area served is constrained by the size of farm holding coupled with the readiness or otherwise of the neighbors to buy water and by topographic features such as roads, canals and watercourses. In general, the area served is of the order of 100 acres or less and IACA has taken 100 acres as the average command of a private tubewell at all stages of development. Installation of tubewells beyond the density of 100 acres per tubewell is expected by IACA to be slow and is taken to be insignificant in their projections, though there appear to be indications that the density is likely to increase in the better farming areas with a corresponding decrease of the area served per tubewell. The average capacity of private tubewells was found by IACA in its watercourse studies and farm surveys to be about one cusec and it is considered unlikely that there will be any appreciable change in this average size. The variations in the quantity of water pumped by private tubewells are greater than the variations in capacity. The actual quantity of water pumped depends on many factors including the capacity of wells, the frequency of mechanical breakdowns, size of farm holdings, land tenure problems, disputes over sale of water and fluctuations in canal deliveries as well as the more obvious factor of crop water demands. On average, a private tubewell is operated for about 2,400 hours a year to pump about 180 to 200 acre-feet a year, representing a utilization rate of about 27 percent. There is considerable incentive at present for a higher utilization rate as canal deliveries are frequently irregular and many of the tubewells are installed on large farms with a correspondingly high demand for additional water supplies. The fact that average utilization rates are at present rather low indicates that there are constraints on the use of individual tubewells under private enterprise. IACA has therefore assumed that the utilization rate of 200 acre-feet a year would not on the average be exceeded in the future when there would be more reliable canal deliveries and when tubewells would be installed in the smaller farm holdings. The low utilization rates do not provide a true reflection of the utility of private wells for the reason that the owners would limit pumping to times of necessity. The water pumped from private wells would therefore tend to have a greater value per unit consumed than the basic flow delivered through a public system whether the latter be derived from surface or groundwater sources.

From its study of trends, IACA expects private tubewell development to be most rapid in Bari and Rechna Doabs where, as mentioned before, some of the best farming areas are found and where most of the early initiative has been shown.

The rate of installation of private tubewells is expected to be slower in the relatively backward areas of the Lower Indus and in Thal Doab and the 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 rapid stage of development has already been reached in Bari Doab whereas development has only just started in the Lower Indus Region.

IACA's projections for private tubewells in the canal commanded areas are shown in Table 3-5, in the hypothetical case of there being no public tubewell projects other than the completed SCARP I. No projections have been made for the Vale of Peshawar where the aquifer conditions are uncertain and where well drilling may be more difficult. It can be seen that development is expected to be very rapid until towards 1975 but that the constraints on development would impose a slower rate of installation thereafter. Even in 1975, less than half of the potential development would have taken place in the canal commands as a whole

TABLE 3–5
IACA's Projections for Private Tubewells in Operation Without Any Public Tubewell Programs
(thousand wells)

	Private Tubewells in Operation				Full Development[a]
	1965	1970	1975	1980	
Canal Commanded Areas:					
Vale of Peshawar	—	—	—	—	—
Thal Doab and Indus Right Bank	1.2	3.7	7.0	9.5	30
Chaj Doab	0.8	3.0	5.3	6.8	16
Rechna Doab	9.8	16.1	20.8	22.9	31
Bari Doab	13.0	27.0	36.0	41.0	53
Sutlej and Panjnad Left Bank	1.4	4.0	6.2	7.6	18
Lower Indus	0.7	2.2	5.1	7.7	23
Total Canal Commanded Areas	27.0	56.0	80.0	96.0	171
Outside Canal Commands	5.0	9.0	14.0	20.0	25
Total Private Tubewells	32.0	65.0	94.0	116.0	195

[a] Full development is taken as full coverage at 100 acres per tubewell and applies at dates which vary but are all after the year 2000.

while in Bari and Rechna Doabs, the most advanced regions, about two-thirds of the potential development would have taken place. These projections emphasize the need to recognize private tubewell development opportunities in the determination of priorities for private groundwater development.

Integrated Public and Private Tubewell Development. In practice, public tubewell projects would continue in parallel with the private development. As public tubewells come into operation in a project area, the installation of private tubewells in the area is expected to reduce itself to an insignificant level. According to the IACA projections under the proposed expansion of the public program, the number of private tubewells in operation in the canal commanded areas would reach a peak by around 1970. Private tubewells would continue to be installed in nonproject areas but the total number in operation would decline to insignificance by 1985 when public tubewell coverage of the usable groundwater areas is expected to be complete. Private tubewells would, however, continue to make a valuable contribution to irrigation outside the canal commanded areas and may in many cases continue to be operated in conjunction with public wells. The IACA projections are shown in Table 3-6. It should be noted that by 1980 public tubewells would have substituted for some 93,000 private wells that would otherwise have been installed and in operation in accordance with the IACA estimates.

IACA has emphasized that its projections are based on data for only a few years at an early stage of development; it is therefore difficult to assess the limits of accuracy of the development which has been projected. It should also be noted that IACA's projections of private tubewells in operation are based on a continuation of existing trends without any specific stimulation unless there is a falling off in the rate. However, since the IACA Report was published, valuable information on private tubewell development in Lower Rechna Doab has been produced by Tipton and Kalmbach Inc. (T&K) for WAPDA in the SCARP V Project Report of August 1966. T&K's investigations of private installation in over two million

TABLE 3-6
IACA'S PROJECTIONS FOR PRIVATE TUBEWELLS IN OPERATION WITH IACA PUBLIC TUBEWELL PROGRAM[a]
(thousand wells)

Region	Private Tubewells in Operation				
	1965	1970	1975	1980	1985
Canal Commanded Areas:					
Vale of Peshawar	—	—	—	—	—
Thal Doab and Indus Right Bank	1.2	2.4	2.8	—	—
Chaj Doab	0.8	—	—	—	—
Rechna Doab	9.8	10.3	9.4	—	—
Bari Doab	13.0	25.5	19.5	1.3	—
Sutlej and Panjnad Left Bank	1.4	2.9	—	—	—
Lower Indus	0.7	2.0	2.5	1.7	—
Total Canal Commanded Areas	27.0	43.0	34.0	3.0	—
Outside Areas	5.0	9.0	14.0	20.0	25.0
Total Private Tubewells	32.0	52.0	48.0	23.0	25.0

[a] Numbers given are IACA original projections, they have been subsequently revised to include more recent counts as well as changes in priorities. See Chapter IV.

acres in the Lower Rechna Doab provide some confirmation for the IACA figures. The average command of private tubewells is 100 acres and the average delivery from a tubewell is about 200 acre-feet a year, both of which figures are the same as used by IACA. However, T&K place greater emphasis than IACA on the constraints of farm size, land tenure and finance. They show that the initial rapid installation of private tubewells occurred on the larger farms and that this lead is not automatically being followed on the small farms. The rate of installation of private tubewells has in fact declined sharply since 1963 in this specific area where a high density has been reached and in the view of T&K will continue to decline.

T&K were also making detailed studies of private tubewell development in Bari Doab. Figures for private tubewells in over 500 union councils were being collated and analyzed. It would appear that the figures for Bari Doab bear out the general expectations of IACA but that T&K find about 2,000 more wells in existence and expect the constraints on further development to be more severe than projected by IACA. In particular, T&K find that the commanded areas and the utilization rates of private tubewells decrease as the density of wells increases. They tentatively expect that the average tubewell command in the Bari Doab may reduce to about 60 acres and that on this basis the area commanded would not exceed about 60 percent of the culturable area.

Under IACA's proposed program for public tubewell projects, the main and crucial influence of private tubewells on agricultural production would be during the next decade. The differences between the IACA and the T&K projections for private tubewell development in the northern zone are not great during this period but the IACA projections are slightly higher.

The Study Group considers it essential that the IACA projections for private tubewell installation should be achieved and where possible exceeded if there is not to be a serious shortfall in the growth of agricultural production.

The present policy of the Government of West Pakistan to encourage private tubewell development is strongly endorsed by the Study Group. The Study Group recommends that it should be supported through the provision of technical advice on the construction and siting of private wells and through an expansion of the activities of the ADB in providing loans.

A consolidation of the IACA program for public tubewells is consolidated with the projections for private tubewell installation as shown in Table 3-7. The figures

TABLE 3-7
PRIVATE AND PUBLIC TUBEWELLS IN OPERATION ACCORDING TO THE IACA PROJECTIONS

	1965	1975	1985	2000
Number of Public Wells:				
In Usable GW. Zones	2,200	19,800	34,300	35,000
In Saline GW. Zones	—	200	9,800	15,000
Number of Private Wells:				
Electric Powered	9,000	26,000	23,000	30,000
Diesel Powered	23,000	26,000	2,000	3,000
Total Pumping (MAF):				
For Irrigation	11	33	45	50
For Drainage[a]	—	15	18	27

[a] Not strictly pumping: figures given are the recharge to the saline areas and would include some horizontal drainage effluent.

are based on the assumptions that the private wells would have a capacity of about one cusec as compared with four cusecs for the public wells and the projected annual yields would be about 200 acre-feet and 1,000 acre-feet a year respectively.

Canal Enlargement and Remodelling

The present withdrawal capacity of the canal system is 13.3 MAF/month, which equals or exceeds the combined mean flow of the Indus, Jhelum and Chenab for all except the three summer months of high flow, June, July and August. During these three months the combined mean flows are about 23, 32 and 28 MAF respectively. In addition, in May and again in September there is also a period of about two weeks when the natural flows of the three rivers exceed existing canal capacity. The above comparison of natural flow and canal capacity is not in itself a measure of the scope for canal enlargement. Some of the surplus flow has to be hypothecated for storage in the new reservoirs and there are problems of geographical distribution and considerable variations from the mean conditions. It must also be borne in mind that canal enlargement alone as a means of using surplus river flows would not be very effective in adding to achievable kharif cropping intensities without complementary additional supplies from storage reservoirs and groundwater at the beginning and end of the season since there are few summer crops that can be matured within the short period of high flow. Additional water would be needed for planting and maturing of most crops.

The potentiality for canal enlargement has been carefully analyzed by IACA and they estimate that the total withdrawal capacity would have to be increased by about 40 percent to some 19 MAF/month in order to achieve the 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 a CCA of 29.5 million acres). Remodelling on this scale coupled with IACA's surface water storage program would, by the year 2000, result in complete diversion of the mean year river flows into the system. Any water that enters the sea in a year of mean inflow to the Plains would be essentially derived from saline drainage effluent discharge either through the river channels or through the proposed Left Bank Outfall (see Chapter V-B and Map 7).

The need for canal enlargement varies considerably between different areas according to the availability of usable groundwater and the original design of the canals. The need would be greatest in areas where the underlying groundwater is not of a suitable quality to be used for irrigation and the potential demand of the crops must be met from surface supplies alone. Many individual canals in such saline zones would require increases of 100 percent or more in capacity. On the other hand, there are intensive areas where development of fresh groundwater in combination with surface water deliveries in the existing canal system would be adequate for optimum irrigation supplies. Within the development of a CCA of about 29.5 million acres, IACA estimated that varying degrees of canal enlargement would need to be undertaken over about 16 million acres to permit full agricultural development.

IACA has considered the possibility of enlarging certain canals beyond the level required to meet the surface water requirements of the optimum cropping intensities in an integrated ground and surface water supply. The purpose would be to maintain sufficient flow in the midsummer months to obviate groundwater pumping and the resulting recharge during summer would then be sufficient to meet rabi requirements from groundwater pumping alone. This method could only be applied to fresh groundwater areas which are mainly in the Punjab and would therefore necessitate major link canal enlargement. It would also entail some difficult hydraulic problems in operating the enlarged canal system with wide variations in flow and would be a costly and time consuming measure. It might be adopted in the long term but would find no place in the proposed Action Program, which concentrates on the canal enlargement to remove constraints in the mixing and saline groundwater zones. Additional enlargement may, at some future date, represent an alternative procedure to surface water storage but not before a reasonable degree of regulation has been established on the present variable river flows.

Enlarging the withdrawal capacity of the canal commands would in many cases require enlargement of the capacity of the link canal system. IACA considers that the existing link canals combined with the links under construction are at present adequate to serve the canal system, but that by about 1980 there would be a need for additional link capacity to transfer water across the Punjab to Bari Doab and the Left Bank of the Sutlej River. It is recommended that the possibility should be investigated of constructing a new link canal with a capacity of about 1½ MAF/month on an alignment across the Punjab running from the tail reach of the Chasma-Jhelum link to cross the Chenab River in the vicinity of Chiniot and then leading ultimately into the Sutlej. Such a project would have two major functions. Firstly, as a link it would supplement the supplies to the east of the Punjab Plains in the same way as the links under construction. Secondly, it would add greatly to the flexibility of the irrigation system by bringing much more land under both Jhelum/Chenab and Indus command instead of under the Jhelum/Chenab command alone.

IACA has also examined alternative methods of canal enlargement in relation to different canals and it concludes that the simplest and cheapest method for major enlargement would generally be to construct a parallel channel alongside the existing canal. Where the degree of enlargement required is less than about 60 percent, the existing channels could be widened and deepened.

Costs of enlargement would depend on the increase in capacity required, on the local conditions and in some cases on the complementary enlargement of link canals. It is estimated that within a canal command the investment costs per acre of CCA are likely to vary from about Rs. 100 in areas where enlargement would be slight up to about Rs. 250 in areas where a more considerable degree of enlargement is required. The cost of providing additional link capacity would apply only to canal commands on the tributary rivers and would vary considerably between different areas. As a general average the cost of additional link canal capacity is at least equal to the cost of enlargement within the related canal commands and generally more. Subsequent to the submission of their report, IACA has examined the average cost of canal enlargement, over all parts of the canal network where it is required on the basis of annual incremental water supply. By discounting both costs and incremental discharge at 8 percent, they have arrived at an average cost of about Rs. 19 per acre-foot. After taking into account the limited flexibility in the use of additional water from diversion during high flow months and the consequent need to provide complementary supplies in the early and late kharif period by other means, canal enlargement would appear to be a more expensive form of development than groundwater but cheaper than stored water. This does not, however, imply that there would be a wide choice of mode of development because under IACA's integrated proposals all three modes of development—surface storage, groundwater, and canal enlargement—would have converging functions in the program and their phasing would be interrelated in meeting the projected requirements as explained in Chapter V. The cost analysis does, on the other hand, demonstrate the attraction of canal enlargement and the need for a substantial program of enlargement, especially in the decade 1975-85.

IACA has drawn attention to the need for remodelling and maintenance of the canals to prevent excessive siltation or scouring, when the pattern of surface water distribution is changed. Remodelling and maintenance of this nature is to a large extent a routine matter but would require an increasing rate of expenditure and this has been allowed for in the IACA program.

In connection with future development of the distribution system, IACA has considered the possibility of lining canals as a means of reducing losses due to seepage and reducing the need for drainage in areas underlain by saline groundwater. It is estimated that, discounting the cost of lining at 8 percent, the cost of preventing one acre-foot of water from being lost from the canal would be about Rs. 110. If allowance is made for the saving in drainage of saline groundwater areas, this cost might be reduced to around Rs. 65 per acre-foot. However, drainage to dewater would have to precede lining in areas with a high water table. There are also practical problems in lining in that most of the saline groundwater areas, other than southern rice areas, receive perennial canal supplies. Canal deliveries would have to be maintained and so lining in most areas would have to be associated with the construction of new channels. Because of the comparatively high costs and technical factors involved, IACA has concluded and the Study Group concurs that canal lining would not at present be generally justifiable except in special isolated circumstances and would not deserve priority in the current program for development and water conservation.

A further aspect of the present distribution system is the inflexibility in the method of delivering water through the distributary canals. However, IACA considered that a change to a more flexible system of distribution based on individual demands would involve such large-scale problems of construction and administration that it would have to be deferred until after the currently proposed program for development.

The program for canal enlargement will necessarily be related to the program for groundwater development, subsurface drainage and surface water storage. In areas where there is a high groundwater table, canal enlargement should be preceded by subsurface drainage so as to prevent further waterlogging and reduction in crop yields. The higher cropping intensities which would accompany canal enlargement would accentuate any shortages occurring during the periods of sowing and maturing of kharif crops. These shortages would have to be met by releases from surface storage or by additional groundwater pumping. In addition, an increase in the withdrawal capacity of several canals which command land in the Bari Doab and on the Left Bank of the Sutlej River would have to be accompanied by the enlargement of the RQBS[1] and TSMB[2] (see Map 7) link canals or by the

[1] Rasul-Qadirabad-Balloki-Suleimanke.
[2] Trimmu-Sidhnai-Mailsi-Bahawal.

construction of the new Punjab link canal discussed above. These factors would have to be taken into account in future programming of canal enlargement.

Although much experience has been gained in the construction of new canals in West Pakistan, enlargement of the capacity of existing canal systems on an extensive scale has not yet been undertaken. The enlargement work envisaged would be much greater in scope than any canal remodelling so far carried out, including that required under the Indus Basin Project. The planning, survey, design and construction of the work would be of a magnitude and complexity which would require a strong central organization of the Irrigation Department to carry it out. Methods of carrying out the work with the least amount of disruption of canal operation or interference with the distribution of water supplies would need careful study if loss of production is to be minimized.

IACA estimates that, initially, enlargement could be carried out at an average rate of about 150 miles of channel per year, covering one canal subdivision. A total of about one million acres of CCA would then be provided with enlarged channels by 1975, in selected areas which are not subject to the previously mentioned constraints of drainage, storage availability and link capacity. After this, the rate of enlargement should increase rapidly so that a further five million acres of CCA might be served by enlarged channels by 1985 (see Chapter V). The Study Group urges that steps should be taken at once to prepare plans for the initial works. Bearing in mind that little progress has been made in this direction to date, vigorous action will be required if IACA's projection for 1975 is to be realized.

Surface Water Conservation

Allied to the development of groundwater and the enlargement of canals would be steps to increase the availability of surface water through the medium of surface storage, which would have the prime function of equating seasonal fluctuations of river flows with the seasonal variations in surface water requirements. The present period of water shortage is generally between mid-October and mid-April. With the growth of cropping intensities this period of shortage would gradually expand to include more of October, April, and the early part of May. A second function of storage is to provide regulation of flow within the rabi season, thus enabling the supplies in conjunction with groundwater to match as closely as possible the rabi pattern of cropwater requirements. This would eliminate the severe monthly shortages which occur under the present system and provide the farmer with a firmer base for his cropping program and reduce the risks of employing higher levels of nonwater inputs. Thirdly, the surface reservoirs would in the long term provide a measure of flood control.

Within the context of its principal function, transferring surplus kharif water to rabi shortages, three stages can be distinguished.

1. Replacement of the rabi flows of the rivers Ravi and Sutlej, which are allocated to India under the Indus Waters Treaty.
2. Increasing the availability of rabi supplies by the storing of the firm kharif surplus, i.e., seasonal regulation.
3. In the longer term, utilization of the fuller potentialities of the Indus River by carrying over the larger kharif surpluses to years with lower than average surpluses, i.e., over-year storage.

The first stage of development was substantially completed in 1967/68 as Mangla Reservoir came into operation, but full replacement of the eastern tributaries would not become effective until the Indus link canals have been completed. In accordance with the IACA program, the second stage of storage development to provide seasonal regulation would need to be implemented during the subsequent 30 years. IACA has not programmed for the long term aspects of the third stage providing over-year storage.

For a region that is so dependent on water, the Indus Basin is not well suited geographically for the development of storage reservoirs. The topography of the country does not provide large reservoir sites which would be technically or economically easy to develop. Furthermore, the high silt content of the rivers, particularly of the Indus itself, would result in a fast rate of depletion of storage capacity. The potential reservoirs are discussed in the Study Group's Report, in Annex 2 of Volume I.

The cost of stored water in the Indus Basin has been estimated by IACA taking the Study Group's Dam Site Consultants'[1] estimates of dam cost and relating these to water yield. Stored water at the dam site would thus cost about Rs. 37 per acre-foot. When translated to watercourse head the figure is almost doubled because of distribution losses, thus giving a cost on the land that is about three times the cost of tubewell water, i.e. about Rs. 63 per acre-foot. Large reservoirs tend to generate surpluses or make available quantities of water which may temporarily exceed the farmers' ability to use it efficiently in the early years of the reservoir operation. This would increase the effective cost per acre-foot used. In the conditions of West Pakistan, however, this disadvantage may be partly overcome by overpumping from the aquifer during the years prior to the addition of surface storage and subsequently replenishing it in the years immediately after the commissioning of the reservoir, and thus employing the reservoir as a long-term regulator.

Despite the relatively high cost of stored water, surface storage development would need to proceed for the following reasons:

1. There is a need to regulate the natural river flows in the rabi season; a substantial degree of regulation on the Jhelum River would be provided by Mangla Dam and the principal requirement for the next phase of rabi regulation is on the Indus itself.
2. Provision of surface storage has a key role in increasing the rabi irrigation supplies which would enable Pakistan to move towards self-sufficiency in food grains.
3. The cost of surface storage, although high, is sufficiently below the benefits obtainable for a storage development to be economically viable.
4. Surface storage is an important part of the development plan for without it there could be little development in the extensive areas underlain by saline groundwater, and development would be curtailed in areas where regulated surface water is required for mixing with groundwater.
5. Once groundwater development reaches its full potential, extra rabi water would be available only from storage.
6. In view of the specific constraints and interdependent nature of all modes of water resource development, it is necessary that each should be advanced in accordance with an integrated time schedule. Surface storage has a key role in the

[1] Chas. T. Main International, Inc., Boston.

development and is particularly important in view of the existing familiarity with the distribution and use of surface water supplies. By contrast, there is as yet little experience with large-scale public groundwater development, especially in areas with varying groundwater qualities.

The ultimate storage potentialities of the rivers are best considered in two groups: firstly, storage on the Indus together with its tributaries, the Kabul and Swat, and secondly, storage on the Jhelum jointly with the Chenab.

The Indus has a large seasonal fluctuation in flow; of the total mean annual discharge of 93 MAF about 72 percent or 67 MAF occurs in the four kharif months June to September. The flow of the Jhelum and Chenab display only slightly less seasonal fluctuation with 31 MAF or 64 percent of the total of 49 MAF occurring in the peak four months, May to August—one month earlier than the Indus. Apart from the slightly earlier flood season, the Jhelum and Chenab rivers differ from the Indus in having slightly greater variation in flows from year to year and also in having lower silt loads.

The amount of surplus flow available for storage on these rivers depends essentially on the pattern of irrigation demand and this over time depends on trends in cropping intensities and more particularly in the kharif-rabi cropping ratio. When this ratio is high the storable surplus and indeed the need for storage is low. IACA has calculated the storable surplus on the two river systems on the basis of its agricultural projections which lead towards the following average cropping intensity levels and kharif-rabi ratios:

	Average Cropping Intensity	General Kharif-Rabi Ratio
1975	112%	1.20
1985	125%	1.16
2000	145%	0.94

Under these projected conditions the mean year[1] storable surplus on the Jhelum after full allowance has been made for maximum use of Chenab water amounts to 11.5 MAF in 1985 and 7.5 MAF in 2000. On the Indus the respective values are 38 MAF and 22 MAF. These figures are derived by subtracting the projected kharif irrigation demands under the IACA projected cropping patterns and intensities from the total river flow during the storage period. The sharp decrease in storable surplus after 1985 reflects the influence of the increase in kharif intensity made possible by IACA's proposed canal enlargement. It also demonstrated the extent to which a high degree of river use can be attained with relatively small storage capacities in the Indus Basin where year-round cropping is practiced and when high kharif-rabi ratios are adopted. For the ultimate stage of development IACA has analyzed how frequently reservoirs of given size might approximately be filled on each river system; the results are given in Table 3-8. These frequency figures for filling the reservoirs taken together with the storable surpluses stated above demonstrate the limited potential for storage development on the Jhelum after completion of the Mangla Dam with its useful initial capacity of 5.2 MAF and at the same time emphasize the scope for storage development on the main Indus.

[1] The mean year storable surplus serves only as a planning base and careful attention must be given to variations from the mean.

TABLE 3-8
SIZE OF RESERVOIR RELATED TO CHANCES OF BEING FILLED EACH YEAR
(FULL DEVELOPMENT CONDITIONS)
Jhelum at Mangla

Storage in MAF	Number of Years out of 40	Storage in MAF	Number of Years out of 40
2	40	9	9
3	38	10	6
4	35	11	5
5	32	12	3
6	28	13	2
7	25	14	1
8	17	15	—
	Indus at Attock		
13	40	22	18
14	38	23	16
15	37	24	13
16	36	25	10
17	35	26	8
18	34	27	7
19	33	28	5
20	29	29	3
21	23	30	1

Clearly it is not possible to project ultimate storage potentialities and needs with any precision. The latter depend on an array of trends in food and fiber demands, crop yields and intensities and other factors. A general conclusion which may be drawn from the IACA projection is that the second phase of development, or seasonal regulation, may lead to about 7 MAF of storage on the Jhelum and 20 MAF on the main Indus. Subject to investigation, the present indication is that the third stage, over-year storage, might extend to 9 MAF on the Jhelum and 26 MAF on the Indus. As discussed above, the first major storage reservoir is already under construction at Mangla on the Jhelum River as part of the Indus Basin Project Works.

The principal benchmark in the IACA program is the projected completion of Tarbela Dam on the Indus River in 1974 with an initial live storage capacity of 8.6 MAF.[1] The timing of Tarbela Dam was fixed in the IACA terms of reference but the need and the priority for the project as well as its approximate timing have been confirmed by subsequent studies.

In accordance with the IACA program, the provision of a major storage reservoir at Tarbela in 1974 is adequate to meet the requirement for storage in the system at the time and for some years thereafter. If there were to be other surface storage projects before 1975 they would tend to be in competition with Tarbela within the frame of the IACA program and the economic returns of the projected storage development would consequently be reduced. It has therefore been assumed that storage projects in the next decade would be limited to the already large program of Mangla and Chasma followed by Tarbela.

The future rate of reservoir construction would also be constrained, so far as can be foreseen at present, in that surface storage which is both necessary for

[1] With a minimum drawdown level of 1332.

development of irrigation and justifiable from an economic standpoint would nonetheless remain an expensive form of development. For agricultural development under West Pakistan conditions it is justified only if efficient and effective use to raise agricultural production can be ensured. On this basis of efficient and effective use, IACA projects that the next requirement for major storage after Tarbela would not occur until after 1980. Bearing in mind that the development of surface water storage involves long term planning and investigations there is a clear need for a vigorous program of investigations.

Drainage and Flood Control

Drainage. There is need for surface and subsurface drainage in many parts of the Indus Plains in order to control the damaging effects of: (a) the inundation and waterlogging of arable land caused by local storms and occasional river flooding, and (b) waterlogging and salinity caused by a rise in the water table.

The expected increase in cropping intensities and higher yields accentuates the need for both forms of drainage. More intensive irrigated cropping would lead to greater percolation to the water table and the associated reduction in fallow areas would reduce the present opportunities for disposal of rain flood water from the cropped fields. The projected increases in crop yields would enhance the benefits that can be derived from protection against flooding and waterlogging.

The prevention of damage by storm water, which is particularly severe during the monsoon season, would be effected by a system of surface drainage. In IACA's analysis of the requirement for and capacity of surface drainage in each region, the cost of drainage was compared with the probable crop losses that might otherwise occur. In the northern part of the Punjab, drainage systems with capacities varying from one to five cusecs per square mile indicated a favorable cost/benefit relationship. In the central areas between Multan and Nawabshah, the analysis suggests that there is no justification for surface drainage, but south of this area systems with capacities from one to three cusecs would appear justified (Map 4).

The need for water table control by subsurface drainage is demonstrated in IACA's report on drainage and flood control.[1] The areas in which water table control is needed in the Indus Plains are included within the 11 million acres of the CCA in which the groundwater is less than 10 feet from the surface. Of this total acreage, about 6.5 million acres are underlain by usable groundwater and the control of the water table can in general be expected to be affected by the various public and private tubewell developments proposed in these areas. The balance of 4.5 million acres, underlain by saline groundwater (more than 3,000 ppm), contains about 1.2 million acres that are expected to be developed for nonperennial rice cultivation for which water table control is not required. It also contains about one million acres which have not been included in the 29.5 million acres scheduled for development under IACA's proposals. Although a water table depth of less than 10 feet does not imply an immediate need for drainage, IACA estimates that almost two million acres in the saline groundwater zones of the Indus Plains require special provision for the control of the water table at present or in the near future.

Subsurface drainage would be carried out by tubewells or tile drains, according to local conditions. As stated above, in the usable groundwater zones the recharge

[1] IACA Report, Volume 6, Annexure 8.

would be recovered by the tubewells sunk primarily for the supply of irrigation water, but serving at the same time to check the rise of the water table. In the saline groundwater zones, however, a separate and specific drainage system would be required and the effluent would have to be disposed of through the river system, into the desert, or into the sea, according to circumstances. In the Punjab Doabs the outfalls can only run into the river channels and to avoid excessive salinization of river water, it would be necessary for saline tubewell effluent to be discharged only during periods of high river flow. In IACA's view this would make the annual cost of tubewell drainage comparable with that of tile drainage. In areas in which it is proposed to provide direct disposal facilities to the sea or to the desert, and where the aquifer is suitable for tubewells, tubewell drainage is more economical than tile drainage because large capacity drainage wells could be pumped throughout the year. This applies to the Lower Indus, for which area large outfall drains are planned, and to the Sutlej Left Bank, from which area effluent would be dispersed into the adjacent desert.

Flood Control. High floods have occurred more frequently in the Indus Plains during the last 25 years than over the previous 65 years of record. In the case of the Ravi River, seven out of the 10 highest annual flood peaks observed during more than 90 years of record have actually occurred in this recent period. During recent floods considerable damage occurred, estimates of which are summarized in Table 3-9. Although the damage was often caused by breaching of river bunds, the spill from large natural drainage channels and consequent breaching of canals contributed significantly to the inundation and destruction of crops.

The amount of damage caused by flooding will increase as the state of development rises. Especially in areas scheduled for a high rate of agricultural development, particuarly by tubewells, it would become increasingly important to provide

TABLE 3-9
ESTIMATED FLOOD DAMAGE
1948-1962

	Ravi		Chenab		Indus, Sutlej and Jhelum		Total	
	15-year Total	Annual Average	15-year Total	Annual Average	15-year Total	Annual Average	15-year Total	Annual Average
				(Rs. mill.)				
Private Property								
Crops and Produce	190.0	12.7	59.6	4.0	276.8	25.1	627.2	41.8
Housing	111.0	7.3	64.9	4.3	104.8	7.0	280.7	18.6
Cattle	9.5	0.6	3.2	0.2	2.5	0.2	15.2	1.0
Subtotal	310.5	20.6	127.7	8.5	384.1	32.3	923.1	61.4
Public Installations								
Irrigation Works	31.9	2.1	14.6	1.0	134.2	8.9	180.7	12.0
Roads and Bridges	8.5	0.6	6.8	0.5	38.7	2.5	54.0	3.6
Railway Facilities	12.6	0.9	13.8	0.9	10.8	0.7	37.2	2.5
Subtotal	53.0	3.6	35.2	2.4	183.7	12.1	271.9	18.1
Total	363.5	24.2	162.9	10.9	467.8	44.4	1,195.0	79.5

Source: IACA Report, Volume 6, Annexure 8, page 23.

reasonable flood protection. This would include measures to prevent increases in deforestation and denudation of the upper catchment areas, which probably contributed to the recent apparent rise in flood frequencies. The West Pakistan Flood Commission has developed preliminary proposals for dealing with the flood problems on the Ravi and Chenab Rivers. Proposals for the other rivers are still in the course of preparation and not yet available. In general, the measures proposed contain the items listed in Table 3-10. In accordance with IACA, it would seem reasonable to assume about the same costs for the rivers Sutlej, Jhelum and Indus which would bring total expenditures for flood protection works in the Indus Basin to about Rs. 350 million.

If the proposed works were to be carried out during the next five years, the average annual level of expenditures would be in the neighborhood of Rs. 70 million. Assuming, furthermore, that the average annual damage prevented would equal one-half of the tabulation in Table 3-10, the benefits would, in accordance with IACA, just cover amortization at 8 percent interest and maintenance expenditures. It must be borne in mind, however, that flood control works are frequently undertaken for sociological reasons and cannot always be justified on the basis of quantifiable economic benefits alone.

Interdependence and Integration of Water Development

In the foregoing section, reference was made to the interrelationship between the three principal water development measures of tubewell installation, reservoir construction and canal enlargement and between further water development and drainage. Each must proceed in its proper sequence. In general, subsurface drainage should precede the increased flows to the canal that would result from canal enlargement. Canal enlargement would in itself prove effective only over the mid-kharif months and other developments would have to take place at the same time to meet the kharif crop demands in the early and late part of the season. These factors associate canal enlargement not only with drainage but also with surface storage reservoirs and/or tubewell water supplies in usable groundwater zones. In the zones of intermediate groundwater quality, where mixing of ground and surface water is necessary, a prerequisite to success is the reliability of surface supply and, although some deficiencies might be accepted initially, the efficient

TABLE 3-10
FLOOD PROTECTION MEASURES

	Preliminary Cost Estimates		
	Ravi	Chenab	Total
		(Rs. million)	
Soil Conservation in Upland Areas	2.9	14.3 mm	17.2
Land and Canal Protection (including 125 miles of new bunds, 280 miles of improvement of existing embankments)	39.3	12.7	52.0
Drainage Works (including 850 miles of drainage channel remodelling)	66.7	0.2	66.9
Road and Railway Protection Works	32.1	1.4	33.5
Municipal Protection Works	1.9	5.1	7.0
Total	142.9	33.7	176.6

operation of mixing calls for river regulation by surface reservoirs on both the Jhelum and Indus.

A feature of tubewell development, in addition to its low cost and quick returns, is its flexibility as a means of supplying water in relation to the availability of surface supplies. In the operation of tubewells use could be made of this flexibility by pumping for longer periods than is usual at time of surface water shortage or when the crop water requirements are at a peak. With both private and public tubewells, the pumped water is at present regarded largely as a supplement and not as a substitute for canal supplies. The value of both tubewell and surface water development is enhanced by their joint application to irrigation because incremental surface supplies give rise to greater recharge to the aquifer, thus raising the output of the tubewell fields and at the same time increasing the conveyance efficiency of the surface deliveries.

Total water supplies under the present system might at certain times be more than adequate in tubewell areas while elsewhere crops are suffering shortages. Achievement of the full benefits of groundwater development would require changes in the present methods of allocating water. One of the most important changes required is that groundwater supplies from public tubewells should be treated jointly with surface water supplies in future allocations.

There are three main reasons why integration of supplies through appropriate operation of the system is essential to the success of future development. These may be summarized as follows:

1. Only about half of the CCA proposed for development is underlain by fresh groundwater that can be applied directly to the crops, but surface water supplies could be improved throughout the remainder of the CCA by transfer from fresh groundwater areas. In certain canals, particularly those having relatively large capacities for the areas which they serve, the normal irrigation deliveries at times of high river flow would be sufficient to replenish the aquifer and enable all or most of the demand in the remainder of the year to be met by pumping of fresh groundwater under public tubewell projects. In such cases the rabi surface water supplies could be released and reallocated to other areas. This is referred to by IACA as substitution and further discussed in Chapter V.

2. A further 15 percent of the CCA is in the mixing zones where groundwater would require dilution by surface water before being applied to crops. Only by carefully operated integrated control of surface and groundwater can a satisfactory quality of irrigation water be maintained.

3. Integration of tubewell pumping and surface water deliveries is necessary in order to rationalize the pattern of demand for tubewell pumping power which would represent a substantial part of the total system power and energy demand in West Pakistan.

On the basis of all considerations discussed in Chapter III, IACA has developed a simulation analysis by which it has tested the relative advantages of various combinations of water development activities. This has enabled IACA to outline a comprehensive water development program which is internally consistent, appears capable of implementation and has been successfully tested for its operational feasibility by a sequential analysis covering the period 1965 to 1985 (Annex 5).

The dominant feature of this program is the emphasis on exploitation of fresh groundwater over the first decade (1965-75) supported by surface drainage improvements in the high rainfall areas of the northern zone and some canal enlargement. The operational implications of the withdrawal of the water of the eastern tributaries under the Indus Waters Treaty as well as those of the replacement works scheduled for completion during this decade are fully integrated under this program. At the end of this period (1974/75), main stem storage and regulation (Tarbela) would become available.

Over the next decade (1975 to 1985), public tubewell fields would be extended into the still undeveloped groundwater areas and increasingly would substitute for private groundwater exploitation. Simultaneously, saline groundwater areas would be provided with both vertical and horizontal drainage facilities. Canal enlargement would become increasingly important, especially in the Lower Indus Region, which would also benefit from storage development at Sehwan/Manchar and an associated large feeder canal. In the north, additional link canal capacity would be provided in conjunction with the canal enlargement towards the end of this period.

While the broad frame of future integrated water development has thus been determined in full recognition of the numerous interdependencies and operative constraints inherent in a complex system such as the Indus Basin, a number of choices remained to be made with regard to the specific allocation of resources especially during the first decade. Since this period is predominantly oriented towards fresh groundwater development, the effective choices were largely limited to geographical preferences for public groundwater development.

D. SELECTION OF PRIORITIES

Groundwater Development

The selection of priority areas for groundwater development had as its main objective the allocation of some 13,000 additional public wells for the period up to 1975. The allocation was made in accordance with the production potentialities of the analytical unit areas but within the framework of the various technical factors discussed in the preceding sections of Chapter III. Since no substantial variations in tubewell costs have been observed other than those associated with well capacity variations—the dominating influence in the allocation process was derived from the incremental production attainable with the installation of public wells. This IACA has expressed in terms of "net discounted benefits per four cusec well," installed in a given unit area in 1972 rather than 1977. In other words, priorities reflect the relative merits of early tubewell installation compared with installation at a later date.

The results of IACA's simplified model analysis are summarized here in terms of relative priorities amongst canal commands and parts of canal commands.[1] Because the analysis took account of the present status of production and measured priorities in terms of attainable increments, some of the more advanced areas were given a low priority for public projects relative to the alternative private development. While, especially under application of the technical criteria discussed above, there is ample flexibility in the interpretation of these results, a

[1] Further details are given in IACA's Report, Volume 2-A, Annexure 1, Economics, especially Table 2, page 34.

pattern of priorities emerged, giving highest priority to most of the Peshawar Vale areas. Areas for which a similar but slightly lower priority was derived were Rohri North (mixing zone), Thal (fresh groundwater), Lower Chenab (fresh groundwater—perennial zone), and Bahawal below MB Link (fresh groundwater—perennial zone). Next as a general priority group came the fresh groundwater areas and some mixing areas of the Punjab and Bahawal regions. Groundwater development in the Sind is generally given a low priority, beyond the 1965-75 program, with the exception of Rohri North and Rohri South and Dadu North. The areas that do not come within the pre-1975 priority ranking are for the most part in zones of intermediate groundwater salinity but some of these areas must for practical reasons be taken in with their contiguous fresh groundwater areas in the same commands. Notable exceptions to this general description of the lower priority group are large fresh groundwater areas in the Bari Doab and fresh groundwater areas in Ghotki. Here it is the projected benefits of private tubewell development that reduces the potential benefits of public development, though in this context some reservations might well be applied to the latter area because of a fast rising water table encountered there.

In a separate analysis employing linear programming techniques, the Study Group has reviewed the regional allocations of scarce resources derived by IACA. The Study Group's model, like that developed by IACA, considers the specific implementation constraints for public groundwater development and canal remodelling. Beyond that, however, it gave explicit recognition to the scarcity of surface water during the rabi period before and after the completion of Tarbela, the scarcity of public development funds, the scarcity of foreign exchange as well as the impact of alternative growth targets for the agricultural sector. Given the difficulty of a judgment about future implementation capacity and resource availabilities, this programming exercise was used to trace the effects of alternative levels of resource availabilities upon size and composition of investment plans. When using the same assumptions about resource availability as were made by IACA, this analysis of the Study Group confirms to a considerable extent the allocation of scarce resources derived by IACA.[1] Within the frame of assumptions made, especially with regard to private tubewell development and the absorption of additional surface water in specific areas, the analysis showed that, if the scale of public tubewell program for the period 1965 to 1975 is reduced from a total of 20,000 tubewells to 17,000, the priority of tubewell projects in Shujaabad, Fordwah Sadiqia, Bahawal, and Rohri South would best be deferred for public groundwater development until after 1975.

IACA has reviewed the results of its analyses in the light of the quality of information used. On this basis IACA excluded from its development program all Peshawar Vale areas because the data base for groundwater hydrology and geology was insufficient for the purpose. In these areas further investigations would thus be called for to confirm or otherwise reject the high priority status so far established. In its final analysis IACA has further relied more heavily on its technical criteria

[1] The Study Group's linear programming analysis is presented in detail in Supplemental Paper No. IV, Volume III.

TABLE 3-11
POTENTIAL PRIORITY AREAS FOR PUBLIC GROUNDWATER DEVELOPMENT BEFORE 1975

Area	Million Acres of CCA
Rechna Doab:	
Lower Chenab (perennial)–fresh area	0.717
Bari Doab:	
Dipalpur above B.S. Link–total command	0.372
Ravi-Dipalpur Link Internal–total command	0.595
Mailsi below SM Link–fresh area	0.393
Sidhnai (nonperennial)–fresh area	0.190
Sutlej Left Bank:	
Bahawal above MB Link–total command	0.051
Bahawal below MB Link (perennial)–fresh and mixing area	0.165
Bahawal below MB Link (nonperennial)–fresh area	0.195
Qaim–total command	0.042
Fordwah Sadiqia–fresh and mixing area	0.360
Panjnad Abbasia–fresh and mixing area	0.878
Indus Canals—Punjab:	
D.G. Khan–fresh area	0.482
Paharpur–fresh and mixing area	0.080
Thal–fresh and mixing area	1.360
Indus Canals—Sind:	
Dadu North–fresh area	0.082
Rohri North–fresh and mixing area	0.598
Rohri South–fresh and mixing area	0.528

where priorities derived in accordance therewith did not coincide with those established on the resource allocation model.

After exclusion of ongoing groundwater development projects from its listing of priority areas, IACA has determined 17 areas of sufficiently high priority to be developed through public tubewell installations in the period up to 1975. These are listed in accordance with their regional distribution in Table 3-11. While the tentative list of priority areas accorded in principle with the general development criteria of IACA, it did not yet provide a satisfactory basis for selection of project areas. Further factors had to be taken into account in project area identification and in establishing a timely sequence of development. Amongst these, IACA gave special significance to the following: (a) state of investigations required for project formulation; (b) introduction of Tarbela water in 1974/75; (c) extent of high water table and/or extensive waterlogging; (d) estimated annual recharge; (e) incidence of soil salinity; (f) the need to formulate projects on a contiguous area basis; and (g) existing and projected private tubewell development. The qualitative recognition of all factors, technical criteria, economic determination of priority areas, elements of project formulation, led IACA to diverge partially from the above list.

On pragmatic grounds, but guided by quantitative analyses, IACA has thus concentrated its proposals for new public tubewell projects before 1975 in three major regions of the Indus Basin.[1] The project areas are identified (see Map 5)

[1] With the exception of Haveli (Shorkot-Kamalia).

and their main groundwater characteristics are given in summary Table 3-12. Aspects pertaining to project formulation and evaluation are discussed in Chapter IV.

Drainage and Flood Control Priorities

Drainage requirements resulting from a rising water table in usable groundwater zones are in general met by IACA's priorities for tubewell development. To the extent that tubewells cannot perform the dual function discussed above because of saline groundwater conditions, tubewell installation for the purpose of drainage alone has been assigned lower priorities. Horizontal drainage in the form of tile drainage is proposed as pilot schemes in conjunction with the tubewell projects in Shorkot-Kamalia and the Lower Bari Doab command. In order to gain experience with this type of drainage, tile drains are also proposed at an early stage in two Ghulam Mohammed Barrage commands, namely K.B. Feeder and Tando Bago. Other vertical and/or horizontal drainage works mainly associated with canal enlargement would, in accordance with IACA, be carried out generally in conjunction with the increase of canal capacities.

As discussed above IACA has established a need for surface drainage only in the north of the Punjab and the south of the Sind. Within these zones it did not prove possible to analyze the relative priorities for development; thus IACA's

TABLE 3-12
PRIORITY PROJECT AREAS IDENTIFIED BY IACA FOR PUBLIC TUBEWELL DEVELOPMENT BEFORE 1975

Name of Project Area	Principal Canal Command	(000' acres)	Fresh	Mixing	Saline	Water Table 10'
			(%)	(%)	(%)	(%)
Rechna Doab:						
Shorkot Kamalia	Haveli	294	76	11	13[a]	78
Bari Doab:						
Ravi Syphon Dipalpur Link	Haveli	595	43	45	12[a]	30
Dipalpur Above BS Link	Haveli	372	92	8	—	55
Dipalpur Below BS Link	Haveli	611	59	41	—	28
Shujaabad	Sidhnai	379	80	20	—	74
Sutlej Left Bank:						
Fordwah Sadiqia	Sidhnai	359	66	34	—	56
Bahawal-Qaim	Sidhnai	522	64	36	—	7
Panjnad Abbasia	Sidhnai	878	82	18	—	83
Lower Indus:						
Begari Sind	Sidhnai	349	100	—	—	90
Sukkur Right Bank	North West and Dadu North	273	59	41	—	97
Rohri North	North	598	75	25	—	40
Rohri South	North	528	76	24	—	5
Total		5,758				

[a] CCA as stated includes some drainage of saline areas and canal remodelling. The public tubewell developments alone would cover 0.257 M.Ac. in Shorkot Kamalla and 0.522 M.Ac. in Ravi-Syphon-Dipalpur Link.

program for drainage depends largely upon the judgments they have made in the light of their field observations. Broadly they attach high priority to two major surface drainage schemes. One is the GOP Sukh Beas Nallah scheme in the Bari Doab for which they prepared a project report[1] and the other is LIP's proposed Left Bank Outfall Scheme in the Lower Indus Region (Map 7). In addition the IACA program allows for various small drainage undertakings in the Rechna Doab and for ongoing works in Ghulam Mohammed command. For the Sukh Beas project IACA proposes some modifications to the GOP proposals. A descriptive summary of the main features of the project is given in Chapter IV.

The Left Bank Outfall Drain in the Lower Indus Region is described in Chapter V. Although the greater part of the work is programmed for execution in the period 1975-85, the expenditure to be incurred in the Third and Fourth Plan periods is large and is estimated at about Rs. 380 million. IACA endorses this scheme and its timing, although no project report is as yet available. IACA's conclusions on flood control measures were summarized earlier in this chapter. Its analysis, albeit based on very limited data, shows that there is not a strong justification for flood protection works. However, flood protection benefits are not always readily quantifiable and to the extent that lives are endangered and the general confidence is undermined such measures should be given proper prominence. For this reason, IACA has allocated some Rs. 74 million for flood protection in the Third Plan period. A draft flood control plan for West Pakistan is presently under preparation by the West Pakistan Flood Commission, and, once it has been finalized, these allocations may need to be revised in accordance with the project content of that plan. IACA does not foresee a case for large expenditures on flood control over the next decade; however, in its program the need to deal with some of the more urgent measures of flood control and associated drainage works is recognized.

Canal Enlargement

IACA's analysis and allocation of canal enlargement priorities were based on the specific limitation stated in Section C of this chapter—that not more than one million acres of the system should be enlarged over the next 10 years which, in terms of acres, is much more restrictive than the limitation imposed on public tubewell development (around 10 million acres). Beyond 1975, the analyses were based on a further two million acres of enlargement works in the period 1975-79 and three million acres in 1980-85. The balance of the program needed to complete the work on the 16 million acres where limitations of canal capacity apply would be executed between 1985-2000. The allocation of priorities has been further influenced by the assumption that link canal capacities would not be increased before about 1980 and the Sehwan Barrage, with its feeder canal to increase deliveries to the Lower Indus Left Bank area, would come into service in 1982.

IACA's analysis[2] showed that prima facie there were high returns to be expected from canal enlargement in many parts of the Punjab where the groundwater was either unusable or approached the upper limit of salinity for mixing with surface

[1] IACA's Comprehensive Report, Volume 12A, Annexure 15B, "Sukh Beas Nallah Drainage Project."
[2] IACA's Report, Volume 2A, Annexure 1 "Economics."

water. In the Sind, Khairpur West and Khairpur East saline groundwater zones offered the most favorable returns. After taking due account of the limitations stated above, IACA derived the following priorities for canal enlargement in the period 1975:

Command	M.Ac
Ravi Syphon-Dipalpur Link	0.207
Lower Bari Doab	0.093
Haveli (perennial)	0.050
Panjnad Abbasia (perennial)	0.485
Khairpur West	0.124
	0.959

As will be seen from Chapter V, these areas are slightly modified in the IACA program of works, which includes also Khairpur East, but in principle the priority allocations have been retained in the program for irrigation development. The priorities after 1975 are largely governed by the link canal program which is also treated comprehensively in Chapter V.

IV

Priority Development Projects

A. FORMULATION AND EVALUATION OF PRIORITY PROJECTS

General Approach

In the terms of reference, IACA was required to identify projects consistent with sound agricultural development objectives and adaptable to a coordinated program for water and agricultural development in West Pakistan. Projects of high priority were to be studied in sufficient detail to determine the costs and benefits associated with the efficient application and utilization of water. The original expectation was that, excluding ongoing projects, this would entail reviewing the priority status and technical aspects of projects already formulated by the Government of West Pakistan and in addition formulating new projects on the basis of regional priorities established by the Study. In the course of the Study it became apparent that—apart from Tarbela and the Sukh Beas Drainage—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 IACA. With few exceptions it therefore became necessary (contrary to the original expectation) for IACA not only to identify but also to formulate projects on the basis of the regional priorities established and discussed in Chapter III.

With the exception of surface water projects and drainage schemes, all water development projects evaluated and introduced in IACA's development program for the period 1965 to 1975 are thus newly formulated projects. In its approach to project formulation, IACA has made use of the information made available to it by the Government and its consultants and has supplemented existing studies and investigations by field inspection and detailed studies and investigations of its own. All the projects formulated by IACA have as their central objective the further development of water resources for irrigation and the efficient utilization of existing and enhanced irrigation supplies within the project areas. The detailed review and evaluation of one of IACA's project proposals by the Study Group is set out in Annex 7. The results for all of the projects are summarized below. IACA has not formulated and evaluated any nonwater development activities in the form of projects nor has it attempted to establish functional priorities for nonwater activities. The following discussion of projects formulated and evaluated by IACA and their integration into an internally consistent development program is therefore limited to the development of water resources and their use for agriculture.

Surface Water Projects—Tarbela Dam

Background. The harnessing of unregulated and wasteful river flows beyond the surface water storage development at Mangla and Chasma is of high priority for the augmentation of rabi supplies throughout the irrigation system. This is particularly the case in areas where either groundwater mixing is required or where the groundwater is not suitable for irrigation. The various alternative possibilities of providing river regulation and storage facilities were discussed in Volume I of this Report. Here the discussion is limited to the first stage storage development selected and the likely benefits obtainable from this.

In accordance with the Memorandum of Understanding (dated November 14, 1963) between the President of Pakistan and the President of the World Bank, the first part of the Indus Special Study was devoted to the preparation of a report on the "technical feasibility, the construction cost and the economic return of a dam on the Indus at Tarbela." The assessment of the Tarbela Project thus had to proceed before a comprehensive appreciation of the needs for further development of the irrigation system as a whole was available. The evaluation of Tarbela in isolation was completed by IACA on November 15, 1964. On the basis of the IACA studies, the Study Group concluded in its "Report on a Dam on the Indus at Tarbela," dated February 15, 1965, that:

1. The Tarbela project was technically feasible.
2. The financial requirements for construction of the project would amount to $900 million, including power installations but before Pakistan duties and taxes.
3. The return to the economy from agriculture and power would be about 12 percent.

The Memorandum of Understanding further provided that if the Tarbela Project was found justified on the basis of the first phase of the Study, funds available in the Indus Fund after appropriate provision for the Indus Basin Works proper would be available for use on Tarbela.

Consequently the Study Group in its Guidelines, issued to the consultants on March 26, 1965, stipulated that IACA in its projections for future water development had to assume the completion of the Tarbela Dam by October 1973 or 1974.[1] Nevertheless, the Study Group felt obliged to ascertain in accordance with para. 9(e) of the Guidelines that the evaluation of Tarbela Project in isolation would also be valid in the context of the comprehensive phase of the Study. In its endeavor to evaluate Tarbela as an integral part of the system development as a whole, the Study Group received valuable advice from its coordinating consultant, Sir Alexander Gibb and Partners of London.[2]

The Tarbela Project is clearly the first choice for further storage development in the Indus Basin.[3] The indicative sequence of further storage development beyond the 10-year period (1965–75) is discussed in Chapter V below.

[1] Subsequently the target date had to be revised to August 1975 because of further likely delays in the starting date of construction. Partial storage has been assumed for the rabi season 1974/75.
[2] The Tarbela Report, Evaluation of the Tarbela Project within the Development Program of the Indus Basin: Annex 4.1. Sir Alexander Gibb and Partners, London, November 1966.
[3] In this context, the raising of Chasma Barrage is considered an ongoing project.

Tarbela Dam. Construction of the Tarbela Dam is the main element of the Action Program for the further development of gravity irrigation. The Tarbela reservoir as proposed would initially contain 11.1 MAF of gross storage with a live storage of 9.3 MAF at a minimum drawdown level of 1300 feet. For purposes of irrigation planning commensurate with the needs of power development, IACA has adopted a drawdown level of 1332 feet resulting in an initial live storage availability of 8.6 MAF. Because of the high silt content of the Indus water and the associated sediment deposition in the reservoir, the live storage would decrease over time. It is estimated that the reservoir would silt up during a period of approximately 50 years after which time the regulating capacity of the reservoir would be about 1 MAF.

The assumption that construction of Tarbela Dam would be completed in time to serve the crops in the rabi season 1974/75 had to be reassessed, as it became probable that it would not be possible to impound the full amount of 8.6 MAF by that date. IACA assumed that a limited amount of 5 MAF—equal to the projected storage requirements of the rabi season 1974/75—would be impounded during the flood season of 1974. The encountered delay in the start of construction would therefore not affect the irrigation program outlined by IACA. Allowing for sedimentation, the storage volume available for irrigation releases at reference years would be as follows: on completion, 8.6 MAF; in 1985, 7.4 MAF; and in 2000, 5.35 MAF. According to the IACA program, impounding to top water level, i.e. 8.6 MAF, would still become possible by the flood season of 1975 with full availability of storage during the release period 1975/76.

The cost estimates included in the Study Group's report of February 15, 1965 remain virtually unchanged. Total investment requirements including power facilities, allowance for inflation, and financial contingency are estimated to total about $900 million (Rs. 4,284 million equivalent) with a foreign exchange component of about $559 million. The economic costs proper excluding transfer items and expenditures incurred prior to January 1, 1964 would amount to $625 million (Rs. 2,976 million equivalent), with a foreign exchange component of about $390 million. Expenditures would extend over a period of about 11 years including precontract cost incurred since the beginning of 1965.

Function of Tarbela. Historically, the development of water resources in the basin of the Indus and its tributaries has been concentrated in the eastern part of the Punjab, now partially located in India, because the greater part of the irrigable land lies on the eastern side of the Indus Plains. The future diversion of the flows of the eastern tributaries for Indian use under the terms of the Indus Waters Treaty makes it necessary to transfer substantially larger water resources located in the west for use in the eastern parts of the Pakistan Punjab. This is presently being provided for by the construction of a system of large link canals which will transfer Indus waters from the west to the east nearly as far as Islam Barrage (Map 6).

In the absence of storage these diversions will be entirely dependent on the natural flow of the Indus and its tributaries—flows which are largely concentrated in the period from April to October, thus providing mainly water for kharif use. However, even under natural flow conditions, there are frequent water shortages for early and late kharif needs. For winter cropping (rabi), the absence of adequate river flows during the period from October to March constitutes a high risk element from which, especially, the strategically important wheat crop suffers.

After Mangla, which will regulate the river flows of the Jhelum, the Tarbela project storing for release about 8.6 MAF on the Indus would thus be the logical continuation of a shift in water development from the smaller eastern tributaries to the major Indus resources in the west. Because of its regulating effect between seasons, Tarbela would augment total available irrigation supplies by storing surplus flows of the Indus in the summer for use in the rabi months.

The functional contribution of the Tarbela Project in the future development of irrigation can be summarized under these main aspects:

1. The project is a further step in exploiting the huge water resources in the Indus presently flowing to the sea partially unused.
2. The project would provide augmented irrigation supplies and benefit in particular wheat production by increasing the reliability of irrigation supplies for rabi crops as well as the total volume of winter supplies.
3. The project would enable an extended utilization of the link canal system by diversion of storage releases through the link canals for use in the central parts of the basin.
4. The project would increase the recharge to groundwater and so add to the recoverable recharge in usable groundwater zones.

In quantitative terms, the regulating effect of Tarbela would increase the mean flows of the Indus from mid-October to mid-April by about 65 percent.[1] The immediate utilization of such a large increase during one season may be difficult to achieve by the benefiting farmers but the Study Group believes that most of the Tarbela storage releases would be rapidly absorbed since the farmers have generally overextended their cropped acreage relative to existing irrigation supplies in the rabi season.

Interdependence of Tarbela and Water Development Plan. In formulating its water development plan IACA assumed the availability of Tarbela storage by 1975 as discussed above. The increase of Indus flows during rabi by 65 percent at a predetermined point in time from a single indivisible source must of necessity carry consequences for associated resource development activities proposed under an integrated program. These consequences relate in particular to the determination of priorities for groundwater development, canal enlargement, and the need for reallocation of surface water supplies. The implications relevant for planning can be summarized as follows:

1. The need to prevent further deterioration in seriously waterlogged areas requires the provision of sufficient groundwater table control before additional surface water from Tarbela can be admitted. The location and timing of tubewell projects providing such control had thus to be seen in the light of the existence of Tarbela storage by 1975.
2. The need for canal enlargement is dependent upon the increase of surface water supplies at critical months during which existing canal delivery capacities would have a restraining effect on further development. Existing capacities are designed largely to meet kharif needs and are in general underutilized during rabi. However, increased supplies during rabi would also require additional deliveries during the months when kharif and rabi requirements overlap and are likely to exceed delivery capacities. Where this occurs the integration with groundwater development would relieve the constraint by concentrated pumping during overlap months.

[1] Measured at Attock.

3. The timing of the development of areas underlain by less-than-fresh groundwater—water which would either require mixing with fresh surface water or would not be usable for irrigation—would be dependent on the additional availability of surface supplies.

The IACA program for irrigation development (see Chapter V) takes full account of these implications and treats Tarbela as an integral part of a set of mutually dependent water development activities.

While there is some flexibility with regard to the timing of Tarbela in the context of IACA's development program, any deferment would have the following consequences: (a) priorities for tubewell development and the feasibility of mining would need to be re-appraised; (b) canal enlargement could assume increased importance; (c) development of the Lower Indus region would be slowed down since it depends on main-stem storage for additional rabi surface supplies; (d) agricultural growth would be adversely affected and, importantly, the projected production increases in wheat would be jeopardized.

In the absence of an alternative development program without storage equivalent to Tarbela, the repercussions of a deferment can only be quantitatively assessed on the basis of a hypothetical alternative.[1] As far as alternative sequences of storage development are concerned these would largely carry similar implications. In the latter case the problem would be reduced to a comparison of least cost and least risk alternatives.

Tarbela Benefits. In the context of the comprehensive phase of the Indus Special Study it became possible to assess the Tarbela benefits in terms of its contributions within the system as a whole. IACA has assessed the value of stored water from Tarbela in terms of its availability under mean year flow conditions during the so-called scarce period of the rabi season. This period of scarcity[2] has been defined by IACA as the period during which the water requirements of projected rabi intensities would either exceed the existing diversion capacities or the available unregulated river flows. In general, the scarcity has been determined within existing canal capacities except for the period after 1985 when canal enlargement would be expected to figure more prominently in the development program. Within any storage release season, the scarce water period was thus taken to be generally that period of the rabi season during which irrigation demands measured at the rim stations would exceed the river inflow under mean-year flow condition.

The value of scarce rabi water has then been determined by relating total rabi production to total scarce rabi water availability. In accordance with this concept IACA has determined the following values per acre-foot of scarce rabi supplies for reference years:

	1975	1985	2000
Rs./Acre-Foot at Watercourse Heads:	135	150	171

[1] An attempt to quantify the effects of Tarbela deferment has been made in the Study Group's Linear Programming Analysis. This confirms that in terms of net present worth, at an 8 percent discount, the deferment of Tarbela would be more costly to the economy of West Pakistan than the implementation of the proposed program.

[2] 1975: November to March
1985: November to April
2000: October to May

This does not include benefits resulting from recoverable recharge due to additional surface water deliveries during the rabi season.

The specific scarcities employed by IACA for the evaluation of Tarbela water would result from increasing rabi intensities supported by additional groundwater pumping at the beginning and at the end of the rabi season. In this way, the pumping pattern assumed by IACA would create an additional water demand for the interim period of the rabi season which would in turn be met by Tarbela releases. The combined beneficial effects of groundwater pumping and storage releases have then been attributed to the volume of water available during the period of scarcity. The specific scarcity during the rabi season, as defined by IACA, would be dependent on the associated increased water availability during the early and late rabi. This would generally be provided from groundwater. Because the latter is not included in the scarcity definition, IACA's approach tends to overstate the value of Tarbela water. To reflect the interdependence the value of additional water in the rabi season would need to be adjusted by extending the definition of scarcity to all rabi supplies contributing to rabi intensity growth. Alternatively it could be recognized in terms of the economic costs incurred in providing incremental supplies in early and late rabi (e.g. tubewell pumping).

IACA's approach also implies that the marginal value of scarce rabi water is equal to its average value. This would assume constant returns to scale at any point in time and also under conditions of surpluses associating with the sudden availability of rather large quantities of water germane to the nature of storage development. This has been partly recognized by IACA in valuing only those quantities of scarce rabi water which are expected to be readily and efficiently absorbed by farmers and by neglecting any excess availabilities.

IACA's approach was largely necessitated by the absence of an alternative water development program which would minimize the requirement for stored water by a redistribution of the annual groundwater pumping pattern and the possible introduction of groundwater mining. It is further argued by IACA that such a comparison of alternative sequences of water development would have required the determination of priorities under conditions of no stored water availability beyond Mangla and Chasma. This, IACA believes would have led to a different combination of groundwater development priorities than the ones established in conjunction with large-scale main-stem storage development. However, since IACA was required to plan the cohesive irrigation development program on the basis of main-stem storage availabilty by 1974 as a given item, its evaluation of Tarbela is in full accordance with the terms of reference. On this basis, and allowing for operation and maintenance expenditures as well as adding the net value of recharge from the additional surface water used, IACA has arrived at a return on the investment for Tarbela of 13.3 percent inclusive of power benefits.[1]

In testing the results of IACA's evaluation, the Study Group followed a number of approaches outlined in Volume I. In these agricultural studies it has introduced a number of different assumptions relevant to the reservations expressed above on the IACA methodology. Two separate analyses have been carried out. The first one employs the IACA data but relates total rabi supplies to total rabi production

[1] In its evaluation IACA has used the power benefits as shown in the Study Group's Tarbela Report of February 15, 1965.

values in the determination of the value of rabi water in the system over time. The second analysis makes use of the average value per acre-foot of incremental water in priority project areas as determined in the Study Group's project reviews. In this case, the total quantity of Tarbela water is assumed to be distributed and used by farmers throughout the system on the basis that in the short term, temporary rises of the water table could be tolerated in the interest of rapid increase in production and that farmers would have sufficient flexibility with regard to cropping intensities to absorb the marginal quantities of Tarbela water which have been given no value under the IACA approach. In the Study Group's analysis costs incurred for additional recharge pumping have been charged only for the quantity assumed to be recovered for use plus saline recharge pumping but not for drainage pumping in fresh water zones.

The average values per acre-foot of incremental water used in the Study Group's analysis reflect the effect of additional water on both the kharif and rabi seasons. Tarbela is thus regarded as an additional source of water within a fully integrated water supply schedule supporting the agricultural production process as a whole. This appears justifiable on the basis that the growing degree of integration of groundwater and surface water supplies would make the contributions to production of the various sources of water supply increasingly indistinguishable. It also tends to give a more adequate picture of the nature of the development envisaged by IACA under which tubewell pumping patterns, canal diversions and storage releases would be operationally integrated to serve a specified agricultural production cycle. The evaluation based on project reviews extrapolates the average value of incremental water established in project areas to the total quantities available from Tarbela within as well as outside the project areas.

For purposes of comparison the results of the IACA evaluation, the two test analyses, and the results of the Study Group's Report of February 15, 1965 are set out in Table 4-1. Power benefits have been included in the evaluation. However, for purposes of the Study Group's Evaluation II, the power benefits assessed on the basis of the comparison of most feasible alternatives (see Volume I) have been used. Depending on the variations in the assessment of agricultural and power benefits, the latter would vary between 10 percent and 27 percent of total discounted benefits.

While the above results may be indicative of the range within which the return from Tarbela is likely to fall, it is most difficult to establish more than a repre-

TABLE 4-1
RESULTS OF TARBELA EVALUATION

	IACA Evaluation	Modified IACA Evaluation	Study Group Evaluation		1965 Study Group Evaluation
			I[a]	II[b]	
Net Present Worth of Benefits at 8% (Rs. million)	3,770	3,353	1,994	2,241	3,537
Power Benefits as % of Total	10%	10.7%	18.3%	27.3%	18.3%
Benefit/Cost Ratio (at 8%)	1.9	1.8	1.1	1.2	1.9
Rate of Return	13.3%	12.5%	8.4%	9.2%	13.3%

[a] Using IACA power benefits. [b] Using power benefits as assessed by the Study Group.

sentative evaluation because of the complex technical interdependencies of the project with other water development activities and the resulting joint cost and benefit occurrences. The efficiency of this project has of necessity to be seen in terms of its functional contribution within an integrated system. The value of surface water storage is enhanced by the presence of large tubewell fields. Simultaneously the provision of main-stem storage greatly improves the value of tubewell development. The development of the two sources of irrigation supplies not only leads to a greater flexibility in the operation of the system but because of incremental groundwater recharge from regulation of surface water flows both tubewell fields and reservoir operate at a greater efficiency.

The need to develop a balanced supply of irrigation water which reduces the risks involved in the development of groundwater, only makes the exploitation of main-stem storage opportunities the most logical next step in surface water development in West Pakistan. The Study Group is satisfied that the provision of main-stem storage in conjunction with groundwater development is essential to meet the irrigation requirements projected to prevail in the 1970's. The Study Group's analyses show that Tarbela could provide such storage at reasonable cost and would thus make a substantial contribution to the growth of agricultural production as well as towards meeting future power needs. While alternative sequences of storage development appear possible, the Study Group is similarly satisfied that the Tarbela Project would have to be included in any sequence, though possibly at different points in time. Considering the fact that no other storage project of a similar magnitude, which would transfer the irrigation development to the main-stem of the Indus, is advanced enough in preparation and design to effectively compete with Tarbela by 1975, the Study Group firmly believes that the Project should be executed as scheduled.

Tubewell Projects

Basic Considerations. On the basis of criteria discussed in Chapter III, IACA has formulated tubewell projects generally covering from about 300,000 to 800,000 acres and designed to pump on average the mean annual recharge to the aquifer. The additional irrigation supply from groundwater, together with existing surface supplies and their anticipated improvements in quantity and seasonal distribution, would be generally sufficient to obtain cropping intensities of about 150 percent at full delta irrigation applications in fresh groundwater areas.

Where, in the interest of formulating projects on a contiguous land base, it became desirable to include mixing zones within the priority project areas, the cropping intensities tend to be influenced by the availability of surface supplies for mixing with groundwater at watercourse heads. Owing to limitations of canal capacities, this would result in somewhat lower intensities in mixing zones which, in turn, depending on the extent of the mixing area, would lead to overall lower intensities for the specific projects. However, to the extent that project intensities are always based on full delta applications, there would be some opportunities for further increases of intensity, though at some underwatering, subject to the qualifications discussed in Chapter II.

Projects Formulated. IACA has formulated 12 public tubewell projects concentrated principally in three regions, the Bari Doab, Sutlej Left Bank and Lower Indus Region. The total number of tubewells included in these projects would amount to 11,403 of which 4,867 would be of about four cusec capacity and 6,316 of about three cusec capacity.[1] The projects would cover a total CCA of about 5.8 million acres. All tubewell projects formulated have been reviewed by the methods indicated in Annex 6. Table 4-2 sets out the salient features of each of the projects. The location of individual tubewell project areas is shown on Map 5.

Of the total of 5.8 million acres CCA covered by the projects about 4.1 million acres or 71 percent would be in fresh water zones. In about 49 percent of the total area covered groundwater would be pumped initially from a depth of less than 10 feet. The total installed capacity would amount to about 37,000 cusecs, designed to extract about 12.6 MAF at full development. The ultimate cropping intensity achievable in the project areas at full delta varies from 145 percent to 150 percent. In general the ultimate intensity level would be achieved within about 10 years after initiation of the project and depending on the level of intensity presently prevailing.

Cost Estimates. IACA's estimates of investment costs are based on recent experience with bids submitted by international contractors plus separate allowances for overheads of the implementing agency. In general, IACA demonstrates an economy of scale with regard to tubewell capacities as given in Table 4-3.

According to the Table, a five cusec well would appear the most economical size. However, the area covered by an individual tubewell (watercourse), the aquifer characteristics, and the pumping requirements under an integrated system of surface and groundwater supplies generally limit the capacity to about four cusecs or less. In the fresh groundwater zones, IACA has based its cost estimates on a four cusec capacity well. Where mixing is required the capacity of an individual tubewell would be generally less than four cusecs and the costs per cusec proportionately higher.[2] The average capital cost per four cusec well, estimated by IACA at Rs. 90,000, would consist of the following:

	Rs. thousand
Tubewell Construction (excluding power transmission and distribution)	62
Contingency and Engineering (30%)	18
Buildings, Maintenance Equipment, Administration and Supervision During Construction	10
	90

The foreign exchange component of these costs has been estimated by IACA to consist of 62.5 percent of the tubewell construction, 100 percent of plant, machinery and maintenance equipment, and 20 percent of staff housing and buildings, or roughly equivalent to 62 percent of the above shown costs. While no detailed assessment has been made by IACA of duties and taxes, since these are liable to vary over time, the consultant has generally assumed that these expenditures would amount to about 30 percent of the foreign exchange component. In IACA's

[1] Variations in capacity result largely from the different pattern of pumping requirements in fresh groundwater and in mixing zones. In mixing zones capacities would vary from two to three cusecs.

[2] Details are given in IACA's Comprehensive Report, Volume 5, Annexure 7.

TABLE 4-2

GROUNDWATER DEVELOPMENT PROJECTS IDENTIFIED AND FORMULATED BY IACA

Project	CCA ('000 acres)			Number of Wells			Installed Capacity	Depth to Water Table (% of Project Area)		Groundwater Pumped at Full Development	Ultimately Attainable Cropping Intensity
	Freshwater Zone	Mixing Zone	Total	4 Cusec	3[a] Cusec	Total		Less than 10′	More than 10′		
							(cusec)	(Percent)		(MAF)	(Percent)
Rechna Doab:											
Shorkot-Kamalia	222	72[b]	294	370	56	426	1,650	78	22	0.61	149
Bari Doab:											
Dipalpur Above BS Link	344	28	372	580	50	630	2,460	55	45	0.76	150
Dipalpur Below BS Link	362	249	611	473	377	850	3,020	28	72	1.01	150
Ravi Syphon-Dipalpur	257	338[b]	595	440	340	780	2,600	30	70	0.98	150
Shujaabad	303	76	379	576	149	725	2,730	74	26	0.98	149
Sutlej Left Bank:											
Fordwah Sadiqia	237	122	359	495	170	665	2,420	56	44	0.86	145
Bahawal Qaim	335	187	522	618	306	924	3,290	7	93	1.22	146
Panjnad Abbasia	716	162	878	1,315	308	1,623	6,110	83	17	2.37	148
Lower Indus:											
Rohri North	451	147	598	—	1,580[c]	1,580	4,210	40	60	1.21	145
Rohri South	400	128	528	—	1,500[c]	1,500	3,730	5	95	1.14	130
Begari Sind	349	—	349	—	880	880	2,640	90	10	0.72	150
Sukkur Right Bank	160	113	273	—	820	820	2,120	97	3	0.72	150
Total:	4,136	1,622	5,758	4,867	6,536	11,403	36,980	49	51	12.58	150

[a] The capacities of wells included under this category would vary from 2 to 3 cusec.

[b] Including some saline areas for which tile drainage proposals have been made by IACA.

[c] Including tubewells required on remodelling.

TABLE 4-3
IACA ASSESSMENT OF CAPITAL COSTS OF VARYING CAPACITY TUBEWELLS[a]

Capacity	Cost/Tubewell	Cost/Cusec	Cost Index per Cusec
	(Rs. thousand)		
5 cusec	103	20.6	100
4 cusec	90	22.5	109
3 cusec	81	27.0	131
2 cusec	72	36.0	175

[a] Before customs duties and interest and without power distribution and transmission.

assessment total financial requirements per four cusec tubewell before interest during construction would thus amount to about Rs. 102,300.

In its review of the IACA cost estimates, the Study Group has made some adjustments consisting mainly of the following elements:

1. An allowance of 5 percent of direct costs (before contingencies) for project preparation.
2. An allowance for improvement of watercourses of Rs. 10/acre CCA.
3. Separate allowances for engineering and administration during construction of 10 percent of direct costs after duties and taxes.
4. Contingency allowances of 20 percent of direct costs including duties, taxes, administration and engineering.
5. A reduction in the duties and taxes from 30 percent of the foreign exchange component to 15 percent.
6. A downward adjustment in the unit cost of pumphousing.

Including duties and taxes, but before interest during construction, the financial requirements per four cusec well in the Study Group's assessment would thus amount to about Rs. 120,000 or an increase of about 20 percent.[1] The Study Group's more liberal allowance for contingencies, supervision and administration during construction, and improvements of internal water distribution facilities, are intended to take account of the very preliminary state of project preparation, the increasing burden of supervision and administration of a rapidly expanding groundwater development program, and the need to support farmers in watercourse improvements to ensure immediate and efficient use of the groundwater made available by the projects.

The cost estimates of individual tubewell projects would vary in accordance with the proportion of lower capacity wells included under the projects as well as with specific requirements of each project area. Following in general the above estimation procedures the financial requirements before interest but including power transmission and distribution for the 12 projects formulated by IACA would compare as shown in Table 4-4.

Considering the IACA estimates and the Study Group's revised assessment for the specific projects as the range within which the capital costs of groundwater development in West Pakistan are likely to fall, the following general cost criteria can be obtained (total costs including electrification, duties and taxes):

[1] This figure is exclusive of power transmission and distribution. If power is added to the total, the difference between the IACA and the Study Group estimates is reduced to about 10 percent.

TABLE 4-4
FINANCIAL REQUIREMENTS OF THE TUBEWELL PROJECTS FORMULATED BY IACA
(including electrification)

	IACA Estimate		Study Group Estimate	
	Foreign Exchange	Total	Foreign Exchange	Total
	(Rs. million)			
Shorkot-Kamalia	34.5	73.2	35.5	80.6
Dipalpur Above BS Link	48.5	97.2	49.9	104.4
Dipalpur Below BS Link	64.8	129.8	65.8	140.4
Ravi Syphon-Dipalpur	67.6	135.4	75.2	189.8
Shujaabad	55.2	110.5	55.5	117.4
Fordwah Sadiqia	50.6	101.6	52.3	109.5
Bahawal Qaim	69.5	139.3	70.6	148.6
Panjnad Abbasia	123.4	247.1	124.0	261.9
Rohri North	100.7	203.0	99.5	212.2
Rohri South	87.7	176.9	88.3	185.4
Begari Sind	59.5	119.8	60.1	126.0
Sukkur Right Bank	52.9	106.7	52.8	111.0
Total	814.9	1,640.5	829.5	1,787.2

Rs. per tubewell on average overall capacities included: 143,860—156,730
Rs. per cusec of installed capacity: 44,360—48,330
Rs. per acre CCA over all areas included: 285—310

The spread of about 10 percent in addition to the contingency allowances of 20 percent included would appear to provide an adequate safety margin for the high degree of uncertainty necessarily implict in the tentative formulation of the 12 projects proposed.

Interdependence of Tubewell Projects and Water Development Plan. As was pointed out above under "Surface Water Projects," groundwater and surface water developments are mutually dependent to a considerable extent. With the exception of the Sukkur Right Bank project, all tubewell projects would eventually absorb additional surface supplies becoming available after completion of Tarbela. In the early period of operation of the tubewell projects, some substitution of existing supplies would be possible because of the need to over-pump the aquifer for purposes of lowering the groundwater table. The generally attainable cropping intensity of 150 percent would thus be supported by incremental supplies from groundwater as well as surface water.

Neglecting minor variations in timing of tubewell installations likely to occur in the process of program implementation, the integrated increases in irrigation supplies as well as possible substitution effects are demonstrated in Table 4-5. Of the total net increase in water availability at watercourse heads of 13.3 MAF within the project areas by 1985, surface supplies would contribute about 2.6 MAF or nearly 20 percent. Most of the additional surface supplies would be required during the rabi season which presupposes river regulation by storage. Assuming a loss factor of about 45 percent for distribution between storage sites and watercourses, the additional surface supplies required by the priority project areas by 1985 would be about 5.4 MAF at rim stations.

TABLE 4-5
INTEGRATED INCREASE IN IRRIGATION WATER AVAILABILITY IN PRIORITY PROJECT AREAS

	Groundwater			Surface Water			Net Increment: Groundwater[a]		Net Increment: Surface Water		Total Net Increase	
	Existing[a]	1975	1985	Existing	1975	1985	1975	1985	1975	1985	1975	1985
						(MAF)						
Shorkot-Kamalia	0.11	0.53	0.61	0.48	0.60	0.62	0.42	0.50	0.12	0.14	0.54	0.64
Dipalpur Above BS	0.20	0.64	0.76	0.37	0.55	0.69	0.44	0.56	0.18	0.32	0.62	0.88
Dipalpur Below BS	0.38	0.89	1.01	0.71	1.06	1.37	0.51	0.63	0.35	0.66	0.86	1.29
Ravi Syphon-Dipalpur	0.28	0.87	0.98	0.67	0.81	0.84	0.59	0.69	0.14	0.17	0.73	0.86
Shujaabad	0.24	0.78	0.98	0.64	0.79	0.82	0.54	0.74	0.15	0.18	0.69	0.92
Fordwah Sadiqia	0.10	0.61	0.86	0.49	0.45	0.69	0.51	0.76	(−)0.04	0.20	0.49	0.96
Bahawal Qaim	0.17	0.90	1.22	0.91	0.82	1.13	0.73	1.05	(−)0.09	0.22	0.64	1.27
Panjnad Abbasia	0.27	1.66	2.37	1.81	2.08	2.20	1.39	2.10	0.27	0.39	1.66	2.49
Rohri North	0.02	1.07	1.21	1.45	1.27	1.71	1.05	1.19	(−)0.18	0.26	0.87	1.45
Rohri South	0.03	0.91	1.14	1.10	0.76	1.28	0.88	1.11	(−)0.34	0.18	0.54	1.29
Begari Sind	0.02	0.63	0.72	0.65	0.62	0.81	0.61	0.70	(−)0.03	0.16	0.58	0.86
Sukkur Right Bank	0.01	0.64	0.72	0.94	0.50	0.60	0.63	0.71	(−)0.44	(−)0.34	0.19	0.37
Total:	1.83	10.13	12.58	10.22	10.31	12.76	8.30	10.74	0.09	2.54	8.41	13.28

[a] Existing groundwater supplies are provided from private tubewells and Persian wheels. The incremental groundwater supplies shown for 1975 and 1985 would be net of existing private supplies. This would somewhat overstate the contribution of public wells since further private development would be expected until beginning of construction of the public projects. Account has been taken of this in project evaluation.

Considerably less additional surface supplies (about 0.2 MAF at rim stations) would be required by project areas in 1975 partly because of the need for initial over-pumping for the lowering of the groundwater table. As groundwater development would proceed and spread throughout the canal commanded area of the Basin the supply and use of stored water would be increasingly integrated with groundwater supplies providing both for increased flexibility in the irrigation system operation as well as in reliability of supplies during critical periods.

Benefits of Tubewell Projects. Benefits of tubewell projects have been estimated by IACA on the basis of projections of agricultural growth "with" public tubewell development as compared to projections of growth "without" such development. For the "without" case separate estimates have been made for continuing private groundwater exploitation and the likely growth of agricultural production in the absence of any further water development. Detailed water budgets for the individual project areas have been developed by IACA to determine the likely future irrigation regimen supporting the growth of agricultural production under respective conditions of development. On the basis of these water budgets future cropping patterns and cropping intensities have been projected in accordance with the concepts discussed in Chapter II. By comparing the development of the "with" case against that of the "without" case the benefits of public tubewell investments have been measured in terms of the increment of production obtainable under project conditions. In these calculations allowance has been made for all associated current costs including on-farm expenditures and operation and maintenance costs of the projects proper. IACA, however, did not distinguish between the sources of additional irrigation supplies but attributed the total increment to the project, i.e. the investment in public tubewells.

In reviewing the benefit evaluation of the individual tubewell projects account has been taken by the Study Group of the relative contributions to be made by the two principal sources of increased irrigation supplies, namely additional groundwater and additional surface water assumed to be used under the project. In measuring incremental production without further water development after the start of the projects account has also been taken of the displacement of existing and projected private tubewells. Furthermore, wherever deemed technically feasible a check has been made against the alternative of stimulated and accelerated private tubewell development instead of public projects.

Compared to the IACA evaluations, the Study Group in its project reviews has made some adjustments of which the more important are the following: (a) allocation of benefits to incremental surface supplies introduced under the project; (b) independent projections of yields and incremental production for both the conditions of further groundwater development and no further water development in project areas; (c) adjustment of cost estimates, as discussed earlier; and (d) treatment of potential savings to private sector as an addition to benefits rather than a reduction in project costs. Of these, the allocation of benefits to incremental surface water has quantitatively the biggest impact and should be kept in mind when comparing the results of IACA's and the Study Group's evaluation results.

Three criteria have been employed for evaluation purposes: the internal rate of return; benefit/cost ratios at 8 percent interest; net present worth of incremental production at 8 percent interest. Because of the preliminary nature of the project formulation and in the absence of detailed field appraisals the results obtained should be regarded as indicative of the potential pending the results of detailed studies. The realization of this potential would depend on the adherence to the schedules for construction and an immediate and efficient utilization of the projects as implied in IACA's proposals. Table 4-6 summarizes the results of the project evaluations. The results shown above should not be taken in isolation as indicative of the relative priorities of the various projects. Technical interdependencies, especially with regard to the integrated use of groundwater and surface water supplies as well as the state of project preparation and the need to dovetail the proposed program into ongoing programs, need to be considered in the phasing of the groundwater development program.

The comparison with the private tubewell alternatives indicates that especially with regard to the proposed projects for the Bari Doab region (Dipalpur above BS Link, Dipalpur Below BS Link, Ravi Syphon and Shujaabad) the advantages of public development over continued private development are only marginal on the basis of the net present worth of incremental production. In the interest of maximizing agricultural output in the short term, it would therefore seem advisable to defer these projects in favor of areas where there has been little private tubewell development. IACA concurs in general with this view and has consequently given a lower priority to the Dipalpur Below B.S. project. In addition to a better deployment of scarce public tubewells in conjunction with private groundwater development, this would have the advantage of greater flexibility with regard to the ultimate choice of development in areas with high private tubewell coverage. Partially high water tables in the other project areas of the Bari Doab are an important factor in IACA's decision to recommend early implementation. The Study Group, in ascribing some drainage effects to private wells, would suggest that consideration be given to deferment of all public development in the Bari Doab[1] into the Fourth Plan period (after 1970), by which time private initiative would have demonstrated more clearly its capacity for dealing with water table control as well as groundwater development.

On the basis of its reviews, the Study Group concludes that the 12 projects tentatively formulated by IACA are sufficiently justified to merit consideration for execution during the period 1965 to 1975. To the extent that decisions on project preparations have to be made in due course the Study Group would recommend that priority be given to the projects in the following order: Shorkot-Kamalia, Rohri North, Panjnad Abbasia, and Rohri South. Bahawal Qaim and Fordwah Sadiqia should follow during the first half of the Fourth Plan period. The projects Sukkur Right Bank and Begari Sind would appear to warrant consideration only in the later part of the Fourth Plan period. Decision on the Bari Doab projects should be made in the light of further experience with private development as discussed above. The phasing of the projects within the overall frame of the ongoing and future groundwater development program is discussed below in Chapter IV-B.

[1] This does not apply to the Wagah area where public tubewells will need to be constructed in the immediate future to substitute surface water withdrawals under the Indus Treaty.

TABLE 4-6

SUMMARY OF EVALUATION RESULTS OF GROUNDWATER DEVELOPMENT PROJECTS[a]

	Public Development						Private Alternative					
	Rate of Return		Benefit Cost Ratio at 8%		Present Worth of NPV at 8%		Rate of Return		Benefit Cost Ratio at 8%		Present Worth of NPV at 8%	
	IACA	Study Group[b]	IACA	Study Group[b]	IACA[c]	Study Group	IACA	Study Group[d]	IACA	Study Group[d]	IACA	Study Group
	(percent)				(Rs. mill.)		(percent)				(Rs. mill.)	
Shorkot-Kamalia	50	21 (17)	5.4	2.2 (1.6)	401	159	35	88	3.3	2.0	87	95
Dipalpur Above BS Link	50	25 (12)	8.1	3.7 (1.3)	645	150	42	52	5.5	2.1	349	150
Dipalpur Below BS Link	47	36 (12)	11.4	45.0[e] (1.3)	982	192	44	49	7.5	2.5	818	192
Ravi Syphon-Dipalpur	48	25 (17)	4.2	1.8 (1.0)	808	301	46	48	5.0	2.9	352	301
Shujaabad	60	31 (19)	4.1	4.0 (1.8)	593	259	80	74	5.4	2.4	198	178
Fordwah Sadiqia	59	30 (24)	6.9	3.6 (2.4)	681	302	32	84	2.7	2.3	49	87
Bahawal Qaim	33	34 (26)	4.3	3.7 (2.5)	519	431	65	74	4.5	2.1	99	117
Panjnad Abbasia	47	22 (19)	5.1	2.4 (1.9)	1,251	596	18	86	1.6	2.3	115	288
Rohri North	35	16 (16)	3.7	1.7 (1.7)	721	329	29	76	3.3	2.0	90	162
Rohri South	45	23 (19)	4.1	2.3 (1.9)	840	342	n.a.	45	2.5	1.7	196	118
Begari Sind	33	14 (13)	3.4	1.6 (1.4)	424	180	More than 100	21	8.2	1.3	139	41
Sukkur Right Bank	29	16 (14)	3.0	1.8 (1.5)	309	178	More than 100	76	7.7	1.8	153	52

[a] A detailed analysis of one project, Dipalpur Above BS Link, is given in Annex 1.

[b] Including potential private savings; figures in brackets indicate results exclusive of potential private savings.

[c] Before allocation of benefits to incremental surface water supplies.

[d] Based on Study Group's adjusted rates of installation and utilization.

[e] Because of the deduction of potential private savings from project costs for the large number of private tubewells assumed to be in existence at the start of the project in this area, the B/C ratio allowing for such savings would appear overstated.

Drainage Projects

General Aspects. As stated before, drainage requirements resulting from rising water tables are in general met by IACA's priorities for tubewell developments in fresh water zones and partially also in mixing zones. Tubewell installations for drainage only have been assigned lower priorities (see Chapter III). Horizontal drainage in the form of tile drainage for water table control in saline groundwater zones has been proposed by IACA under the Shorkot-Kamalia tubewell project as a pilot scheme. IACA also draws attention to the possibility of employing this drainage technique in the Ghulam Mohammed Barrage area. According to IACA, other subsurface drainage works would be carried out generally in conjunction with the enlargement of canal capacities and thus mainly in the period after 1975.

Requirements for surface runoff drainage and saline effluent disposal have also been studied by IACA. The relative priorities for such works have been discussed above. IACA generally endorses the priority for drainage disposal works in the former Sind as determined by LIP but no project has been formulated or evaluated. With regard to surface runoff drainage, IACA has included in the program 1965 to 1975 the G.O.P. Sukh Beas Nallah Drainage Scheme in the northern and central Bari Doab. This project has been reformulated and evaluated by IACA and the discussion of drainage projects hereunder is thus limited to the Sukh Beas Nallah drainage project. The outfall drains proposed for the Sind by LIP would involve prolonged construction periods. These are further discussed in Chapter V in connection with the long-term aspects of irrigation development.

Description of the Sukh Beas Scheme. The purpose of this project would be to permit reclamation of waterlogged lands and to prevent further waterlogging caused by surface runoff in the upper and central parts of the Bari Doab. The project would include the canalization of the old bed of the Beas River. The course of the proposed drain runs from Kasur in Lahore District to the Chenab River near Jalalpur Pirwala in Multan District. The catchment area is about 5,180 square miles bordering on the Dipalpur, Pakpattan, and Mailsi canals on the east and the lower Bari Doab main canal on the west. The zone of influence of the proposed drainage scheme is shown on Map 5.

Three alternative project proposals for the excavation and channelling of the Sukh Beas Nallah over part or the whole of its length have been submitted by the West Pakistan Irrigation Department to the Planning Commission. The design discharges are the same in each alternative and the main variations are in alignment and side slopes. The total length of the old river bed is about 440 miles. Because of realignment it would be possible to reduce the total length of the drain to about 320 miles. In its review of the Irrigation Department's proposal, IACA has made some adjustments of the project principally consisting of additions to Alternative I and including the following elements: (a) 50 percent increase in capacity in the upper reaches of the drain; (b) provision for induced seepage to the groundwater aquifer in the lower reaches of the drain; (c) extension and remodeling of branch drains; (d) rejection of shallow side slopes as proposed by Irrigation Department in Alternatives II and III to eliminate maintenance. In IACA's assessment the inclusion of these alterations would improve the efficiency of the drainage project.

TABLE 4-7
MAIN FEATURES OF ALTERNATIVE SUKH BEAS DRAINAGE PROPOSALS

	Alternative I	Alternative II	Alternative III	IACA Alternative
Design Discharge Capacity:				
at head	426 cusecs	462 cusecs	462 cusecs	462 cusecs
at tail	2424 cusecs	2424 cusecs	2424 cusecs	2263 cusecs
Length of Canalized Alignment	327 miles	327 miles	448 miles	327 miles
	Alignment to be shortened by excavation of by-passes across necks of sharp bends, and with 6-mile outfall reach.		Original alignment to be adopted and excavated to Lacey section, with 6-mile outfall reach.	As under Alternative I but with extension and remodeling of branch drains.
Side Slope	1:1	1:3	1:3	1:1

The main features of the alternatives, including the IACA adjustments, are summarized in Table 4-7. Field drains would be expected to be constructed by farmers themselves.

Cost Estimates. The estimated capital costs for the alternatives proposed by the Irrigation Department range from Rs. 37.2 million for Alternative III to Rs. 64 million for Alternative I. With the adjustments to Alternative I proposed by IACA, total cost estimates would increase to Rs. 142 million including the following principal items in Table 4-8. IACA estimates that about 8 percent of total capital cost or Rs. 11 million would be required in foreign exchange for earth-moving equipment. Farmers' expenditures for construction of field drains has been assessed at Rs. 13 million in addition to the above cost estimates, bringing total project costs to about Rs. 155 million before interest during construction.

It is proposed that construction should begin without delay and extend over a total period of nine years including completion of field drains. The phasing of expenditures would thus be about as follows (in Rs. millions):

	1965/ 1966	1966/ 1967	1967/ 1968	1968/ 1969	1969/ 1970	1970/ 1971	1971/ 1972	1972/ 1973	1973/ 1974	Total
Public	2	10	20	20	30	30	30	—	—	142
Farmer						2	2	4	5	13
	2	10	20	20	30	32	32	4	5	155

The public expenditures would be mainly incurred for the Irrigation Department force account since it is proposed that the construction would be carried out departmentally.

Drainage Benefits. The main benefits from the project would be the reduction in flood damage for agricultural production as well as for structures and buildings. No attempt has been made by IACA to quantify nonagricultural benefits. Agricultural benefits have been calculated by IACA by comparing the flood damage which would be likely to occur with and without the provision of surface runoff drainage. On this basis IACA has established, taking into account agricultural benefits alone, a rate of return of about 15 percent and a Benefit/Cost ratio of 1.8. On the basis of its estimates, the Study Group arrived at a rate of return of 13 percent on the "Enlarged Project."

TABLE 4-8
SUMMARY COST ESTIMATES

	Rs. Million
Alternative I	
Preliminary Costs and Land Acquisition	5.5
Structures and Buildings	11.7
Earthwork	35.1
Other including Contingencies	11.6
Subtotal	63.9
IACA Additions	
Enlargement of Sukh Beas Nallah	20.0
Extension and Remodelling of Branch Drains	58.0
Subtotal	78.0
Total IACA Alternative	141.9

Considering the fact that the proposed drainage project would serve an area where existing levels of agricultural production are amongst the highest for West Pakistan, the Study Group is satisfied that this project is of high priority. The drainage project would support active private tubewell development as well as public tubewell projects proposed for the later part of the period 1965 to 1975. To the extent that 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 the Bari Doab.

B. SEQUENCE AND FEASIBLE RATE OF TUBEWELL INSTALLATIONS

Public Tubewell Projects

The Ongoing Public Tubewell Program. The "ongoing" public groundwater development program—including some projects which are completed—consists mainly of five projects including a total of 10,118 tubewells. Of these, one project (SCARP I) with 1,980 wells was completed in 1962 and is in operation. In addition, 955 wells of a total of 2,830 had become operational (by 1965/66) in SCARP II. Thus since initiation of the public groundwater development effort on a large scale in the 1950s and the start of construction in 1959, a total of 2,935 wells[1] had been completed by 1965/66. The ongoing projects (SCARP II, III, IV and Khairpur) were in various stages of construction; a further 7,183 wells remained to be completed. Financial and contractual arrangements were firm for only about 50 percent of these wells.

The approximate schedule for 1966–72 as proposed by WAPDA for completion of the ongoing program is given in Table 4-9. This indicated very ambitious targets for 1967/68 and 1968/69. Taking all factors into consideration, including the fact that financial and contractual arrangements had not been completed for 50 percent of the wells included in the Table, the Study Group doubts whether this schedule can be adhered to.

[1] Later figures show that in fact only 2,566 were in operation at this time.

TABLE 4-9
SCHEDULE OF IMPLEMENTATION FOR THE ONGOING PUBLIC TUBEWELL PROJECTS

Project	Completed 1959–66	1966/ 1967	1967/ 1968	1968/ 1969	1969/ 1970	1970/ 1971	1971/ 1972	Total to be Completed
				(well completions)				
SCARP I	1,980							
SCARP II	955	420	630	418	307	100	—	1,875[a]
SCARP III	—	240	570	495	165	—	—	1,470
SCARP IV	—	110	500	780	790	745	345	3,270
Khairpur	—	80	200	288	—	—	—	568
Total	2,935	850	1,900	1,981	1,262	845	345	7,183

[a] Consideration is given by WAPDA to the deferment of 400–500 of these wells located in saline zones.

IACA, in its report on the regional development of the Rechna Doab,[1] suggests the initial inclusion in the ongoing program of only 2,260 wells in SCARP IV;[2] the balance of 1,010 wells would be deferred until after 1973 because of extensive private development in much of the project area. This would considerably reduce the peak targets shown in the table. Nevertheless, even with this adjustment, for the remaining 3½ years of the Third Plan period, this would still amount to a total of about 5,850 wells or about 1,670 wells per year on average. This target rate compares to an average performance between 1959 and 1966 of about 450 wells per annum completed. As discussed in Chapter III, the first year of the Third Plan period (1965/66) showed disappointing progress. Although about 1,000 public wells were drilled, no more than about 140 wells were electrified and brought into operation during 1965/66. Even with full recognition of the work in progress, the nearly fourfold increase in the anticipated rate of implementation of the ongoing program would represent a remarkable step-up in the remainder of the Third Plan period.

The Study Group is not aware that any action was being taken on the scale required to meet the organizational, administrative, and financial requirements necessary to support such a rate of implementation in the final years of the Third Plan. While technically possible the achievement of these targets called for immediate action and the concentrated efforts of all agencies concerned. In particular, this required major procedural improvements, stepped-up financial allocations to the executing agency, removal of the constraints on electrification—especially foresighted and integrated procurement schedules for electrical equipment and supplies—and the urgent establishment of management cadres capable of putting tubewell fields into operation immediately upon completion. The task of developing the necessary organization and the coordination of such actions puts time pressure on giving priority to the ongoing programs.

The ongoing program thus left little room for further expansion in the form of new projects during the Third Plan period. To the extent that the ongoing program runs into the Fourth Plan period (1970/71 to 1974/75), beyond the remaining 1,290 wells as scheduled, it would also affect the initiation and phasing of

[1] IACA's Comprehensive Report, Volume 15, Annexure 15E, page 37.
[2] As of the beginning of 1967, finance had been allocated for only about 880 wells of SCARP IV.

implementation of new projects.[1] However, the Study Group believes that, towards the end of the Third Plan period, a higher rate of implementation approaching a total of about 2,000 wells per annum may become feasible if the actions mentioned have been taken in the meanwhile. The projects identified and formulated by IACA would thus be executed mainly in the period between 1969 and the end of the Fourth Plan period. Project preparation activities, however, would have to be stepped-up as well during the remaining part of the Third Plan period.

The 1965 to 1975 Public Tubewell Program. As stated above, the public groundwater development program proposed by IACA includes a total of 11,403 wells. In view of later information received from Pakistan authorities on the status of the ongoing program, and further considerations of relative priorities, IACA adjusted the sequence of implementation originally proposed in its report.[2] The revised schedule would defer initiation of the Rohri North, Ravi Syphon-Dipalpur and Bahawal Qaim projects by one year and that of Dipalpur Below BS Link by two years. The Rohri South project would be slightly advanced and the Begari Sind project would not be initiated before 1973/74. IACA's revised schedule also takes account of the implementation of SCARP IV as proposed by WAPDA. Initially, IACA had deferred installation of about 1,000 wells of this project beyond the Action Program.

The integration of the IACA proposed projects with the ongoing program, as well as the continuation of the groundwater development in the Fifth Plan period, is detailed in Table 4-10.[3] This schedule shows the number of wells expected to become operational each year. In arriving at this phasing, IACA has allowed for a time lag in electrification of one year after completion of drilling for each group of wells. Also IACA estimates that, since detailed project preparation generally would take about two years, it therefore should start about three years ahead of the date shown in the schedule for completion of the first batch of wells in each project.

Overall, this schedule indicates emphasis on the fresh water areas in the Sutlej Left Bank region and in the Sind, as well as on nonperennial areas with water table problems in the Bari Doab and parts of the Lower Rechna Doab. Areas where the rise of water table would not appear to be an immediately serious threat, and where at the same time private tubewell development has been in the past and is likely to be in the future sufficiently active have been deferred for public development. This applies to the Bari Doab as well as the Lower Rechna Doab. For the latter area, WAPDA prepared and proposed implementation of a large public tubewell project (2,300 wells, SCARP V) to have started in fiscal year 1967/68. The Study Group is in agreement with IACA that the bulk of the SCARP V development should be postponed because of the already over-extended scope of the public program and the appreciable existing and growing private groundwater exploitation in the Lower Rechna Doab. Those parts of the area suffering most seriously from waterlogging and salinity have been included under the Shorkot-Kamalia project which is given high priority.

[1] A decision to defer wells planned for in saline areas in SCARP II could provide some relief in this respect.
[2] IACA's Comprehensive Report, Volume 5, Annexure 7, page 91, Table 8-2.
[3] The ADC Tubewell Drainage Scheme in saline areas of Gaja (62,000 acres), for which no details are available, is not included in this schedule.

TABLE 4-10
ACTION PROGRAM FOR GROUNDWATER DEVELOPMENT[a]
(wells in operation)

Project Area	Total Wells	Remainder Third Plan				Fourth Plan					Fifth Plan[b]	
		1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77
Ongoing Program												
Scarp II	2,830	420	590	615	580	305						
Scarp III	1,470	270	520	465	215							
Scarp IV	3,270	50	370	565	635	600	600	450				
Khairpur	568	80	200	288								
Subtotal Ongoing	8,138	820	1,680	1,933	1,430	905	600	450				
IACA Revised Program 1965–75												
Wagah[c]	95			95								
Shorkot-Kamalia	426			100	326							
Rohri North	1,580				140	360	360	360	360			
Panjnad Abbasia	1,623				183	540	500	400				
Dipalpur above BS Link	630					130	360	140				
Shujaabad	725					165	360	200				
Ravi Syphon-Dipalpur Link	780						170	360	250			
Fordwah Sadiqia	665							150	360	155		

Rohri South	1,500							230	360	360	360	190
Bahawal Qaim	924								210	360	354	
Begari Sind	880								180	360	340	
Dipalpur below BS Link	850								90	360	360	40
Sukkur Right Bank	820									180	360	280
Subtotal IACA	11,498			195	649	1,195	1,750	1,840	1,810	1,775	1,774	510
Total Action Program		820	1,680	2,128	2,079	2,100	2,350	2,290	1,810	1,775	1,774	510
New Projects Initiated at End of Action Program												
Lower Rechna Doab	1,850								180	360 }	Balance of 3,760 to be scheduled.	
Lower Bari Doab	2,630									180 }		
Total Annual Rate of Completion		820	1,680	2,128	2,079	2,100	2,350	2,290	1,990	2,315		
Accumulative Total of Wells in Operation		3,755[d]	5,435	7,563	9,642	11,742	14,132	16,422	18,412	20,727		

[a] Based on WAPDA Program of November 1966 and IACA Revised Program as discussed in the text.

[b] Indicative of overlap only.

[c] Project not formulated; wells required for replacement of surface water withdrawal under the Indus Treaty.

[d] Including 2,935 wells already completed (SCARP I and parts of SCARP II), more recent communications indicate that the number of wells in operating condition may be less.

The revised IACA schedule, including the ongoing projects, called for a rate of completion exceeding 2,000 wells per annum by 1968/69 and reaching 2,350 wells per year in the second year of the Fourth Plan period. An effort of this magnitude would require that the program as a whole be put on a plane of activity entirely different from the present. The process of decision-making within both the executing agency and the complementary authorities would need to be substantially accelerated. Contracting procedures would have to be simplified and speeded-up. Exceptional priority for financial allocation, both local and foreign, would have to be assigned to public tubewell project requirements. In addition and most importantly, immediate steps would have to be taken to train and prepare personnel for the management, operation, and maintenance of the tubewell fields to ensure efficient utilization of the investment.

The ongoing program plus IACA's proposed groundwater development would cover approximately 12 million acres of culturable area by 1975. In other words, intensive agriculture based to a considerable extent on groundwater development would be expected to prevail over an area one-and-a-half times that of the Netherlands. The number of public wells in operation by 1975 would be expected to exceed 20,000. The success of a program of this magnitude will depend to a much larger extent on dedicated local personnel for the operation and maintenance of the well fields and the supporting agricultural services than on the purely technical task of installing wells—the installation task has been and can, in the future, be carried out by foreign contractors. The Study Group would fail in the discharge of its responsibility if it did not warn against a rate of tubewell installation which would exceed the locally available capacity for management, operation and maintenance, and lead to a situation whereby well fields remain either inefficiently utilized or not properly maintained.

It is the Study Group's considered opinion that the proposed public tubewell program is technically feasible and economically justified, but that it would in all probability exceed the local technical and agricultural skills likely to be available. However, the Study Group is equally impressed with the need for a much greater emphasis on agriculture and fully recognizes the importance of tubewell development in increasing production. It is for these reasons that the Study Group suggested the adoption of the IACA schedule as an Action Program for 1965 to 1975, delineating the maximum achievable rate of progress in the field of public groundwater development during this period. At all stages, however, care should be taken that construction of new projects would not be initiated until the completion of ongoing projects is ensured. Overextension in both execution and management could lead to a dispersion of effort, which would endanger the success of the program.

Private Tubewell Development

Past Performance. IACA's proposed program for groundwater development places great emphasis on public tubewells. While the performance of the public tubewell program in the past has fallen very far short of expectations despite the high priority it has been accorded,[1] private tubewell development achieved an im-

[1] The Master Plan for the control of waterlogging and salinity as well as the Second Five Year Plan implied a target rate of public tubewell installation of about 2,000 to 2,500 wells per annum.

pressive rate of progress. As discussed in Chapter I 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.

Private groundwater exploitation has been, in the past, mainly concentrated in the better farming areas of the Bari and Rechna Doabs and in the noncommanded and outside areas. The rapidly growing and aggressive tubewell industry, which has sprung up in the larger urban centers of the Punjab in response to the growing demand, has given farmers ready access to commercial implementation facilities. Because of the possibility of using diesel motors, the electrification constraint which heavily frustrated the public efforts, did not obviously affect the rate of private tubewell installations. In the past, some encouragement for private development has been provided by the Department of Agriculture through grants, technical advice and well drilling, but the bulk of private tubewell development occurred without much public support. The present level of private tubewell development has been achieved substantially without any institutional credit support. Farmers have relied mainly on their own resources and noninstitutional credit.

In quantitative terms, some 25,000 private wells must have been sunk during the Second Five Year Plan period, representing private investments of the order of about Rs. 200 million. As shown in Chapter I, tentative estimates indicated that, by 1965, there were some 34,000 private wells in operation in the Province. The regional distribution is given in Table 4-11.

About 30 percent of the private tubewells were connected to the northern zone electrical grid system. The average capacity of these wells was about 1.2 cusecs. By 1964/65 the rate of construction of private wells was about 6,500 per year. As pointed out in Chapter I, this remarkable achievement of the private sector contributed significantly to the recent growth in agricultural production during the early 1960's. This progress in private tubewell development is the more remarkable in view of the fact that it took place without much public support and en-

TABLE 4-11
REGIONAL DISTRIBUTION OF EXISTING PRIVATE TUBEWELLS
(1965)

Region	Number of Wells	Region	Number of Wells
Peshawar and Swat	n.a.	Thal Doab and Indus Right Bank	1,200
Chaj Doab	800	Sutlej and Panjnad Left Bank	1,400
Rechna Doab	9,800	Lower Indus	700
Bari Doab	15,000[a]	Outside Areas	5,000
Subtotal	25,600	Subtotal	8,300
		Total	33,900

[a] This includes the results of a survey by Tipton and Kalmbach, Inc., which indicated that the number of private tubewells in the Bari Doab actually amounted to 17,117 by 1965, of which about 2,000 are assumed to be in the noncommanded (outside) areas of the doab.

couragement. Given the projected rate of public groundwater development discussed above, growth of agricultural production would continue to depend heavily on the performance of the private sector in the field of groundwater exploitation.

Prospects for Development During 1965–1975. There are widely divergent views on the role private tubewell development is likely to or should play in the future development of groundwater resources in West Pakistan. The difference of opinion arises mainly from the varying emphasis that is being placed on the various constraints likely to be operative in the future. In Chapter III, the constraints governing the rate of private development were discussed in the context of future water resource development. IACA's rate of private tubewell development is based on the assumptions that there would be no sustained efforts to stimulate private tubewell installations and that public development, curtailing private growth in some areas, would proceed as originally scheduled by IACA.

IACA has made projections of future private tubewell installations based on assessments of developments in each of the regions, shown in Table 4-11. In making these projections, IACA has taken into account the changing density of private tubewells, the constraints outlined in Chapter III and the effects of public development. IACA has also projected private tubewell installations in each region in the absence of public development. With the Bari Doab projections adjusted to reflect the recent findings of Tipton and Kalmbach, Inc., the projections are compared in Table 4-12. The IACA "with" public tubewell projection compares to the Planning Commission's estimate[1] of an incremental 40,000 private tubewells to be installed during the Third Plan period, bringing the total in operation by 1970 to about 75,000 wells. In the light of past experience, and the Planning Commission's estimate, the rate of growth implied in the IACA projections appears modest. However, attention must be drawn to the substitution effects implied in the public tubewell program. As indicated in the table the public program would reduce the private wells to be installed between 1965 and 1970 from 33,000 to 21,500, and for the decade 1965 to 1975, from 62,500 to 18,500 private wells. In other words, about 70 percent of the projected additional and feasible private well installations—amounting to about 44,000 wells—would not take place because of the competition of the public sector in the development of usable groundwater. This would mean that, in monetary terms, some Rs. 400 million of private investments would have to be substituted by scarce public funds at initial outlays substantially higher than those required for the installation of private pumping capacity.

The rate of growth of operating private wells implicit in the above projections is less than half the rate experienced during the later part of the Second Five Year Plan period. In absolute terms, the average annual rate of private well installation would drop from about 5,000 wells to slightly more than 4,000 wells per annum. Given proper incentives, institutional credit facilities, and a policy conducive to private development as envisaged in the Third Five Year Plan,[1] a substantially higher rate of private installations may be achievable. While there may be a gradual slowing down in 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

[1] Government of Pakistan, The Third Five Year Plan (1965–1970), May 1965, page 300.

TABLE 4–12
GROWTH OF PRIVATE TUBEWELL INSTALLATIONS BASED ON IACA PROJECTIONS

Region	"With" Public Development				"Without" Public Development			
	1965	1970	1975	1980	1965	1970	1975	1980
	('000 wells)							
Peshawar and Swat	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Chaj Doab	0.8	—	—	—	0.8	3.0	5.3	6.8
Rechna Doab	9.8	10.3	7.6	—	9.8	16.1	20.8	22.9
Bari Doab	15.0	29.0	24.5	1.3	15.1	29.0	38.0	43.0
Thal Doab and Indus Right Bank	1.2	2.4	2.8	—	1.2	3.7	7.0	9.5
Sutlej and Panjnad Left Bank	1.4	2.9	1.0	—	1.4	4.0	6.2	7.6
Lower Indus	0.7	2.0	2.5	1.7	0.7	2.2	5.1	7.7
Outside Areas	5.0	9.0	14.0	20.0	5.0	9.0	14.0	20.0
Total	34.0	55.5	52.5	23.0	34.0	67.0	96.5	117.5
Rate of Growth		10.0%	(−)1.5%	(−)17.0%		15.0%	7.5%	4%

brought about by public stimulation and encouragement. If, over time, this latter supposition proves to be correct, the proposals to install public tubewell projects in areas with a high density of private wells should be reconsidered. The need for such reconsideration would seem to apply with particular force to areas such as the Lower Rechna Doab and the Bari Doab.

Preliminary estimates indicated that the total number of private wells installed between 1965 and 1966 in the northern zone alone exceeded 8,400; about 7,900 were apparently new wells while the remainder were replacements. Nearly 65 percent of the new wells installed are diesel-driven. In view of this recent performance, and assuming that active support for private development is forthcoming and any undue competition by public groundwater development is carefully avoided, the Study Group sees no compelling reason why an average annual rate of installation of about 6,500 private wells, achieved at the end of the Second Plan period, should not be maintained during the Third Plan period. This would bring the number of private wells in operation to 66,500 by 1970.[1] Thereafter, substitution by public wells may become more accentuated. Land tenure conditions may increasingly interfere with efficient utilization of private wells. To the extent that the average command per well tends to decrease proportionately to the increase in well density, there seems to be ample room for the projected number of wells, especially if the noncommanded outside areas are taken into account. Considering the assumed relative short life of private wells, replacements of existing wells would also become increasingly important.

However, using the projections of private tubewell growth in conjunction with public development as set forth above, private tubewells and Persian wheels would be expected to provide about 10 MAF of irrigation supplies at watercourse head by 1970 within the canal commanded areas and about 1.8 MAF in the outside areas. This would be about 1 MAF more than the public program could at best con-

[1] Adopting the annual rate of installation achieved at the end of the Second Plan period (6,500 per annum) as compared to the Planning Commission's projection of 40,000 over the five-year period, or an annual average of 8,000 wells.

TABLE 4-13
ESTIMATED MEAN YEAR GROUNDWATER AVAILABILITY AT WATERCOURSE HEADS WITHIN CANAL COMMANDED AREAS

	1970	1975
	(MAF)	
Historic Groundwater Supplies:		
Private (including Persian wheels)	7.0	7.0
Public	2.7	2.7
Subtotal	9.7	9.7
Development of Groundwater Supplies Above Historic:		
Private (including Persian wheels)	3.0	1.5
Public	7.5	19.3
Subtotal	10.5	20.8
Total	20.2	30.5
Requirement in Sequential Analysis:	21.7	31.0

tribute in accordance with the revised schedule also discussed above. Furthermore, this resource development would be brought about without major public investments. The total availability of groundwater supplies as calculated in the Sequential Analysis[1] would nearly be reached in 1970, and also in 1975, though with decreasing reliance on the private sector. The quantities of groundwater available shown in Table 4-13 represent only those pumped within the canal commanded areas and do not include private tubewell pumping in noncommanded areas. Continued private groundwater development on about the scale recently experienced is therefore not only desirable but imperative in the short run if the essential growth of agricultural production is to be achieved. The Study Group would strongly suggest that the Pakistan authorities implement policies conducive to rapid private tubewell development. The improvement of existing institutional supports, in particular credit facilities, technical advice, and council for cooperative ownership and utilization, should be given high priority. Financial resources required for such support would be small if compared to the savings to the public resources on the scale indicated.

IACA expects both private and public tubewells to make important contributions to agricultural growth in the short run. However, IACA regards the distribution of surface and groundwater under full public control as fundamental to the efficient long-term development of water resources, especially because of the need for integrated use of ground and surface water, particularly in mixing zones, and the requirements for effective water table control. IACA maintains that, from a social point of view, public tubewells would ensure a fairer distribution of water, protect the position of the small farmers, and would likely be the only feasible solution to the latent problems of groundwater rights.

[1] Sequential Analysis of a Program for Irrigation and Power Development in West Pakistan, Annex 3.2, Sir Alexander Gibb and Partners, London, September 1966, page 23.

TABLE 4-14
COST OF GROUNDWATER PUMPING AS PROJECTED BY IACA

	Public Tubewells		Private Tubewells	
	Electric		Electric	Diesel
	3 cusec	4 cusec	1 cusec	1 cusec
Assumed Lifetime (years)	20	20	10	10
Capital Cost (Rs. '000)	81	90	7	9
Annual Costs (Rs./year):				
Depreciation and Interest at 8%	7,290	8,100	980	1,260
O&M Including Power (fuel)[a]	8,650	11,630	2,300	3,560
Total Annual Cost (Rs.):	15,980	19,730	3,280	4,820
Assumed Annual Pumpage (acre-foot)	875	1,170	200	200
Average Annual Cost per Acre-Foot (Rs.):	18.2	16.9	16.4	24.1

[a] Based on IACA's assessment of economic power or fuel cost. The fuel cost at a rate of Rs. 1.40 per gallon of diesel fuel appears high. Subsequent studies suggest Rs. 0.91 would be a more accurate figure. Assuming a fuel cost of Rs. 1.0, the average annual cost per acre-foot pumped by diesel powered wells would be about Rs. 20.0. It should also be noted that IACA based its assessment of private pumping costs on the use of 16 hp engines.

While the Study Group appreciates IACA's reasoning for eventual complete public control over all water resources, it has some hesitation with regard to the operational practicability, at least for the first five to 10 years. The integrated irrigation system is meant to provide a service to the farmers who, through their efficient use of the water supplied, determine the success of the system's operation. Farmers' control over at least part of the groundwater exploitation would tend to make them more independent of the rigidities associated with the installation of public tubewell fields as well as the water distribution, project operation and maintenance under absolute public control over all water resources. Increased flexibility of the operation of public well fields may also be achievable through procedures under which farmers would participate in the operational decision-making. However, as demonstrated above, in the short run the role of private groundwater development is indispensable.

On the basis of its estimates of capital cost and current expenditures for public and private tubewells, IACA concludes that there does not appear to be any significant difference between public and private wells in terms of the costs per unit of water pumped.[1] Table 4-14 summarizes IACA's cost projections for the various modes of groundwater exploitation. In this comparison, the capital costs do not include transmission and distribution of electricity since these have been accounted for in the power rate. Private diesel-driven tubewells would appear to be the most expensive form of groundwater exploitation, mainly because of the comparatively high costs assumed for diesel fuel. However, diesel wells would have the added advantage of being independent of power supplies, thus providing an interim solution in areas not yet electrified and also providing a considerably high degree of reliability in areas where power is available but not always dependable. Farmers are already beginning to recognize this by increasing the proportion of installations of diesel-driven wells. (For a discussion of the cost of private tubewells, see Volume III, Supplemental Paper No. 5.)

[1] IACA Comprehensive Report, Volume 5, Annexure 7, page 43.

The cost differential for public and private electric wells is negligible even though private wells are assumed to have a considerably shorter lifetime as well as a lower rate of utilization. If based on comparable quantities of water pumped, private wells would show a superior cost efficiency. However, because of limited commands and difficulties in water distribution, higher rates of utilization of private wells than those used in the cost comparison may be achieved only in individual cases. Nevertheless, while private wells may be pumped at lower rates than public wells, this would generally reflect a pumping pattern directly related to the farmer's actual water requirements rather than to generalized requirements used to establish pumping patterns for large areas. It would therefore tend to lead to a more efficient use of the groundwater pumped. A further and frequently neglected aspect of private tubewells is the fact that they provide a power plant on the farm which can be and is being used for stationary implements such as threshers, grinders, and fodder choppers.

As far as the cost efficiency of groundwater exploitation by individual wells is concerned, there is little demonstrable difference between public and private wells. It may, however, not be possible to achieve the same degree of uniform coverage of large contiguous areas with private wells as is possible under public development. This could result in less effective water table control as well as an overall lower rate of groundwater abstraction. The Study Group would therefore, as stated before, accept the public development as scheduled for the Action Program as indicative of the maximum and would urge the Pakistan authorities to continuously observe the relative performance of public and private development of groundwater resources. In the interest of rapid development, emphasis on public or private groundwater exploitation in usable groundwater zones may be changed from time to time as the relative advantages emerge more clearly.

Integrated Sequence of Groundwater Exploitation

The project content of the groundwater development program discussed above emphasizes the accelerated installation of tubewells in areas underlain by usable groundwater. Both public and private development are important to this program, with emphasis on the latter in the near future and an increasing shift in emphasis on to public development in the later part of the period under consideration. Tubewell installation for the single purpose of water table control in non-usable groundwater zones has been given low priority and would most likely have to be carried out entirely by public means. The proposed program is thus essentially a dual purpose scheme with the primary function of augmenting existing irrigation supplies.

While in practice there would be some flexibility in deciding on the timing and sequence of tubewell projects, it was necessary for IACA to establish a sequence of groundwater exploitation for programming purposes. The extent to which groundwater made available at watercourse head is to be met by public projects and by private tubewell development are compared in Table 4-15. The table clearly demonstrates two elements of great significance for the strategy to be followed during 1965–1975. Firstly, the Action Program as now proposed would by and large meet the required quantities calculated by IACA throughout this period. Secondly, private groundwater exploitation is definitely dominant throughout the Third Plan period and continues to make an important contribution up to

TABLE 4-15
GROUNDWATER PUMPED UNDER THE ACTION PROGRAM

	1965/66		1969/70		1974/75	
	Canal Commanded Area	Outside Area	Canal Commanded Area	Outside Area	Canal Commanded Area	Outside Area
No. of Tubewells in Operation:						
Public	2,900	—	9,600	—	20,700	—
Private	29,000	5,000	46,500	9,000	38,500	14,000
Estimated Annual Pumpage in MAF:						
Public	2.7	—	10.2	—	21.7	—
Private	7.0	1.0	10.0	1.8	8.5	2.8
Total	9.7	1.0	20.2	1.8	30.2	2.8
Private as percent of Total:	72%	100%	50%	100%	28%	100%
Requirement as Calculated in the Sequential Analysis:	9.6	—	21.7	—	31.0	—

1975. It may be that the public program as proposed represents the maximum number of wells likely to come on flow, while the number of private wells scheduled represents a decreasing rate of growth of new installations and may well understate the probability; this interpretation of the figures indicates that care should be taken not to interfere with private development until or unless the successful implementation of consecutive public well fields appears ensured or desirable.

C. FINANCIAL IMPLICATIONS OF THE ACTION PROGRAM 1965 TO 1975

Public Expenditures for Investment

The public investment requirements of the projects included under the Action Program for 1965–75 are summarized in Table 4-16. Total outlays until completion of the projects including interest during construction would amount to approximately Rs. 8.3 billion. Of this amount Tarbela alone would account for about Rs. 5.8 billion or about 70 percent. The ongoing tubewell projects would require Rs. 991 million or roughly 12 percent. The remaining Rs. 1.5 billion or 18 percent of total investment requirements would be for the new tubewell projects and the Sukh Beas scheme to be initiated during the period under consideration. These estimates of financial requirements do not include the investment requirements for transmission and distribution of power to public tubewells.

The Action Program as scheduled would require total public allocations for investment (excluding interest during construction) of Rs. 2.5 billion during the Third Plan period and about Rs. 3.9 billion during the Fourth Plan period. An overrun into the Fifth Plan period involving some Rs. 132 million would occur because of the construction schedules of the various projects. The level of investments would increase from about Rs. 110 million per annum at the start of the period and reach a level of nearly Rs. 900 million at the end of the Third Plan period. During the Fourth Plan period, annual investment expenditures would be generally maintained

TABLE 4-16
PUBLIC INVESTMENT REQUIREMENTS OF THE ACTION PROGRAM

	Third Plan Period					Fourth Plan Period						
	1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	Total
						(Rs. million)						
Tarbela:												
Investment Requirement[a]	12.9	94.2	111.4	565.5	629.7	616.9	694.0	625.5	531.2	321.3	81.4	4,284.0
Interest during Construction[b]	0.4	4.4	10.2	31.4	70.1	112.9	160.1	210.5	259.0	301.0	332.8	1,492.8
Subtotal	13.3	98.6	121.6	596.9	699.8	729.8	854.1	836.0	790.2	622.3	414.2	5,776.8
Sukh Beas:[c]												
Investment Requirements	2.0	10.0	20.0	20.0	30.0	30.0	30.0					142.0
Interest during Construction	0.1	0.4	1.7	3.3	8.4	14.7	23.2					51.8
Subtotal	2.1	10.4	21.7	23.3	38.4	44.7	53.2					193.8
Tubewell Projects:[d]												
(a) Ongoing Program:												
Investment Requirements	96.5	204.4	248.7	143.0	90.5	60.0	45.0					885.1
Interest during Construction	11.5	24.5	29.5	17.2	10.9	7.2	5.4					106.2
Subtotal	108.0	228.9	275.2	160.2	101.4	67.2	50.4					991.3

(b) Action Program[e]												
Investment Requirements			25.4	80.6	122.1	182.7	205.4	194.5	172.9	165.2	50.8	1,199.6
Interest during Construction			1.3	4.3	10.5	17.3	22.0	20.7	21.3	20.7	15.9	134.0
Subtotal			26.7	84.9	132.6	200.0	227.4	215.2	194.2	185.9	66.7	1,333.6
Total Tubewell Projects	108.0	228.9	301.9	245.1	234.0	267.2	277.8	215.2	194.2	185.9	66.7	2,324.9
Total: Public Projects												
Investment Requirements	111.4	308.6	402.5	809.1	872.3	889.6	974.4	820.0	704.1	486.5	132.2	6,510.8
Interest during Construction	12.0	29.3	42.7	56.2	99.9	152.1	210.7	231.2	280.3	321.7	348.7	1,784.8
Grand Total	123.4	337.9	445.2	865.3	972.2	1,041.7	1,185.1	1,051.2	984.4	808.2	480.9	8,295.6

[a] Based on schedule of economic cost, see Annex 4.1, especially Appendix 1, Sir Alexander Gibb and Partners, The Tarbela Project, London, November 1966.

[b] Compound interest @ 6 percent per annum based on equal monthly disbursements.

[c] As per schedule in the text.

[d] Based on IACA's estimates and recent IBRD review of Khairpur estimates; simple interest for two years @ 6 percent per annum.

[e] Based on expenditure schedules of project reviews and phased in accordance with groundwater program as shown in Chapter IV B; exclusive of investment in transmission and distribution.

at the same level except for a tailing off in the later years of the Fourth Plan period.

Compared to the level of public expenditures for water development in West Pakistan during the Second Plan period (Rs. 1.4 billion total), the Action Program represents an increase of nearly 80 percent for the Third Plan period and a two-and-a-half-fold increase for the Fourth Plan period. This does not yet, however, take into account the ongoing Indus Basin Works, other water and drainage development projects not included in the program, and nondevelopment expenditures. The substantial increase in financial requirements for water development in the Third and more particularly the Fourth Plan periods may strain the resources available to the public sector and finance may act increasingly as a constraint on the rate at which public water development might take place.

Private Expenditures for Investment

Private investment in water development during the period of the Action Program would be expected to total about Rs. 760 million. Almost all of this would be for the installation of new and the replacement of existing private tubewells. The table below summarizes the anticipated private investments commensurate with the Action Program and the number of private wells in operation. As already anticipated in the Third Five Year Plan, the average annual level of expenditures during the Third Plan period represents a substantial increase over private investments in the past. While no information is available on the past rate of investments in replacements, this will acquire increasing importance as the number of private wells in operation increases. Thus the level of investment in new installations is expected to drop slightly below the level reached in the later part of the Second

TABLE 4–17

PRELIMINARY ESTIMATE OF PRIVATE INVESTMENT REQUIREMENTS OF THE ACTION PROGRAM 1965–75[a]

	Private Tubewells		Sukh Beas Drainage	
	New Installations	Replacements[b]	Farmer Investments	Total
		(Rs. million)		
1965/66	43.0	34.0	—	77.0
1966/67	43.0	38.3	—	81.3
1967/68	43.0	42.6	—	85.6
1968/69	43.0	46.9	—	89.9
1969/70	43.0	51.2	—	94.2
1970/71	11.8	52.4	2.0	66.2
1971/72	11.8	52.5	2.0	66.3
1972/73	11.8	52.5	4.0	68.3
1973/74	11.8	52.5	5.0	69.3
1974/75	11.8	52.5	—	64.3
Total	274.0	475.4	13.0	762.4

[a] For purposes of estimation, equal annual installments during the five-year periods have been assumed. Actual installments in any one year could deviate considerably from the above schedule.

[b] Estimated on the basis of replacement of 10 percent of wells in operation at respective years.

Plan period because substantial replacements are anticipated. This should not create any great financial problems in view of the high return on private tubewells.

The Action Program as outlined does not foresee substantial new private groundwater development to occur during the Fourth Plan period except in the outside areas and some new installations in the Indus Right Bank and Lower Indus regions. Replacement investments therefore would account for the bulk of private investment during this period. However, this assumption may need to be revised in the light of the rate of public groundwater development. It may indeed become necessary to stimulate private investment in new tubewells throughout the period of the Action Program should there be need to compensate for shortfalls in the public groundwater program. In any case private investments occurring in any parts of the Province and beyond those presently scheduled should find, where technically and economically justified, ready support in the interest of improving agricultural output beyond that projected.

Compared to public investments, the private investments during 1965–75 appear much less accelerated. While this may be an underestimate it should also be recognized that new private investments would be more difficult to bring about. The more prosperous and enlightened part of the farming community most likely has already participated to a considerable extent in private groundwater development. To an increasing degree new investments would thus depend on farmers with less of their own resources, limited access to noninstitutional credit and a much higher dependence on institutional credit. Considering the important contribution that private development is expected to make particularly during the Third Plan period, it appears imperative that the supporting facilities, e.g. institutional credit, technical advice and agricultural extension, are readily available to the private entrepreneur. This may require further improvement of existing credit channels and most likely an overall review of existing credit policies. The Study Group, therefore, would invite the attention of the Pakistan authorities to the need for support of private groundwater development and suggest urgent consideration by the authorities of possible means for such support.

Total Financial Requirements for the Action Program 1965 to 1975

Total financial requirements for the Action Program, including both public and private investments, would amount to about Rs. 7.3 billion before interest during construction and exclusive of electrification. Of this amount Rs. 4.3 billion or 59 percent would be for surface water development and Rs. 2.9 billion equivalent to about 40 percent would be for groundwater development. The remainder of Rs. 155 million represents the investment of the Sukh Beas Drainage Scheme. About 90 percent of the total financial requirements would have to be met from public sources. Table 4-18 summarizes the total investment requirements of the Action Program and gives an indicative phasing of expenditures. As indicated earlier in Table 4-17, interest during construction would amount to an additional Rs. 1.8 billion. The above estimates should be regarded as preliminary and would need verification in the light of results of detailed project preparation. The amounts are, however, indicative of the order of magnitude of finance required should the Action Program be adopted in the form outlined.

The public project content of the proposed program for the Third Plan period would remain within the total Third Plan allocations. This, however, does not take

TABLE 4-18
TENTATIVE ESTIMATE OF TOTAL PUBLIC AND PRIVATE INVESTMENT REQUIREMENTS (EXCLUDING INTEREST DURING CONSTRUCTION) OF ACTION PROGRAM
1965–75

	Surface Water	Drainage	Groundwater	Total
	(Rs. million)			
1965/66	12.9	2.0	173.5	188.4
1966/67	94.2	10.0	285.7	389.9
1967/68	111.4	20.0	359.7	491.1
1968/69	565.5	20.0	313.5	899.0
1969/70	629.7	30.0	306.8	966.5
1970/71	616.9	32.0	306.9	955.8
1971/72	694.0	32.0	314.7	1,040.7
1972/73	625.5	4.0	258.8	888.3
1973/74	531.2	5.0	237.2	773.4
1974/75	321.3	—	229.8	550.8
1975/76	81.4	—	103.3[a]	184.7
Total	4,284.0	155.0	2,889.6	7,328.6

[a] Replacements for private wells (Rs. 52.5 million) included.

account of the planned expenditures for investigations, flood regulation, and other expenditures totalling about Rs. 400 million (see Chapter VII). In the private sector, investments would be expected to exceed those provided for in the Third Plan period by about 43 percent, mainly resulting from heavy replacement investments as pointed out above. The aggregate financial requirements for the Third and Fourth Plan periods are discussed further in Chapter VII.

V

Program for Irrigation Development

A. THE DEVELOPMENT PROPOSALS

In accordance with the terms of reference, IACA's work was concentrated on the formulation and evaluation of the projects reviewed in Chapter IV. Longer term planning for the Indus River Basin was limited to the preparation of outline proposals intended as guidance for further development beyond 1975. The Action Program described in Chapter IV relates only to the Government's ongoing projects and to those projects formulated by IACA and given priority for execution in the period 1965–75. In this Chapter, IACA's longer term proposals for irrigation development in the Indus Basin are reviewed, and the results of IACA's water allocation, distribution and system operation studies are summarized.

The immediate objectives of a program for irrigation development in West Pakistan are to supply more water to the farmers and to deliver it to the land in a manner which is timely and suited to the crop calendar. The program would also serve to provide subsurface drainage to waterlogged areas, and to improve surface drainage in those parts of the northern Punjab and southern Sind where crop losses frequently occur from the flooding that follows heavy storms.

The present demand for water, and the potential increase in future demand, are so large in the Indus Basin that for the period up to 1975 demand would at all times exceed the feasible rate at which new water development works can be implemented. In the light of these considerations, IACA has selected a development program for this period that lays heavy emphasis on tubewell development in the usable groundwater areas, and has phased tubewell construction throughout the Indus Plains in accordance with the economic and technical criteria discussed in Chapters III and IV. From the standpoints of the feasibility rate of installation, operational efficiency and cost, all as estimated by IACA, no other mode of water development can compete with tubewells where these can be employed for the exploitation of usable groundwater. In addition to affording flexibility in construction and use, tubewells provide the most rapid and the cheapest means of making additional irrigation water available on the land. Tubewells have the advantage that they deliver water directly to the farm watercourses, and so overcome the constraining effect of the present limitations on canal capacity. They also provide a mode of development in which individual landowners or farmers can participate, and to this extent they assist in overcoming the present serious financial and implementation capacity constraints. In the usable groundwater zones tubewells provide irrigation water quickly and cheaply while simultaneously providing water table control. Development based on tubewells in the usable groundwater zones is therefore the most appropriate and the most economical means by which to provide additional water supplies.

For the decade 1965–75, surface water storage developments are very largely predetermined. The Government program calls for completion of the ongoing Mangla project[1] by 1967, as was accomplished, provision of a small element of storage at Chasma Barrage by 1971, and completion of the Tarbela Dam storage scheme by 1975. The only major addition which could be made to this program would be the raising of Mangla, which could be done by about 1971/72, but this proposal is discounted on grounds of hydrology and cost.

As discussed in Chapter III, another method of bringing increased water supplies to farmland is to enlarge the canals, and IACA has included about one million acres of canal enlargement works before 1975. This figure reflects IACA's estimate of the design, administrative and construction resources available to execute such works and the interrelated technical factors, notably, the limitations of link canal capacity to bring the bulk supplies of water to the headworks of the enlarged canals. It also reflects the general shortage of river flow at critical times of the year to fill the enlarged systems, a shortage which will remain until reservoir storage is brought into effect.

Thus, to summarize the program for the first decade, the Tarbela Dam Project would be the major new surface storage undertaking after Mangla. In addition to the large amount of effort and finance that must be devoted to the Tarbela dam project, IACA proposes that a tubewell program be undertaken up to the limit of the administrative and financial resources available. IACA also includes a considerable amount of drainage works and a substantial though restricted program of canal enlargement. The effects of all these works on the water supply are discussed further in Section C of this Chapter, and summarized here in Table 5-1.

[1] Low Mangla Dam is designed essentially to replace the withdrawal of waters by India from the eastern rivers under the Indus Water Treaty.

TABLE 5-1
WATERCOURSE DELIVERIES IN PERIOD 1965–75
MEAN YEAR INFLOW
(MAF / year)

	1965	1970	1975	Increment 1965–75
Surface Water	58.0	56.0[a]	63.0	5.0
Public Tubewells	2.7	10.0	22.0	19.3
Private Tubewells (including Persian wheels)	7.0[b]	10.0	8.5	1.5
Total	67.7	76.0	93.5	25.8

[a] Estimate as derived from sequential analysis with adjustments for surpluses; the reduction in surface water use results from the pumping pattern adopted in the sequential analysis which allows for over-pumping to lower the water table in certain areas.

[b] Includes 1.7 MAF from Persian wheels; canal commanded areas only.

In addition to the totals given in the table, the amounts pumped by private tubewells expected to be installed in areas outside the canal commands are estimated to increase from about 1 MAF in 1965 to about 2.8 MAF in 1975 (see Chapter IV).

Beyond 1975 the planning for irrigation development in the Indus Basin becomes more complex. The various methods of irrigation development—notably, surface supply, tubewell supply, subsurface drainage and canal remodelling—together with agricultural constraints on the intensification of farming, become more closely interrelated, for reasons that have already been discussed in Chapter III.

With the introduction of 8.6 MAF of stored water in the Indus at Tarbela there would be a radical change, in terms of both quantity and seasonal pattern of delivery, in the rabi flows available for diversion into the canal system. Water available in the rivers during the period of scarcity, i.e. November to April, would be increased by about 30 percent once the reservoir comes into full operation in rabi 1975/76.[1] The completion of Tarbela would come at the end of the first phase in the comprehensive development of the water resources of the Basin. Its additional water deliveres and flow regulation, superimposed on the large tubewell developments of the period leading up to 1975 and the regulating effects provided by Mangla dam on the Jhelum, would create a situation whereby irrigation supplies could be matched, to a much greater extent, to the water requirements of the crops instead of to the natural flows in the rivers as they are at present. The water supplies in the period following the completion of Tarbela would be generally adequate to meet the assumed needs of the increasing cropped acreage projected by IACA at full delta, including the conversion of areas from nonperennial to full perennial cropping where this has not already been achieved by tubewells alone.

IACA assumes that the present shortages in water supply and the related practices of underwatering should have been largely overcome by 1975–80. A continued program of tubewells and an increased rate of canal enlargement would have to take place in order for irrigation development to enable further expansion of the cropped acreage.

The IACA program for the decade 1975–85 calls for the extension of public tubewell fields over the outstanding usable groundwater area, and the full integration of groundwater and surface water supplies. The improvement in irrigation supplies and the control of the water table in usable groundwater zones would form the background to the canal enlargement program, which would be greatly accelerated at this stage and would take the leading role in further development. IACA allows for complete enlargement of the canal system serving some 16 million acres of canal commanded land by the end of the century, in addition to major works on new, and enlargement of existing, link canals.

The Lower Indus Region and the Sutlej and Panjnad Left Bank Region would benefit particularly from canal enlargement. Additional diversion would be provided in the Lower Indus Region with the construction of the Sehwan Barrage, which would also include an important storage element (1.8 MAF). This would serve a new feeder canal included in IACA's program for 1982. A start would be

[1] As discussed in Chapter IV, 5 MAF of stored water, or less than full capacity, is assumed available in 1974/75.

made to provide additional link canal capacity in the Punjab so that it could be completed by 1985, by which time this capacity would be essential.

Associated with canal enlargement would be subsurface drainage of saline groundwater areas. This must precede the intensification of irrigation in all high water table zones, with the exception of certain rice lands. Construction of other storage reservoirs after Tarbela would take place primarily in the Indus Valley where they would be needed to meet the rising demand for water and to make good the loss of capacity caused by siltation of the earlier reservoirs.[1]

The program for irrigation development, as foreseen by IACA, would be completed around the year 2000, by which time water supply would be the limiting resource. For this and other reasons a salient feature of the development program is the emphasis on intensification of agriculture within the existing system, rather than expansion of canalization into new areas.

The program of irrigation development works proposed after 1975 would result in growth in water supplies, measured at watercourse head, as given in Table 5-2.

Under the IACA program, public tubewells would virtually supersede private tubewells within the canal commanded areas of the Indus Basin by about 1985. Whilst recognizing the importance and merit of the underlying reasoning, the Study Group would wish to retain an open mind on the relative contributions the two modes of development are likely to make to groundwater exploitation over the longer term. This difference in viewpoint, though fundamental and of great significance in the long-term, does not have any major impact on the short-term proposals.

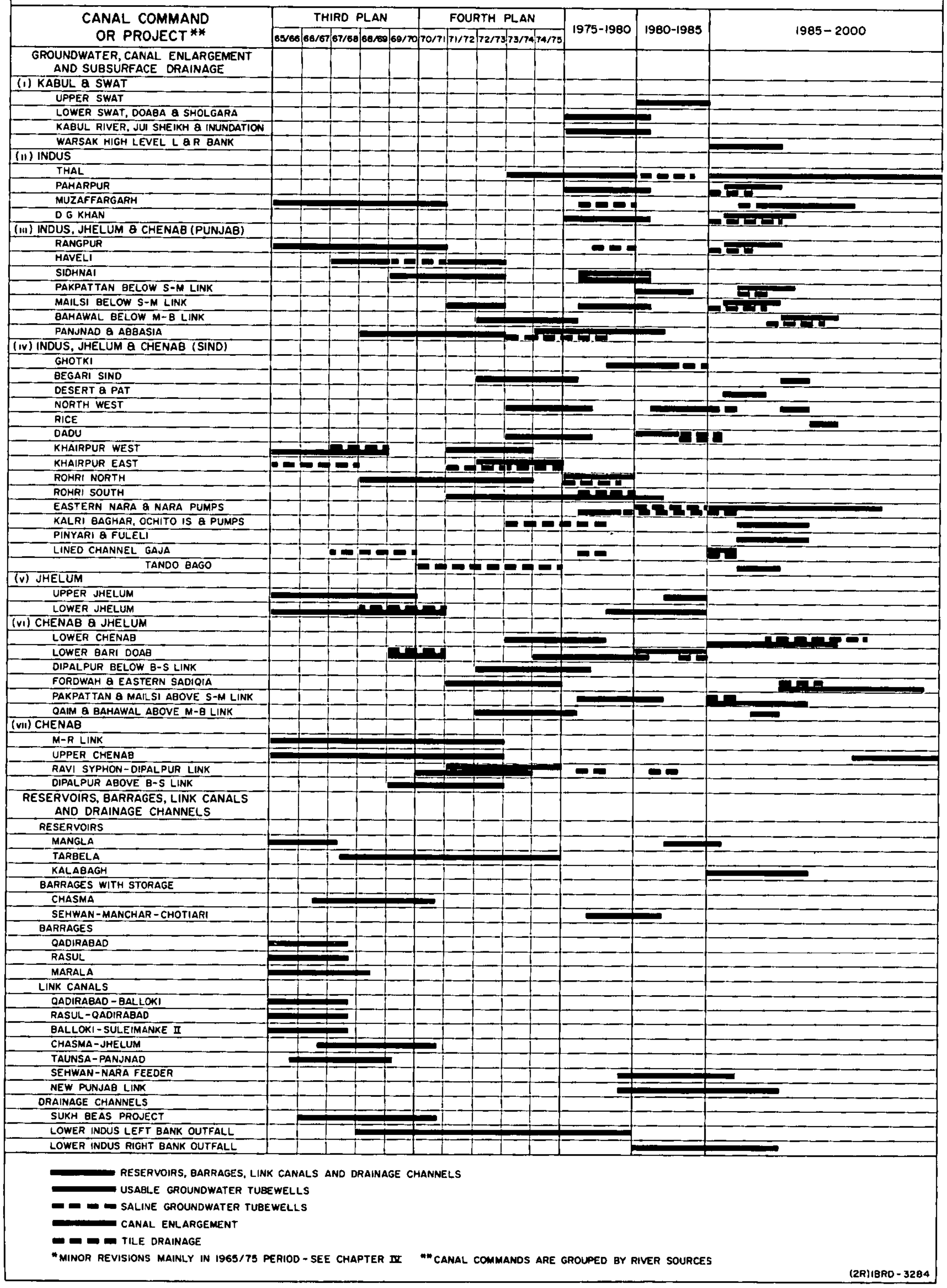
The Study Group considers, with more emphasis than IACA, that both public and private tubewells should be afforded high priority and support in the early stages of development. Both modes of development should be pursued vigorously, each being employed in a manner designed to yield the maximum combined benefit. The decade 1965–75 demands the fullest possible utilization of both possibilities, and with judicious allocation of spheres of influence they would become strongly complementary rather than competitive, as commonly depicted. While firm judgments made at this time may well be based on sound principles, at best such judgments can only be based on inadequate evidence of the eventual relative advantages of the two possibilities under West Pakistan conditions. For these

[1] The program for investigations of further storage possibilities is treated in the Study Group's Report, Volume I, Annex II.

TABLE 5-2
MEAN YEAR
WATERCOURSE DELIVERIES IN PERIOD 1975–2000
(MAF/year)

	1975	1985	2000	Increment 1975–2000
Surface Water	63	77	91	28
Tubewells	30	40	44	13
Total	93	117	135	41

REVISED* IACA PROGRAM FOR IRRIGATION DEVELOPMENT



reasons, the Study Group would prefer to see judgment on the long-term public/private question made later, in the light of careful analysis of performance after, say, five years' time.

B. THE DEVELOPMENT PROGRAM

Period 1965 to 1975

IACA's comprehensive program is set out in Figure 5.1. Tubewell development and land drainage works have been shown there under the canal commands where they are located. Although project areas have in fact been identified for the early period, as shown in Chapter IV, canal commands only have been used in this outline of the program in order to maintain consistency with the period after 1985, for which years project areas have still to be defined.

A description has been given in Chapter IV of an Action Program comprising the surface storage, tubewells and drainage projects as set forth in Table 5-3.

Most of the tubewell projects cover only parts, and often small parts, of the canal commands stated, and hence it will be seen from Figure 5.1 that further tubewell development often occurs in the same commands at later dates. The list of tubewell projects in Table 5-3, together with projects in Figure 5.1 scheduled for commencement near the end of the period 1965–75, would comprise an installation of 17,800 public tubewells in the decade. These wells, together with some 2,900 existing wells, would cover eleven million acres (about 60 percent) of the usable groundwater areas of the Plains by 1975. In addition, as estimated in Chapter IV, there would be about 52,500 private tubewells in the Indus Basin by 1975, and the combined pumping of private and public wells would approach the estimated recharge to the aquifer.

The large Sukh Beas drainage scheme, described in Chapter IV, would have substantially overcome the outstanding surface drainage problems of the important Bari Doab Region by the end of the decade.

Finally, the completion of the Tarbela Dam Project in 1975 would provide the first step in the control of the Indus River, and would mark the completion of an initial phase in the achievement of an integrated system of ground and surface water delivery throughout the Indus Plains. In addition to the ongoing and Action Program projects listed above, IACA has included in the 1965–75 program some GOP projects which have not yet been formulated, but have been tentatively identified and were not referred to in Chapter IV.

Drainage works to be started during 1965–75, other than the Sukh Beas scheme, would be the Left Bank Outfall, several small drainage schemes in Rechna Doab, and some rice area drainage in Ghulam Mohammed command.

The Left Bank Outfall is the first stage of the large drainage complex proposed for the Sind by the LIP consultants. It would have the objectives of removing saline subsoil drainage water to the sea from the greater part of the Indus Left Bank south of Sukkur, and at the same time providing surface drainage in areas south of Nawabshah (see Map 7). 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 LIP consultants at Rs. 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

TABLE 5-3
ACTION PROGRAM—1965-75

Project	Canal Commands or Parts of Commands Served	Construction Period	CCA Served
			(mill. acres)
Surface Water Projects[a]			
Tarbela Dam	All commands	1967/75	—
Ongoing Tubewell Projects			
Scarp II	Upper Jhelum Lower Jhelum	1964/71	1.6
Scarp III	Muzaffargarh Rangpur	1965/70	0.9
Scarp IV	Marala Ravi Link Upper Chenab Lower Chenab	1966/73	1.7
Khairpur	Khairpur East Khairpur West	1966/69	0.3
Subtotal CCA			4.5
New Tubewell Projects			
Wagah[b]	Wagah	1968/69	0.05
Shorkot-Kamalia	Haveli Lower Chenab	1968/70	0.3
Rohri North	Rohri North	1969/74	0.6
Panjnad Abbasia	Panjnad Abbasia	1969/73	0.9
Dipalpur above BS Link	Dipalpur above BS Link	1971/72	0.4
Shujaabad	Sidhnai, Mailsi below SM Link, Lower Bari Doab	1970/73	0.4
Ravi Syphon-Dipalpur Link	Ravi Syphon-Dipalpur Link	1972/74	0.6
Bahawal Qaim	Qaim Bahawal	1973/76	0.5
Fordwah Sadiquia	Fordwah and E. Sadiquia	1973/74	0.4
Rohri South	Rohri South	1972/76	0.5
Sukkur Right Bank	North West Dadu	1974/77	0.3
Dipalpur below BS Link	Dipalpur below BS Link	1974/76	0.6
Begari Sind	Begari Sind	1974/76	0.3
Subtotal CCA			5.8[c]
Drainage Projects[d]			
Sukh Beas Scheme	Most of Bari Doab Region	1966/71	

[a] A small amount of storage (0.5 MAF) would be provided at Chasma Barrage.
[b] Small project designed to replace water withdrawn under Indus Treaty. It was not evaluated.
[c] Rounded figures, for details see Chapter IV.
[d] Another first-stage project, the Lower Indus Left Bank Outfall Project, is described in this Chapter.

years, necessitates an early start, and IACA has concurred with the LIP consultants' proposals that construction start in 1968. This would mean that a program of studies and site investigations had to be rapidly undertaken. Total expenditures for these works during the Third and Fourth Plan periods have been estimated at Rs. 374 million.

Some of the more urgent work of canal enlargement in the Basin would be undertaken before 1975 but only in canal commands where it does not involve additional link canal capacity. The program would allow for implementation of canal enlargement works, including pilot projects, during the first decade, as shown in Table 5-4. The areas shown are mainly in saline groundwater zones, but in some cases, such as Panjnad Abbasia, mixing zones are included.

TABLE 5-4
CANAL ENLARGEMENT 1965–1975

Canal Command	Million Acres
Khairpur East	0.330
Khairpur West	0.124
Panjnad Abbasia	0.100 (balance of 0.545 MAc for completion, mainly after 1975)
Ravi Syphon-Dipalpur Link	0.330
Lower Bari Doab	0.070
Haveli	0.060
Total	1.014

The program for canal enlargement is generally based on the priorities set out in Chapter III, Section D, except that Khairpur East, an entirely saline groundwater area of 330,000 acres CCA, has been added. This addition follows the LIP consultants' program except that they anticipated that construction work in the southern part of the area would be continuing into the Fifth Plan period. Thus only about 125,000 acres would be completed by 1975, which would reduce the total coverage of canal enlargement completed before 1975 to about 800,000 acres. (The acreages tabulated above are the result of IACA's more specific identification of canal enlargement requirements.) Also, the canal delivery constraint in Ravi Syphon-Dipalpur Link command would probably be relieved by a small degree of underwatering or, alternatively, minor adjustments in the cropping patterns. This would further reduce the need for canal enlargement during the period of the Action Program.

The small area (70,000 acres) shown for canal enlargement in the Lower Bari Doab is in the head reach of that command where IACA has proposed a pilot tile drainage project. A similar small tile drainage scheme (37,000 acres) has been proposed in the Shorkot-Kamalia project area in the southern tip of the Rechna Doab, and is discussed in Chapter IV. Both are saline groundwater areas.

The more important tile drainage projects proposed are in the Lower Indus Region where they would constitute the commencement of an extensive program to be implemented later, mainly in the Nara command (Table 5-5). Horizontal drainage has been introduced in pilot projects in the IACA program in order to

TABLE 5-5
TILE DRAINAGE PROJECTS STARTING BEFORE 1975

Command	Area M.Ac.	Construction Period
Khairpur East	0.03	1971/75
Kalri Baghar (Ochito and pumps)	0.12	1973/78
Tando Bago	0.09	1970/75
Lower Bari Doab	0.07	1969/71
Haveli	0.04	1969/70
Total	0.35	

gain experience with this drainage method under West Pakistan conditions,[1] as part of an effort to determine the most appropriate method for draining saline areas.

Period 1975 to 2000

Tubewells. As may be seen from Figure 5.1, the initial emphasis after 1975 would still be on the completion of the public tubewell program in the usable groundwater zones, and after 1975 a progressive substitution of public for private well development would take place in the IACA program. While this appears logical in the context of IACA's planning approach, the decision for large-scale substitution for private development should be reviewed in each case. By 1980 only a few such areas would remain undeveloped by public wells, notably Upper Swat, part of Pakpattan, and part of Ghotki and Warsak. By 1985 only the Warsak area would remain to be done. As the tubewell program in usable groundwater areas approaches completion, the resources required for such work would be diverted to the drainage of saline groundwater areas to make possible the further intensification of irrigation by canal enlargement. Some of the saline areas with shallow water tables require urgent attention and would be tackled at an early date, notably those in the Panjnad Abbasia and Rohri commands. From 1980 onwards there would be a steady program of tubewell installation in saline areas amounting to about 500 units per year. The projected numbers of public tubewells in all groundwater zones would be as Table 5-6.

The phasing of tubewell development as proposed by IACA after 1975 can only be taken as a broad indication of priority. Much is based on judgments which must be checked by further investigations and analyses. IACA's proposed sequence of tubewell development in the various regions is summarized below (see Map 6) in seven groupings.

1. Kabul and Swat Rivers. Initial emphasis should be placed on the Lower Swat area, where some areas of shallow groundwater occur, and on the Kabul River command. Later development would extend to the Upper Swat and Warsak's High Level commands where the groundwater potentialities appear less attractive.

2. Areas commanded by the Indus River alone. The Thal, Paharpur and D. G. Khan tubewell developments have been phased to come into operation by about the end of the Fifth Plan period, consistent with the objective of completing the development of usable groundwater areas by that time. About half the commanded land in each area is underlain by fresh groundwater, and roughly another quarter

[1] Details are given in IACA's Comprehensive Report, Volume 6, Annexure 8.

TABLE 5-6
PROJECTED NUMBER OF PUBLIC TUBEWELLS IN OPERATION

	1975	1980	1985	2000
Usable Groundwater Zones	20,200	32,200	34,300	35,000
Saline Zones	500[a]	4,500	9,800	15,000

[a] IACA'S estimates raised by 300 wells to account for Government intention to place drainage wells in SCARP II saline area.

in each would cover mixing zones of varying quality. The remaining portions of area are underlain by saline groundwater which should not require subsurface drainage by tubewells until later in the program, as indicated in Figure 5.1.

A saline area of 70,000 acres, mainly in the Muzaffargarh commands of the SCARP III project area, has been scheduled for drainage in 1976. Drainage would be provided for the rest of the saline area in this and the adjacent Rangpur command, after 1985, though it is now understood that WAPDA's consultants propose to include these in the ongoing SCARP III program.

3. Areas in the Punjab commanded jointly by the Indus, Jhelum and Chenab Rivers. The first priority for a major saline groundwater tubewell drainage scheme in the Punjab has been given to the Panjnad Abbasia area, where waterlogging is already a problem with a water table shallower than 10 feet in nearly 85 percent of the total CCA of 577,000 acres.

Early priority has also been given to those parts of the Sidhnai canal command usable groundwater area which lie outside the Shujaabad project area. Here the groundwater is generally of good quality, and the area is at present served with perennial supplies of water.

Pakpattan below S.M. link has been given rather low priority in the program for usable groundwater zones, mainly for the reason that a high proportion of the area (70 percent) falls in the mixing zone.

Mailsi below S.M. link is an area for which IACA deferred public development in favor of private development (except for 98,000 acres in the Shujaabad project). It is hydrologically well suited to tubewell development by virtue of being predominantly in a good quality groundwater zone. It is included in the 1975–80 period as part of IACA's program to complete public tubewell installations in all usable groundwater areas. The Study Group has some reservations about this proposal, and would recommend that it be reviewed in the light of future progress in the private sector.

Saline groundwater drainage has been programmed to follow in the Pakpattan and Mailsi commands, both above and below the SM link, in conjunction with canal remodeling, mainly in the period 1985–2000.

4. Areas commanded jointly by the Indus, Jhelum and Chenab Commands in the Lower Indus. By 1975 the only outstanding tubewell installations of importance in usable groundwater areas in the Lower Indus amount to 360,000 acres in the Ghotki command. Following the LIP proposals, IACA designated this initially as a private development area to be superseded by public tubewells in 1979–85. Since the submission of the LIP and IACA Reports, WAPDA has stated that a more immediate program may have to be undertaken here because of the rapid rise in groundwater that has recently occurred. If the waterlogging hazard cannot be avoided by better control of surface water supplies, and if private tubewell development does not make sufficient progress, the IACA priority for Ghotki may have to be revised.

The main tubewell program in the Lower Indus after 1975 would be in the saline groundwater areas, and the order of priority has been largely that provided by the LIP Report which places initial emphasis on the Rohri and Gaja commands, followed by Eastern Nara. The Rohri and Nara proposals are related to increased surface water supplies that would come from canal enlargement. The first group of Gaja tubewells would be designed to replace the present ADC project wells in this already waterlogged area, and the balance of the saline area would be drained in the early 1980's.

5. Areas commanded by the Jhelum River alone. All usable groundwater areas would be previously developed in this region by the SCARP II project, but there would remain about half a million acres underlain by saline groundwater in the Lower Jhelum command that would call for tubewell drainage before canal enlargement could be effected. IACA has scheduled this work for 1976–83. IACA has suggested in its report that the saline groundwater areas of SCARP II in the Lower Jhelum command should be deferred until after 1975. The Study Group does not disagree with IACA's suggestion, but has nevertheless retained the GOP schedule for the currently ongoing SCARP II program, including the saline groundwater areas.

6. Areas commanded jointly by the Chenab and Jhelum Rivers. These areas, which stretch across the central parts of the Rechna and Bari Doabs, contain some large usable groundwater sites where IACA would defer public tubewell development in favor of private enterprise. This would include the greater part of the area designated for SCARP V, and the extensive perennial areas of the Lower Bari Doab and Pakpattan and Mailsi above SM link. But, in accordance with its principle that all groundwater areas should ultimately come under public control, IACA would include the usable groundwater zones of these commands in the public tubewell program as an early priority in the period following completion of the Action Program works described in Chapter IV. The related saline areas have deferred tubewell development, again in conjunction with canal enlargement, and are phased mainly for the period 1985–2000.

7. Areas commanded by the Chenab River alone. Tubewell installation in these areas would be almost entirely included in the ongoing SCARP IV scheme and in the proposed Action Program. Only small saline areas would remain to be drained in the Ravi Syphon-Dipalpur link command in the 1980's.

Canal Enlargement. The priorities for canal enlargement after 1975 finally adopted by IACA vary considerably from those derived from the economic analysis. The enlargement of the canal systems within the commands depends, as stated before, both upon the program adopted for the enlargement of the link canals, which provide for the bulk water transfers to the various barrage headworks, and also upon subsurface drainage which must be phased to come into effect before more surface water can be introduced in the areas concerned. As may be seen from Figure 5.1, the emphasis on canal enlargement would not begin until around 1980, in anticipation of the increase in link canal capacity as proposed by IACA in the Punjab. This would require the construction of a new canal leading from the Chasma Jhelum Link eastwards across the Punjab and connecting up with the main canals of the Chaj, Rechna and Bari Doabs enroute. At about the same time (1982) IACA has scheduled the Sehwan barrage and Sehwan-Rohri feeder for completion. This feeder would be the first stage of the Sehwan-Nara feeder referred to in Figure 5.1. The geographical priorities are described below:

1. Kabul and Swat Rivers. IACA has not developed a case for canal enlargement in this area, though some work may be required on a limited scale late in the program. IACA does, however, draw attention to what may prove an exception to their concept that new areas should not be taken into the canal system when they refer to the possible extension of the Upper Swat canal system to incorporate a further 200,000 acres of CCA.[1]

[1] IACA's Comprehensive Report, Volume 18, Annexure 15H.

2. Areas commanded by Indus River alone. The canals in these commands are relatively large, and attainable intensities with the existing design capacities are, in general, little less than the average agricultural maximum set at about 150 percent. There are, however, extensive saline areas in Thal, Paharpur, D.G. Khan and Muzaffargarh (amounting in total to about 600,000 acres), and about the same area of mixing zones in Thal that would call for some degree of canal enlargement late in the program.

3. Areas in the Punjab commanded jointly by the Indus, Jhelum and Chenab Rivers. Rangpur command, like the Indus commands referred to above, calls for very little canal enlargement. This would mainly be some in a 10,000 acre saline groundwater zone, and IACA would defer such work until late in the program.

The present cropping intensity is high in those parts of the Sidhnai command not included in the Shujaabad project, but there is considerable underwatering. Tubewells alone would provide only a partial solution because of the existing canal capacity constraints. IACA has given this area a high priority for canal enlargement in the period following the Action Program, and this work could be undertaken together with public tubewell installation in the period 1976–81.

Pakpattan below SM link would require extensive remodelling in all groundwater zones, and this has been scheduled after 1985 at the same time as the saline groundwater drainage and when additional link capacity should be available to the Bari Doab.

Mailsi below SM link, on the other hand, would require remodelling only in the saline and a small part of the mixing areas. This work would be undertaken at the same time it begins in the adjacent Pakpattan command.

High average intensities can be achieved with tubewells and existing canal capacity in Bahawal below M.B. link and this command has been given relatively low priority for canal enlargement.

Panjnad Abbasia would be given the highest priority for the enlargement of a large part of the canal system. Even with tubewells, but without canal enlargement, big areas of mixing zones would be constrained to about 120 percent (full delta) cropping intensity, and the saline zones would be constrained to much lower levels. After the construction of the Chasma-Jhelum and Taunsa-Panjnad links there should be adequate capacity to provide supplies to an enlarged canal system, and thus achieve 150 percent cropping intensity in such areas.

4. Areas Commanded Jointly by the Indus, Jhelum and Chenab Commands in the Lower Indus. Canal enlargement would form a very important part of the development program in the Lower Indus. The program may be divided into three phases: the early work in Khairpur, which could be undertaken without major link canals; the enlargement of the Rohri and Nara commands as part of the Sehwan-Nara feeder scheme; and the canal enlargement in other commands where the general priority for such work is relatively low, with the exception of Dadu South; there, the existing canal capacity restrains intensities to about 90 percent as compared with a potential intensity of 150 percent.

The Khairpur enlargement program has been discussed eearlier in this chapter. It involves a total of about 450,000 acres in the saline zones of the two branches of the command where otherwise the achievable full delta cropping intensities would remain low (about 100 percent).

In the Lower Indus, the main canal enlargement program hinges essentially on the Sehwan Barrage Project. This project would serve two purposes. First, it would act as a diversion dam to command a major feeder canal, which would run eastwards to convey more water into the Rohri and Nara commands. Second, it would provide about 1.8 MAF useful storage capacity. The LIP Report[1] proposed that the Sehwan barrage and that reach of the link canal serving Rohri South should be completed by 1976, but the additional works required to develop the storage possibilities of the barrage should be deferred until the early 1980's. IACA has concurred with the date for bringing the storage element into service, but considers that the barrage function and the Rohri Link canal should be deferred in order to treat the Sehwan project as a single stage operation, except for the Rohri-Nara link which would follow later. Recent proposals made by WAPDA are similar to those in the LIP Report, except for deferment of an extensive canal enlargement program in the Rohri North and South saline and usable groundwater areas. However, without substantial canal enlargement the benefits of the barrage and feeder would be limited. Under the latest WAPDA proposal, the Sehwan project, without canal enlargement, would serve the initial purpose of raising the intensity by 12 percent in the 880,000 acres of saline zone in Rohri South. Under the IACA proposals the intensities would already be raised by 13 percent above present levels by tubewell projects and Tarbela rabi supplies,[2] and before Sehwan would come into operation.

There would, therefore, be no clear advantage in adopting an earlier planning date for the Sehwan Barrage than that proposed by IACA, unless the canal enlargement of Rohri South and North can be advanced considerably on the date proposed by IACA. IACA has examined this possibility and judged that it is not feasible.

This conclusion does not detract from the importance of investigating the Sehwan project at an early date, because there is a paucity of information for such an important project. It is suggested that a feasibility study, including appropriate investigations and surveys, be carried out and a project report on the whole scheme be prepared during the Third Plan period so that a program for detailed investigations, which would follow in the Fourth Plan period, can be clearly identified. Such an investigation program would be a few years in advance of that proposed in the IACA Report.

Figure 5.1 retains the program shown in the IACA Report, with canal enlargement in the Rohri North, South, and the Nara commands, all phased in accordance with the construction program for the Sehwan Barrage and the Sehwan-Rohri feeder (scheduled for completion in 1982), and for the Rohri-Nara feeder (scheduled for completion after 1985).

5. Areas commanded by Jhelum River alone. An intensity of 150 percent could be achieved over most of these commands once tubewells have been installed (SCARP II program). There are, however, canal constraints in parts of the mixing, and in the whole of the saline, areas for which canal enlargement is proposed in the period 1978–85. IACA considers that the canal enlargement in the Lower Jhelum command, which is included in the present SCARP II proposals, could be carried out more efficiently if it were combined with the construction of the proposed new Punjab link canal. This work has therefore been deferred until the Fifth/Sixth Plan periods.

6. Areas commanded jointly by the Chenab and Jhelum Rivers. In the Lower Chenab Command there are large areas of saline and mixing zones, and the attain-

[1] Lower Indus Report, Hunting Technical Services Ltd. and Sir M. MacDonald & Partners, 1966.

[2] IACA's Comprehensive Report, Volume 20.

able intensity (at full delta) would, on average, be limited by canal capacity to about 114 percent. Despite this, IACA believes canal enlargement should only be undertaken following the introduction of the new Punjab link, and have phased this work for the period after 1985.

In the Lower Bari Doab area above SM link there are about 200,000 acres of saline and mixing groundwater zones that would require extensive canal remodelling. This has been phased to coincide with the completion of new link canal capacity to the doab in the early 1980's.

The remaining commands in this group are in the Sutlej Valley, and would come later in the canal enlargement program as the new link capacity would be extended to reach them. The Sutlej Valley commands, other than the usable groundwater areas included in the tubewell projects, would remain very constrained by existing canal capacity, but their full development must be deferred until much more water can be transferred from west to east across the Punjab.

7. Areas commanded by the Chenab River alone. No major canal remodelling, beyond that tentatively scheduled before 1975 in the Ravi Syphon-Dipalpur link command, is proposed for this area because it can reach almost full intensity with public tubewell development and existing canal capacity. Minor exception is the perennial area of the Upper Chenab command, where some remodelling is included late in the program to raise the achievable intensity from about 145 to 150 percent.

Storage Dams and Barrages. Surface storage reservoirs included in the program in Figure 5.1 are summarized in Table 5-7. This sequence of storage development would be subject to change, however, depending on the findings of ongoing and further investigations.

No new barrages other than IBP works and Sehwan are included in IACA's program, except that the proposed new Punjab link canal may call for barrage crossings of the Jhelum, Chenab and Ravi Rivers. This again would be subject to the findings of ongoing and future investigations.

Drainage Works. The major surface drainage works have already been referred to, except for the Lower Indus Right Bank Outfall drain. Its location is shown in Map 7. The drain would serve the Gudu and Sukkur Right Bank areas and drain their effluent into the Indus downstream of the proposed Sehwan Barrage. It is the main feature of the final stage of the LIP consultants' drainage proposals, and is scheduled by IACA for completion by about 1990.

TABLE 5-7

Reservoir	Live Storage Capacity	Date of Completion
	(MAF)	
Mangla	5.20 (replacement works)	1967
Chasma (Barrage)	0.27	1971
Tarbela	8.60	1975
Sehwan (Barrage)	1.80	1982
Mangla (Raising)	3.55	1986
Chotiari	0.90	1990
Kalabagh	6.40	1992

C. WATER AVAILABILITY AND USE

Water Requirement and Distribution Analyses

In order to set the Action Program for the next decade in long-term perspective, it was necessary to derive an indicative development program for the Basin beyond the period of the Action Program. It was also necessary to analyze the patterns of water use over time relative to potential water availability. Three reference years (1975, 1985 and 2000) were used for detailed analysis of their aspects. In addition, each year from 1965 to 1985 was analyzed against historical and synthetic sequences of river inflow.[1]

These water distribution and use analyses were undertaken in three stages: one for the calculation of water use within the canal commands, a second for the distribution to canal commands from the river rim stations—point where river enters the Indus Plains, and reservoir sites for each reference year, and a third[2] was a sequential study testing the operational feasibility of the program. Allied to these water distribution studies a number of reservoir operational studies were carried out for Mangla and Tarbela reservoirs to determine their behavior for both irrigation and power purposes.[3]

For the purpose of the water distribution analysis, the 42 principal canal commands in the Indus Basin were subdivided according to the partitioning of commands that arises from IBP works and from proposals made by the LIP consultants in the Lower Indus. Further subdivision was made to account for differences in existing design capacities of canals (discharge factor). These considerations resulted in the adoption of 61 units of analysis. Each unit of analysis was then further subdivided and treated separately for the four groundwater salinity zones given in Chapter III, e.g. fresh groundwater, two mixing zones of intermediate salinity, and a saline (unusable) zone. The analysis for the reference years dealt with three alternative states of water development. For each of these states it gave the water requirements associated with the achievable levels of cropping intensity for each zone in each canal command. The alternative states of water development are designated, for purposes of this chapter, A, B, and C.

A. Either no development of groundwater or partial development by private tubewells. Watercourse deliveries were limited in this case to the capacity of the canal system, to which was added the appropriate quantity of groundwater pumped by private wells, based on the projected growth of private tubewells for the particular command.

B. Full development of groundwater by public tubewell projects. In this case an integrated system was assumed whereby withdrawals from the aquifer would be balanced by recharge to it. In the mixing zones groundwater and surface supplies would be used simultaneously in accordance with the stipulated mixing ratios. In the fresh groundwater zones the greater part of the pumping would be in rabi in order to economize in the use of scarce surface water at that time, and to overcome canal delivery constraints during seasonal overlaps.

[1] Sequential Analysis of a Program for Irrigation and Power Development in West Pakistan, by Sir Alexander Gibb and Partners, September 1966, Annex 3.2.

[2] Computer program developed by WAPDA's consultants, Harza International and used by Sir Alexander Gibb and Partners in cooperation with Harza in the Sequential Analysis.

[3] See Annexes to this Volume and Supplemental Papers in Volume III.

C. Canals enlarged in addition to public tubewells to allow full intensity to be attained, particularly in the saline and mixing zones.

Estimates were also made for present conditions and during the period prior to 1975, in the canal commands which were included in the sequential study. Transitional states were assessed from present watercourse deliveries, with the associated underwatering and unregulated deliveries, to optimal deliveries. These transitional states were assessed in three ways.

1. In canal commands where public tubewells were to be installed, full delta watercourse requirements were assumed to coincide with the implementation of the project.
2. In the commands supplied by the Jhelum and Chenab Rivers, the Mangla reservoir was assumed to be capable of regulating rabi flows. In these areas, historic seasonal totals were maintained but redistributed by months in accordance with the computed requirements.
3. In those commands served by the Indus main stem where no public tubewell development was scheduled before 1975, the mean historic monthly deliveries were maintained without regulation.

In conditions (1) and (2), an allowance was made for the contribution of private pumping.

Important factors in the water distribution planning were the assumptions made by IACA with regard to historic flows. These were generally taken as the monthly mean deliveries over the period 1952 to 1963, but in the newer, developing commands (such as Ghotki and Thal) recent deliveries were used. This method of deriving a historic basis tends to be more favorable than actual occurrences of water deliveries because it understates the impact of adverse variations from the mean. IACA's treatment of water distribution in the immediate future should therefore prove to be on the conservative side because the canal command analysis maintains water supply conditions which are everywhere at least as good as the mean for the recent past, and generally better.

The study of watercourse requirements related water availability and use on the basis of the state of development assumed to prevail in each canal command in the reference years 1975, 1985 and 2000. These states are essentially a reflection of the development program for tubewell installation and canal enlargement as described in the foregoing Section B. Broadly, this meant that by 1975 most commands were taken to be in state A and B and very few in C. By 1985 few would be left in state A, and a greater number would have moved to state C as canal enlargement progressed. By 2000 the whole Basin, with very minor exceptions, would have reached states B and C, and all constraints on the achievement of the full agriculture intensity would have been removed. For each canal command a number of variables had to be associated with a given state of development, and these included the following: the cropping pattern; crop water requirements per unit area; canal capacity; canal and other losses; recharge to aquifer; agricultural limitation to cropping intensity. This last limitation—the agricultural limitation to cropping intensity—relates only to the situation where increased water availability would permit an expansion of cropped acreage, but farmers fail to do so. The constraints on intensities were refined by successive analyses.

TABLE 5-8
PROJECTED WATERCOURSE REQUIREMENTS IN IACA PROGRAM'S
(MAF/year)

Year	Total Use	Incremental Use	Cumulative Incremental Use
1965	68		
1970[a]	75	7	7
1975	94	19	26
1985	117	23	49
2000	135	18	67

[a] Figures derived from Sequential Study.

The information provided by the analyses was essentially the following: (i) monthly surface water requirements at watercourse head to achieve the cropping intensities set by agricultural constraints or by canal capacity; (ii) monthly quantities of groundwater pumped for irrigation or as saline drainage effluent; and (iii) the attainable cropping intensities with full delta water application in each of the groundwater quality zones.

The surface water requirements were then aggregated to derive the requirements for stored water and the pattern of its release from the reservoirs.[1] A summary of the analyses and the results obtained will be given in one course below.

The sequential study,[2] which essentially simulated the operation of the entire irrigation system under conditions of the proposed development program, provided a check on the internal consistency of the IACA program and demonstrated that it would operate successfully over a range of river inflows taken over a sequence of years. Some of the principal results of this study are included in the following paragraphs of this section.

The Results of the Water Requirement Analyses

The results of IACA's analyses, in terms of growth in watercourse requirements in the Indus Basin, are given in Table 5-8. These watercourse requirements would be met by deliveries, based on mean-year conditions, from surface and groundwater sources in the proportions as given in Table 5-9. The monthly distribution, as well as geographical location of use, has been fully recognized in the table aggregates and is given more fully in Annex 5. This tabulation shows that the proportional contribution from groundwater is expected to more than double over the first 10 years. Thereafter the ratio of groundwater to total would remain fairly constant, because, under balanced recharge pumping, the permissible pumping would become directly proportional to the canal supplies. The increment in canal supplies after 1975 and up to full development follows the pattern of demand created by canal enlargement and the provision of additional surface reservoirs.

The contribution of private tubewells to the total groundwater abstraction is currently about 50 percent. Although the private supplies rise rapidly from 5 to 8 MAF in the decade 1965/75, the relative contribution is projected to fall to about 25 percent of total by 1975 and would continue to fall thereafter as public tubewells replace private installations. The distribution of water use between

[1] IACA's Comprehensive Report, Volume 5, Annexure 7, Chapter 7.
[2] Annex 5.

the main sectors of the Basin for the reference years is given in Table 5-10. The distribution of the water supplies between these three sectors—Peshawar, the Punjab, and Sind—would remain fairly constant over time, with the Punjab areas taking a slightly increased share. The initial trend in greater favor of the Punjab is largely attributable to the more extensive ongoing tubewell program in the northern part of the Basin.

Although the comparison is not fully valid, for reasons of difference in crop water requirements and other factors, these proportional deliveries of water can be related to development acreages. This approximate comparison is given in Table 5-11.

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FIGURE 5 2

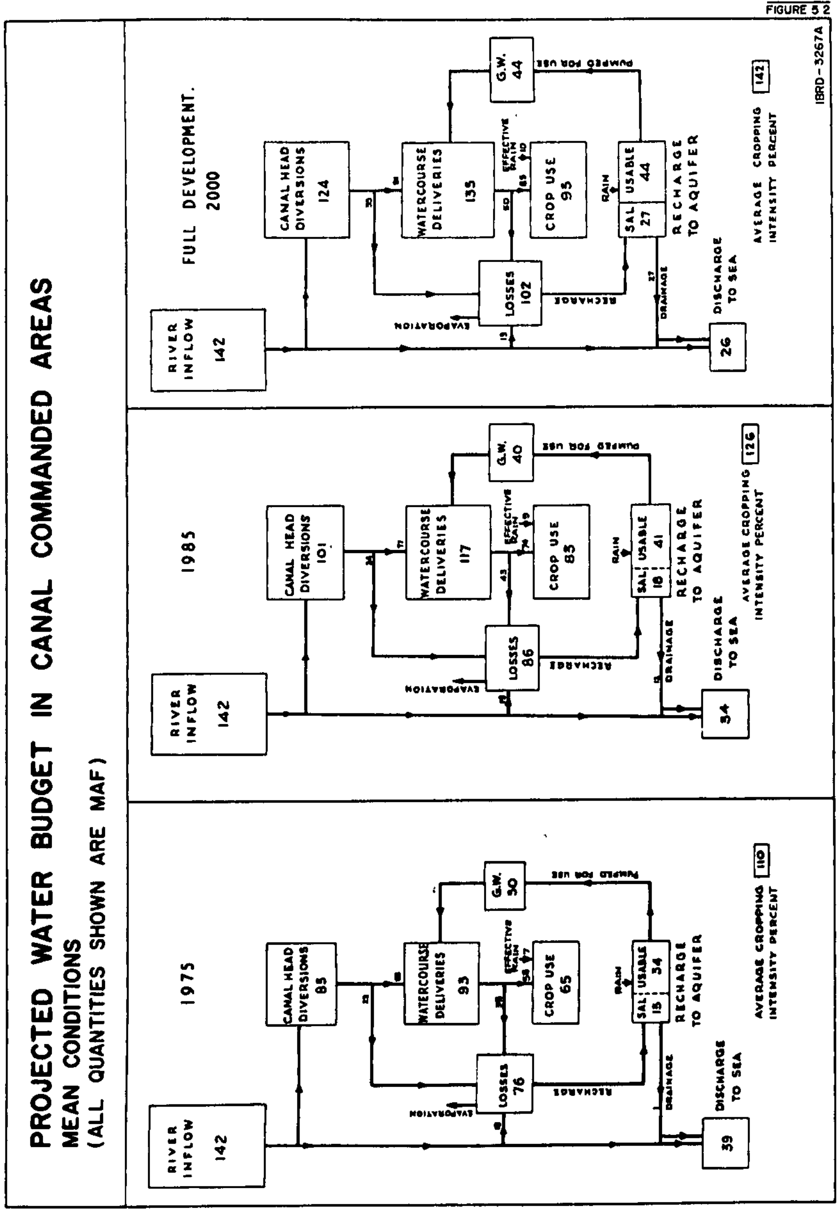

TABLE 5-9
RELATIVE USE OF SURFACE AND GROUNDWATER MEASURED AT WATERCOURSE HEAD

Reference Year	Surface Water MAF	Surface Water Percentage	Groundwater MAF	Groundwater Percentage	Total 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 as derived from sequential analysis with adjustments for surpluses; the reduction in surface water use results from the pumping pattern adopted in the sequential analysis which allows for over-pumping to lower the water table in certain areas.

A further breakdown of the results of IACA's analyses dealing with the relative requirements for surface and groundwater in the canal commanded regions of the Basin is given in Table 5-12. This table demonstrates the rapid growth in groundwater contributions that would be made by the tubewell program in the Punjab, particularly in the Chaj, Rechna and Bari Doabs. By contrast, the Lower Indus and Vale of Peshawar, with their more limited usable groundwater resources, are likely to remain much more dependent upon surface water supplies.

Surface Water Requirements at Canal Head and Comparison with River Inflow

The surface water components of the watercourse deliveries can be expressed in terms of canal head deliveries, after due allowance for canal losses. The total quantities for the reference years are given in Table 5-13. For comparison, the mean combined river inflows available to meet the projected demands are also shown in the table. The comparison of requirements with demand gives, however, no more than a general impression of the periods when water should be stored and when it should be released from storage. Apart from the complex matter of limitations in regional distribution from the individual river sources and distribution losses in the rivers and link canals, it is also necessary to make allowance for variations from the mean-flow conditions and for time lags. In making proposals for the operation of the reservoirs at Mangla and Tarbela (see Chapter V-D), IACA has adopted solutions which offer a compromise between mean river flow conditions and low flow conditions which might occur fairly frequently. In this context, it will be seen in Chapter V-D that an operating reserve is left in the

TABLE 5-10
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	38.0	68
1975	1.9	2.0	61	65.0	31	33.0	94
1985	2.8	2.5	75	64.0	39	33.5	117
2000	2.8	2.0	85	63.0	47	35.0	135

TABLE 5–11
POTENTIAL DEVELOPMENT ACREAGES (CCA)

	Million Acres	Percent of Total
Vale of Peshawar	0.8	3
Punjab	19.7	67
Sind	9.0	30
Total	29.5	100

Tarbela reservoir at the end of March for release in April and May, which are months when shortages would occur from time to time. As a very general rule, storable surpluses would occur mainly in June to September, in the first 20 years or more of the program and deficiencies against demand would occur from October or November until about April or May, depending on the state of development reached in the program of irrigation projects and on river flow conditions.

Results of Surface Water Distribution Analysis

This analysis was a logical continuation of the analysis of water requirements in canal commands and was devised to provide the following information:

- Water requirements by months at the rim stations of the rivers and at the reservoirs of Mangla and Tarbela, by integrating and transferring the water requirements for the various canals to these points of supply.
- Reservoir storage and operational requirements by comparing the water supply requirements with the patterns of river flow at the rim stations and above the reservoirs.
- Link canal capacities required to distribute the supplies at the various stages of development given in the program.

TABLE 5–12
WATERCOURSE DELIVERIES TO CANAL COMMANDED REGIONS OF INDUS BASIN
(MAF/year)

	1965		1975		1985		2000	
Region	G/W[a]	S/W[b]	G/W	S/W	G/W	S/W	G/W	S/W
Vale of Peshawar	—	1.7	0.03	1.88	1.21	1.63	1.21	1.60
Thal and Indus Right Bank	0.7	5.6	3.89	5.03	6.68	6.02	7.48	7.75
Chaj Doab	0.6	3.2	2.92	2.80	3.61	3.74	3.69	3.91
Rechna Doab	4.6	6.6	8.08	6.95	8.59	7.94	9.23	9.18
Bari Doab	3.1	9.0	7.62	11.41	10.63	13.13	11.59	14.76
Sutlej and Panjnad Left Bank	0.6	6.4	3.21	7.53	4.45	9.46	4.93	12.60
Lower Indus	0.1	25.5	3.66	27.19	5.15	34.31	5.87	40.97
Total	9.7	58.0	29.41	62.79	40.32	76.40	44.00	90.77

[a] Groundwater
[b] Surface water

TABLE 5-13
PROJECTED CANAL HEAD SURFACE WATER REQUIREMENTS FOR REFERENCE YEARS AND COMPARISON WITH RIVER INFLOW
(MAF/year)

	1975	1985	2000	Total Inflow of Indus, Jhelum and Chenab
				(mean year)
October	7.51	8.16	9.85	5.51
November	3.71	4.40	5.52	3.20
December	3.50	3.90	4.57	2.81
January	4.00	4.52	5.24	2.77
February	5.90	6.40	7.33	3.01
March	5.58	6.09	6.91	5.07
April	5.09	6.71	7.96	8.24
May	7.07	8.26	10.26	14.22
June	10.45	13.25	16.42	22.73
July	10.97	13.64	16.85	32.04
August	11.22	14.03	17.39	28.39
September	9.92	12.06	15.25	13.19
Total	84.92	101.42	123.65	141.18

The analysis is complex, as would be expected with such a large irrigation system, and the following should be regarded as only an outline description. The surface water requirements derived from the canal-command analyses, described in the foregoing parts of this section, were accumulated at the barrage pond or headworks from which they would be drawn, either directly by irrigation canals or by the link canals. The water requirements at the headworks were then transferred upstream through the distribution network of link canals and river reaches to the rim stations. Various conditions of river flow were compared with the water requirements at the rim stations and the monthly surpluses or shortages in flow were determined from this comparison. The analyses made allowances for seepage and evaporation losses from the link canals and rivers, though it must be stressed that reliable data on these factors are lacking.

Allowance was also made for the important gains in the river reaches in the form of regeneration flows from the river banks, where water is stored at periods of high flood. The net river and link canal losses on the system, after allowing for regeneration, are estimated at about 19 MAF per year. Time lags were built into the analysis and these assume considerable importance in such a large system. There would be about two weeks between Tarbela and Ghulam Mohammed Barrage depending on river stage.

The system was divided into the three main irrigation zones (see Map 6): (i) those areas commanded only by the Chenab River, (ii) the Jhelum or Jhelum and Chenab Commands, and (iii) the Indus, or Indus, Jhelum and Chenab Commands. In addition, separate allowance was made for Kabul river inflow after providing for the Kabul and Swat Commands.

After meeting the requirements in zone (i), any remaining flows are served into zone (ii) by passing them from Marala to Khanki headworks or beyond. The analysis showed that Chenab flows at Marala were adequate to meet the requirements of zone (i). The analysis of zone (ii) determined the minimum requirements at Mangla after allowance for the available Chenab flow. A release pattern was selected for Mangla, and shortages and surpluses were noted. The surpluses were passed to Trimmu for use in zone (iii).

The distribution analysis showed shortages at Mangla amounting, for example, to 0.29 MAF[1] for mean river flow and 1.72 MAF for low rabi flow conditions in 1975. The year 1985 showed a slight increase over these figures. However, the analysis did not make allowance for potential overpumping of public tubewell fields, although by that year under IACA's program extensive tubewell fields would be in operation in the areas served by Mangla. The sequential analysis does take well-field capacity fully into account, and demonstrates that in 1975 the shortages should prove to be quite negligible provided that substitution of good quality groundwater for surface water can be made operationally feasible.

Shortages in the transitional period from 1965 to 1975 would, however, be more important. For both mean inflow conditions and a historical sequence of actual water years, the sequential study shows the system totals occurring in the rabi months (Table 5-14). The total shortage under mean flow conditions of 8.2 MAF over the 10-year period occurs mainly in two periods—the first two years, and the two years immediately prior to the completion of Tarbela in 1975. The shortages in the first period arise from restrictions of the Ravi and Sutlej flows to allow for the application of the Indus Waters Treaty. Depending on how these waters will actually be withheld, this may prove to be a somewhat conservative estimate.

The impact of Mangla reservoir in 1968 reduces shortages to a low level, but the demand later rises in anticipation of Tarbela storage. These shortages are equivalent to only about 3 percent of the deliveries in October-April 1973, rising to 3½ percent for the comparable period in 1974.

The absence of shortages under mean year conditions in the sequential analysis after 1975 shows that the IACA program would operate satisfactorily. This is because it is designed to meet requirements under conditions lower than the mean river inflow. The historical sequence of river inflow gave, as would be expected,

[1] This result is largely attributable to the fixed release pattern as well as the rigid crop calendars used, and the shortage may not prove so much in practice.

TABLE 5-14
SYSTEM SHORTAGES
(MAF)

Year	Mean Year	Historical Sequence[a]
1966	2.30	3.69
1967	1.97	4.13
1968	0.08	1.12
1969	0.40	0.45
1970	0.29	—
1971	0.27	0.96
1972	0.62	0.58
1973	1.03	1.70
1974	1.23	2.48
1975	0.04	0.48
1975–1985	no shortages	shortages less than 0.5 at all times

[a] Based on the actual water years 1926 to 1945, see Annex 3.2.

somewhat larger shortages than under mean inflow. Neglecting the first two years, 1966 and 1967, the October to May shortages averaged about 3¼ percent in the period 1968–75 with the highest amounting to 6½ percent in 1974.

In conclusion, the sequential study has shown that the IACA program contains adequate facilities to meet the projected irrigation demands, though there would be some shortages in the early years before that program would come fully into effect. Furthermore, in project areas developed before 1975 the IACA estimates of full-delta requirements, used in the analysis, are liberal when compared with those derived by Pakistani experts for the types of crops now grown, and still likely to be grown in large measure, during the transitional period (1965–75) when potential shortages may cause concern.

The analysis of link canal behavior was not intended to produce figures for actual operation of the links, but rather to show the minimum requirements and thus indicate potential capacity constraints up to 1985. The only significant constraints appear in the links serving the Bari Doab and the Sutlej Valley (RQ and QB, see Map 7).[1] IACA considers that this constraint could be alleviated by adjustments to the relative use of the public tubewell fields and the surface flows. It is estimated that more serious link capacity constraints would develop by 1985, and hence IACA has proposed a new trans-Punjab link system. This would result because the IACA program defers canal enlargement within the commands until 1975 and later where this would necessitate link canal enlargement.

Surface Water Storage Requirements

IACA has derived demand estimates for storage by first using the groundwater available from the tubewell fields, then the natural river flows, and finally the releases from storage reservoirs. The last item is thus derived as a residual demand, and in consequence is the most sensitive to any changes in the pattern of requirements. Although this approach is not applicable to an operational study, and for this reason was not used in the sequential study, it is appropriate for the main purpose of determining stored water needs. Natural river flow and tubewells provide the cheaper sources of supply, whereas stored water costs about three times as much as groundwater. The IACA approach therefore leads to sparing use of the most expensive source of additional water.

The total storage demand can be attributed to two main zones of the Basin—the areas supplied by the Jhelum and Chenab, and the areas supplied from the Indus. Although Mangla reservoir on the Jhelum theoretically commands almost the whole Basin, in practice its use will be reserved primarily for use upstream of the TSMB link (see Map 6). Prior to 1974, it would also be used between the TSMB link and the Panjnad confluence with the Indus.

IACA has based its projections for storage on mean river flow conditions on the assumption that variations below the mean would be compensated for adequately by overpumping of public tubewell fields. This concept has been shown to be satisfactory by the results of the sequential study.

An important consideration in any study of demand for stored water is that the provision of storage generates its own demand, and the decision on reservoir tim-

[1] Rasul-Qadirabad and Qadirabad-Balloki.

ing essentially hinges on what points of time one assumes demand would be growing fast enough to justify the construction of a given amount of storage.

IACA has shown that in the case of Mangla, as would be expected with a reservoir built for replacement of lost river flow, the existing demand approaches its capacity of 5.2 MAF. While IACA employed a then current capacity estimate of 4.5 MAF in its analysis, the difference between this and the latest figure of 5.2 MAF is too small to call for a revision of the work. This is especially the case when practical operational problems are taken into account, and also when slightly more than mean year storage requirements are desirable in the early years of the program because few tubewell fields would be installed to provide a buffer against shortages and low flow conditions.

The Jhelum storage requirements would rise slowly over time to 7.5 MAF at the stage when agricultural development would enable cropping intensities approaching 150 percent, but some of this demand could be transferred to the main Indus if a link system is built across Punjab commanding land above the level of TSMB link. Further storage could be provided on the Jhelum by the raising of Mangla dam. This would theoretically add 3.55 MAF, but by the time this is needed the enlarged reservoir could probably not be filled every year because of the increased demand on the river for kharif crops. IACA has stated that it is not possible at this time to be conclusive on either the eventual need or precise timing of the raising of Mangla, but IACA does not foresee its need until about 1985–90.

IACA projects a more clearly defined and rapid growth in demand for stored water on the Indus main stem. This would amount to 5 MAF in 1975, 9 MAF in 1985, and 19 MAF at full development of cropping intensities by the end of the century.

In order to test the sensitivity of its analysis, IACA calculated the storage requirements on the system under lower than mean flow conditions, but without using the spare tubewell field capacity as was done in the sequential study. When compared with total water use figures (see Tables 5-8 and 5-13), the differences are not great (Table 5-15).

The separate discussions of Jhelum and Indus storage should not detract from the possibility of a high degree of interchangeability within the system, which may be further improved as new link canals are developed.

Water Allocations—Present and Future

The river flows entering the Indus Plains are presently allocated in accordance with procedures based on the unratified Sind-Punjab Draft Agreement of 1945.

TABLE 5-15
STORAGE REQUIREMENTS AT VARIOUS FLOW FREQUENCIES
(MAF)

	Mean Year		1-year-in-2 Flows		3-year-in-4 Flows	
	1975	1985	1975	1985	1975	1985
River Jhelum	4.3	4.5	5.4	5.6	6.0	6.0
River Indus	5.0	8.8	5.7	9.7	6.9	12.1

These procedures take into account the various possible conditions of river flow, and also a time lag of 10 days between the Punjab and Sind.

Various priorities are established under the terms of this draft agreement. For example, the Thal Canal, Sukkur Barrage and certain former old inundation systems share first priority on the main Indus, and thus have fairly well sustained deliveries. The new canals at Taunsa, Gudu and Ghulam Mohammed barrages, on the other hand, have low priority and therefore suffer more marked shortages.

Similarly, the Upper and Lower Jhelum Canals, Upper and Lower Chenab Canals, and Lower Bari Doab Canal have priority in the Punjab. These "five linked canals" supply a large, and predominantly perennial, area amounting to the whole of the CCA in Chaj Doab, most of the CCA in Rechna Doab, and over one quarter of the CCA in Bari Doab. The other canals of the Punjab have varying degrees of lower priority. The least favored area is the Sutlej Valley and the southernmost part of the Punjab.

The procedures set by the Sind-Punjab Draft Agreement, though influencing the immediate future plans for the Basin, need to be brought up to date in order to take into account the following new factors which were not foreseen in the Draft Agreement: (i) public tubewell contributions; (ii) the IBP works; (iii) main river storage in addition to IBP works; (iv) changes in designed discharges of canals.

In the IACA program for irrigation development and water distribution, the present and immediate future importance of the Sind-Punjab Draft Agreement has been carefully taken into account, mainly through the careful regard for historic deliveries described above. Furthermore, the priorities that have been assigned to public tubewell fields would provide valuable buffers against shortages in some of the low priority areas of the Punjab.

D. SYSTEM OPERATION

Future Water Rights and Allocations

It has been stated above that the procedures for allocating water, which have in the past proved successful, must be amended to allow for the changing conditions of the future. These changes are coming about almost immediately with the completion of the IBP works,[1] and with the completion of large numbers of additional public tubewells included in the current Government program.

An ideal system of water allocation is one based on demands which, for each individual watercourse area, would be varied throughout the season in accordance with the crop water requirements of the farmers. IACA concluded, however, that such a system could not be achieved in the foreseeable future. The principal reason for this conclusion is that the existing canalization system (as described in Chapter III) has been designed for almost constant flow in the distributary canals, the latter having very few control structures. The constructional and hydraulic problems of changing the system into one operating according to demand are too large to contemplate in the face of other needs for irrigation development. It will, therefore, be necessary throughout the foreseeable future to continue procedures

[1] IACA's Comprehensive Report, Volume 5, Annexure 7.

based on determining surface water allocation and distribution in advance, though leaving some discretion to officials at appropriate levels to deal with temporary emergencies that inevitably arise from time to time. Such predetermination of allocations should, as hitherto, be based on indents for surface water that are compiled from estimates of cropped acres, which in turn are dependent on the likely availability of supplies. These estimates are made up by the irrigation officials at the beginning of each season. For example, in the Punjab the extent of the rabi wheat acreage can be forecast with reasonable accuracy by mid-November and approximate estimates can be prepared much earlier.

An important need at the present time is to form an organization to establish and authorize procedures for changes in the water allocation patterns. This would be required not just for the immediate purposes referred to above, but also to undertake periodic reviews. With the implementation of a development plan, changes in supply and demand conditions will occur continually. Such an organization should not be called upon to undertake the complex matter of distribution analysis, which can only be handled by an experienced and qualified team of irrigation engineers, but it should be responsible for the policies and general principles that must be established with proper authority. These should take into account a range of administrative, legal and sociological factors, in addition to the largely predominant technical considerations. This consideration does not set aside the need for close cooperation at all stages of planning and implementation between the various agencies concerned with project execution, water allocations and distributions, but is intended to bring about major improvements in this respect and, in particular, to bring more agricultural expertise and outlook into water distribution policy.

IACA has set out basic criteria which should be taken into account in the preparation of a new system of water allocation and distribution.[1] These are summarized as follows:

Public Tubewell Fields. Allocations to the farmers should be based on total integrated supplies of surface water and groundwater from public tubewell fields. Furtheir reference to this matter is made under operation of public tubewells below.

Known Obligations. Known obligations must be related to historic deliveries insofar as these meet known and established needs. It would be illogical and generally wasteful of water at this time to treat known obligations either on the basis of theoretical obligations that have never been met, or conversely on the basis of historic deliveries that are surplus to needs. The latter point will call for careful consideration in the Sutlej Valley where, in the past, high summer flows have been available which may have been in excess of requirements for short periods of time. Although there is a need to improve water supplies in this area, there is clearly little purpose in doing so other than on a full seasonal basis. The main limitation to kharif cropping is the water supply in the early part of the season, and this governs the level of demand in the mid-kharif period when river flows are high.

Seasonal Allocations. Storage reservoirs should be used to regulate river flows so that the total water supplies delivered to the fields are related as closely as possible to the estimated water requirements of the crops. With the introduction of stored water "known obligations" should be reconsidered, and where necessary

[1] IACA's Comprehensive Report, Volume 5, Annexure 7, "Water Supply and Distribution."

redistributed on a seasonal, instead of the present monthly or 10-day basis, to the advantage of the farmers.

Filling of Reservoirs. Reservoirs would normally be filled only with water which is surplus to basin requirements, but where conflict in demands may arise in exceptional circumstances it may be appropriate for priority to be given to reservoir filling because of the greater value relating to rabi crops, especially wheat.

Additional Supplies. Areas with present high priorities for canal deliveries (see Chapter V-C) should not necessarily have any special priority for additional supplies that would become available from storage reservoirs and public tubewell fields.

The application of these five criteria is essential to the successful operation of IACA's development proposals, and indeed to the efficient use of the water resources that are available to agriculture at present, and would become available in the future. The first criterion relates to the integrated operation of the surface and groundwater supplies. The other four are of particular importance to the economical use of stored water, which is not only expensive to provide but will, as development proceeds, remain scarce.

Operation of Public Tubewell Areas and Water Allocations to Them

In order to ensure a satisfactory and economical integration of water supplies (see Chapter III-C), it would become necessary to adopt a more complex system of operation than has hitherto been used. The complexity stems not only from the basic need to proportion groundwater pumping and canal deliveries, but also from lack of homogeneity in the canal systems serving the individual project areas. Here it is important to bear in mind that most of the public tubewell fields would not cover discrete canal command units, but only parts of canal commands. Furthermore, there would be a need to vary the surface water deliveries as between fresh groundwater zones, mixing zones and saline zones. The last two zones must receive a priority for surface deliveries in times of shortage, whereas in the fresh groundwater zones temporary surface water deficiencies could be offset by overpumping. Ultimately, a technological advance towards the proper operation of the tubewell project areas would lie in operation of the tubewell fields by centralized remote control, coupled with some degree of remote control of the canal flows, but for the immediate future this would represent too big a step. Individual manual control, together with a good system of communications, is the more feasible method for the present. Remote control and other similar advances in operation, including some separation of surface water deliveries to mixing and saline areas, must be gradually developed, and the appropriate stages for their application should be related closely to the expansion of the tubewell fields and the consequent formation of larger entities for ground and surface water integration.

The more critical times of the year for system operation would be when tubewells are supplying a large or exclusive contribution to crop needs in the fresh groundwater zones, and this would normally be in the mid-rabi months. This period would prove the more critical because each tubewell would be designed to serve its own discrete area (normally an area of 200-600 acres served by one watercourse), and if the well goes out of service large, or even complete, deficiencies in supply would occur.

To minimize operating hazards at this critical time, care must be taken to ensure that well maintenance receives special emphasis in the previous period. This would also leave the operating agency greater staff resources to concentrate on the canal maintenance that must be mainly undertaken in the midwinter period when flows are lowest. Such carefully programmed maintenance would lead to a more economical employment of maintenance staff, to the extent that staff personnel are interchangeable. The structure of the operating and maintenance staff organization is discussed in IACA's Comprehensive Report.[1]

In making allocations to canal commands which would contain public tubewell projects, the "known obligations" referred to previously should be treated on the basis of total water delivered at watercourse heads, regardless of whether it is derived from ground or surface sources. In these terms, future deliveries would greatly exceed "historic" deliveries. In this way some of the "historic" deliveries from surface sources would be replaced by groundwater. This principle forms part of the planning of the ongoing project SCARP IV and would, in varying degree, be extended to other projects. There would be need for a transition period from the present level of "historic" surface water deliveries until the time when the principle of water substitution can be implemented, because the farmers need time to gain confidence in the reliability and quality of the groundwater supplies. For these reasons, the allocations of water to the various canal commands of the Plains where public tubewells are programmed would need to undergo frequent change.

Indents for surface water supplies should be prepared in greater detail than hitherto, and with careful regard for the rate of growth of cropping intensity. The latter point would call for close collaboration between the irrigation and agricultural officers, especially in regard to the tubewell fields themselves, but also in the associated canal commands.

Water Allocations to Areas without Public Tubewell Development

IACA has not projected any similar adjustment in surface water supplies in areas where private tubewell development would predominate. Allocations to canal head, and through the distribution system, in areas not covered by public tubewells, would have to be maintained at least at established "historic" levels. This is necessary not only to protect the needs of cultivators who have no private tubewell supplies, but also to satisfy cultivators' expectations and rights to the relatively cheap canal water.

These areas would also gain considerable benefits from the construction of the storage reservoirs at Mangla and Tarbela, and later from other reservoirs. With the advent of regulation by storage dams, the "historic" deliveries should be adjusted to the advantage of the farmer, the past pattern of monthly delivery being amended to suit indents that are better related to the seasonal pattern of crop needs.

Additional rabi supplies from the storage reservoirs would be allocated in areas where waterlogging from high groundwater is not a current or imminent hazard. The presently adopted priorities (discussed in a later section below) should not

[1] IACA's Comprehensive Report, Volume 8, Annexure 11.

necessarily be followed in making such allocations, but allocations should be based on continuous review of the relative developments in the system at large.

Phases of Development and Their Influence on Water Distribution

The first revision of water allocations was to come after the Mangla reservoir came into operation in 1967, aimed at the first objective of putting into action an initial system of operation. It was recognized that there may be certain difficulties in meeting allocations during the transitional period over which the IBP works are brought into operation. However, IACA has demonstrated in its studies, and it has been confirmed in the Sequential Analysis on the basis of the proposed program and distribution criteria, that the shortages which may occur should not be of serious proportions (see Section V-C). Much depends on the attitude taken towards "known obligations" but if the principles set out by IACA can be adopted —and these are based on historic mean deliveries rather than on theoretical obligations—it should prove possible to maintain previous standards in irrigation supplies, and in some cases to improve them by better regulation within the rabi season.

By 1970, when the Indus link canals are scheduled to come into operation, the whole of the Sutlej and Ravi flow would be available to India. The link canals would overcome such problems as may have arisen in serving water to Trimmu and Panjnad in the kharif months during the earlier transitional phase. Mangla reservoir should remain hypothecated to its replacement function, but at the same time operational instructions should allow for improved seasonal regulation.

Tubewell fields built in the latter part of the Third Five Year Plan, including the important SCARP IV project, should be integrated with the water allocation and distribution plan. In accordance with its design, SCARP IV would release most of the present rabi supplies now flowing to the Upper Chenab canal for use elsewhere in the Punjab.

Little change would be called for on the Indus main stem until 1975, when Tarbela would come into service and public tubewells would begin to make major contributions to water requirements.

The advent of Tarbela in 1975 would provide a full opportunity to bring about a major and widespread improvement in water distribution and availability. In this sense, Tarbela represents a conclusive stage in the large water development program proposed for the first decade. From this point of time onwards, it should prove possible to match water allocations fairly closely to anticipated crop needs in most parts of the Basin. Certain constraints would still exist, however, notably in canal capacities in the saline and mixing areas. The need for drainage would still inhibit water allocations to some areas, but broadly the patterns of water supply and demand could be closely related, and in many areas the full requirements of the farmers would be met from a combination of surface and groundwater deliveries.

Reservoir Operation and Release Patterns

IACA has also carried out some operational studies on the reservoirs at Mangla and Tarbela in order to determine the expected pattern of water release and the related hydroelectric power output. IACA's studies indicated that, with the level of development expected by 1975, the period when irrigation requirements would exceed river flow would normally extend from October to the end of March. By 1985 this period would include April and the early part of May. In exceptional cases, shortfalls of river flow against requirements would occur outside these periods. Special attention was given to the conditions that would obtain in years of low rabi flow, since the pattern of release would be more significant at such times than in years of average or above average flow. During years of low rabi flow deficiencies in surface water deliveries must be spread throughout the rabi season. This is not only to mitigate their effects on the crops, but also so that they may be made up as far as possible by overpumping in the tubewell fields.

Although IACA gave priority to irrigation needs in deriving the suggested release patterns, some allowance was made for electrical demands on the hydroelectric installations in the storage dams and the interrelated power demand of groundwater pumping. The public tubewell fields, which would be integrated with the surface supply system, should be operated mainly in rabi from October to March when there is surplus power available, and as little as possible in April and May when hydro power is in short supply. This has the added advantage of permitting reservoir levels to be held slightly higher in the late part of the storage release period. Based on these considerations IACA developed release patterns for Mangla and Tarbela.

For Mangla, IACA determined the monthly storage release requirements on the Jhelum at Mangla for various conditions of inflow as set out below in Table 5-16. The requirements stated in the table represent the requirements of those canal commands (see Map 6), which rely on the Jhelum and Chenab for their supplies and cannot be served directly by the Indus link canals. The patterns of requirements for 1975 and 1985 do not differ very much, and in the case of the Jhelum the extent of the period of storage requirement remains much the same, namely October to March inclusive. On the basis of these considerations, IACA proposed the following release pattern for Mangla reservoir as set forth in Table 5-17.

TABLE 5-16
MONTHLY STORAGE REQUIREMENTS ON THE RIVER JHELUM
(MAF)

River Flow	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
				1975				
Mean	1.30	.63	.51	.48	1.23	.45	0	4.29
Median	1.59	.75	.64	.61	1.42	.48	0	5.39
Low Rabi	1.51	.75	.63	.67	1.64	.84	0	6.05
Critical[a]	1.28	.62	.63	.73	1.65	1.16	0	6.03
				1985				
Mean	1.57	.67	.43	.39	1.26	.19	0	4.51
Median	1.86	.78	.56	.52	1.45	.53	0	5.60
Low Rabi	1.77	.78	.55	.59	1.67	.89	0	6.24
Critical[a]	1.54	.65	.52	.64	1.66	1.19	.07	6.27

[a] It should be noted that the critical year 1954/55 was not the worst occurrence on the Jhelum, and that it was no more than a low rabi year.

TABLE 5–17
MANGLA RELEASE PATTERN
(percentage of useful storage)

Storage Release							Reservoir Filling				
Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
23	15	10	10	24	18	Nil	24	36	31	9	Nil

For Tarbela, the requirements for storage as calculated by IACA are set forth in Table 5-18. This table demonstrates how the period of requirement tends to extend, both with time and with the occurrence of more critical conditions of inflow. It is on these grounds that IACA proposes to have some 15 percent of the capacity available in Tarbela after the end of March, as previously referred to in Table 5-13. The release pattern derived by IACA for Tarbela would thus be as set forth in Table 5-19.

IACA's studies of reservoir operation were not intended to provide more than a guide for future planning. A detailed set of operating instructions must now be prepared by WAPDA, in conjunction with other Government Departments concerned, as a matter of some urgency, especially for Mangla.

To test the validity of their water distribution studies, IACA has examined the probable deficiencies that would arise at Mangla and Tarbela under the rather severe conditions of low rabi inflow. The results are given in Table 5-20. Deficiencies as determined have been treated on a two-monthly basis, partly because this would smooth out sharp distortions and partly because, in some months, the water requirements of the crops have been treated to a limited extent on the same basis. The deficiencies are in no case more severe than would be expected. In practice, they would be alleviated by two factors.

First, there would be considerable public tubewell development by 1975 and 1985 with capacity to overpump during the mid-rabi and in April and May, when larger deficiencies would occur at Mangla and Tarbela respectively.

Second, as stated earlier, Mangla's initial live storage capacity should now be taken as 5.2 MAF or 5.06 MAF by 1975, and not the 4.75 MAF upon which the above deficiencies were based.

TABLE 5–18
MONTHLY STORAGE REQUIREMENTS ON RIVER INDUS

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
					1975				
Mean	0	0	.79	1.77	2.21	.25	0	0	5.02
Median	0	.15	.91	1.79	2.24	.65			5.75
Low Rabi	0	.27	.94	1.80	2.41	1.31	.17		6.90
Critical	0	.53	1.35	2.02	2.70	1.58	1.54	1.30	11.01
					1985				
Mean	0	1.21	1.35	2.41	2.73	1.02	.12		8.83
Median	0	1.37	1.39	2.50	2.75	1.43	.28		9.70
Low Rabi	0	1.49	1.33	2.55	2.90	2.02	1.45	.39	12.11
Critical	0	2.05	1.61	2.84	2.29	2.29	2.80	2.96	17.91

TABLE 5–19
TARBELA RELEASE PATTERN
(percentage of useful storage)

Storage Release								Reservoir Filling			
Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Nil	8	11	21	26	19	10	5	45	55	Nil	Nil

Detailed Water Distribution Analyses

As stated in Section C above, the water distribution analyses carried out by the Study Group's consultants were designed to set the Action Program for the next decade into its longer term perspective, to match the general pattern of water use against availability, and also to check the operation of the IACA plan of development against a possible repetition of historic sequences of river inflows to the Basin. These analyses were not intended to provide detailed estimates for specific water allocation or distribution patterns, but nevertheless they form a useful framework upon which to build up detailed studies of future system operating procedures and rules. These detailed studies should be pursued. A start has been made by WAPDA as part of its responsibility for operation of Mangla dam; the Department of Irrigation and Power had undertaken similar studies of Mangla operations over the immediate future. But Mangla represents only part of the new operational problem. In its broader context, the distribution studies must embrace all the new situations set by the introduction of the IBP link canals and their new transfers of water to the eastern Punjab. These and other aspects of the redistribution of surface water, including the implementation of tubewell programs, involve a number of other agencies including the Agricultural Department, ADC and the LWDB. The procedure for bringing together the views and experience of the various agencies and applying them to a study of water distribution is essentially a domestic one that can only be decided by the Government, but the Study Group attach such importance to this matter that certain suggestions are set out here.

In the next Chapter, the Study Group endorses IACA's proposal that a Provincial Irrigation Authority be formed to make basic policy decisions on barrage allocations, reservoir release patterns, and other major policy issues such as the use of tubewell fields in relation to surface water deliveries. This body would clearly be charged with the responsibility to ensure that all Government agencies concerned with irrigation should cooperate in the framing of new policies and water allocations, but it would not itself be expected to undertake the detailed analyses of water distribution which should remain the task of the irrigation experts. In the normal course of events, all water distribution analysis *per se* would be undertaken by the Irrigation and Power Department, which in any case is faced with the implementation of the procedures finally adopted. However, in view of the rather special nature and magnitude of the present task, and on account of the particular role played by WAPDA in the IBP works, in the current operation of Mangla and in the public tubewell program, there is a strong case to set up a semi-independent Working Group or Working Party for this purpose, to be staffed by, say, the Irrigation and Power Department, WAPDA, Agricultural Department, and Planning and Development Department. The head of such a Working Party,

TABLE 5-20
SURFACE WATER DEFICIENCIES FOR LOW FLOW CONDITIONS (1975)
(MAF)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Mangla (Low Rabi Flow)								
Irrigation Requirement	2.83	1.24	1.05	1.13	2.19	2.01		
River Flow	0.82	0.49	0.42	0.46	0.55	1.17		
Storage Requirement	1.51	0.75	0.63	0.67	1.64	0.84		
Storage Release[a]	1.09	0.71	0.48	0.48	1.18	0.85		
Deficiency	0.43	0.04	0.15	0.19	0.46	—		
Deficiency as % of Requirement	13%		15%		11%			
Tarbela (Critical Year Flow)[b]								
Irrigation Requirement	1.43	1.73	2.34	2.90	3.46	2.56	2.75	4.04
River Flow	2.19	1.20	0.99	0.88	0.77	0.98	1.21	2.74
Storage Requirement	—	0.53	1.35	2.02	2.69	1.58	1.54	1.30
Storage Release	—	0.69	0.95	1.80	2.24	1.63	0.86	0.43
Deficiency	—	—	0.40	0.22	0.46	0.05	0.68	0.87
Deficiency as % of Requirement Surplus			12%		7%		23%	

Source: IACA's Report, Volume 5, Table 1-3.
[a] Based on Mangla Capacity of 4.75 MAF.
[b] The "critical year" rabi flow has been adopted for this illustration of deficiencies because it contains lower October and May flows than the "Low Rabi Flow." The flows in these months have considerable importance to Tarbela operation.

who would need to be a highly qualified irrigation engineer, could be answerable to either the Provincial Irrigation Authority or, better, to some intermediate Advisory Provincial Irrigation Authority, or better, to some intermediate Advisory Committee drawn from the main Government departments.

The Working Party would need to be well staffed with technical officers competent to carry out the detailed calculations and analyses that the situation demands. At the same time, this staff would need to be fully conversant with the practical problems of operating the irrigation system. Clearly the largest contribution to such an establishment would come from the Irrigation and Power Department and WAPDA, but at the same time it would be necessary to incorporate one or more agronomists, a crop water expert, and an agroeconomist. Legal advice would also be required at this level in order to save time and trouble when new water allocation policies are offered for approval to the Provincial Irrigation Authority. To economize in technical services, it would be advisable, with this organization, to attach to the Working Party those consultant services in water distribution that are currently retained by individual Government departments. The Working Party should be given a program of work related in particular to the dates when the various IPB works, and the public tubewell fields now under construction, come into service.

VI

Agricultural Inputs and Supporting Services

A. FARM INPUTS

General Considerations

Despite continuing efforts to promote better farming practices and the employment of physical inputs such as fertilizer, better seed, and plant protection on a wider scale, the present level of adoption by the vast majority of farmers is still very low. The Study Group would not only endorse, but would add to the emphasis which IACA has placed on the importance of improving farming standards. In general, IACA advocates the simultaneous development of improved water supplies and improved farming, with the main emphasis on water while other inputs increase to the maximum extent it considers feasible. The Study Group supports this policy and agrees that, to the extent farm inputs are in short supply, development areas with adequate and assured water supplies should have priority. To a greater extent than IACA, however, the Study Group considers that there is scope for increased productivity within the prevailing conditions of water supply. The watercourse studies[1] suggest that unreliability of water supplies, rather than the absolute quantity of water made available, is in many cases the most serious deterrent to greater investment and enterprise by the farmers. This could no doubt be assisted by better operation of the irrigation system, and would improve with the development of private and public tubewells and with the regulation of the river flows provided by the link canals, Mangla reservoir and, in due course, by Tarbela.

The Study Group would place at least as much emphasis on the efforts required to bring about better farming as it would on further water development. As a broad generalization, it would appear that IACA may well have overestimated the implementation capacity for water development, and, by comparison, underestimated the capacity to stimulate, and the benefits which could accrue from, the use of other inputs. A rapidly expanding use of agricultural inputs would call for organizational and institutional improvement in all sectors—procurement, distribution, promotion, and technical and financial support. It must, however, be emphasized again that no single input in isolation, be it water, fertilizer, seed or anything else, would succeed or make much of an impact on its own. The proper application of the various inputs in the right combination, at the right time, and in the appropriate manner depends essentially upon the skill and judgment of the farmer.

[1] See Annex 1.

Unless the majority of farmers have the knowledge and the incentive to enable them to apply the opportunities which can be opened up for their particular circumstances, the whole developmental effort could be seriously impaired. This underlines the importance of agricultural education, research and extension in the realization of the potential which undoubtedly exists.

The progress which has been made in some directions is impressive. Probably the best examples are fertilizer usage, development of improved varieties of wheat and rice, and private tubewell installation. The quantities involved, however, are as yet very small in relation to the opportunity and need. The organizational and institutional difficulties of rapid introduction of the whole package of inputs are formidable. This applies to water and fertilizer, but with even greater force to other inputs such as plant protection, improved seed varieties, mechanization, agricultural credit, genetic improvement of the livestock herd, and the general dissemination of information on the adoption of better crop and animal husbandry practices. Nevertheless, West Pakistan's agriculture will become increasingly dependent on the proper use of such inputs.

The efficient utilization of existing irrigation supplies, as well as those to be developed, depends to a very large extent upon the availability and application of nonwater inputs in proper combination. In its projections of agricultural growth in West Pakistan, IACA has assumed a continuing increase in the use of such inputs. The growth projections are thus the result of an envisaged program of water development as well as increased provision and use of agricultural inputs. As discussed in Chapter II, the Study Group believes that great scope exists for a development strategy which gives high priority to, and adequate incentives for, the distribution and use of these inputs. The Study Group believes that if proper public support is given, some of the IACA projections of input use could be exceeded, and it therefore looks upon these projections as the minimum requirement needed to support the agricultural growth projected by IACA.

The input requirements, including a somewhat more optimistic assessment of the increased use of fertilizer, are discussed below in more detail. While recognizing the inherent difficulties, the Study Group is convinced that an agricultural breakthrough can only be achieved if water development is matched with a corresponding increase in the use of other inputs. Further water development alone would only extend and continue the traditional pattern of agriculture. The transformation of agriculture in West Pakistan from a subsistence oriented to a commercially oriented pattern will proceed only as fast as the responsible institutions succeed in making farmers aware of the untapped opportunities available to them, and provide the incentives and the means for their exploitation.

Fertilizer

Taking into account the projected increase in cropped acres from 41.6 million in 1965 to nearly 60 million acres by the end of the century, IACA has projected fertilizer requirements by regions for the reference years 1975, 1985, and 2000. These estimates are based on both prescribed rate of application for major crops and increasing coverage of the areas assumed to receive fertilizer applications (see Annex 8). IACA's rates of application have been developed from rates presently recommended by the Department of Agriculture. IACA also took into account the spread of new and improved wheat varieties. It assumed that some 50 percent of the area would be covered by new or improved varieties by 1975, and the whole wheat area by 1985.

The aggregate fertilizer requirements based on the above outlined assumptions would rise from about 90,000 nutrient tons at present to about 320,000 nutrient tons by 1975, and to slightly above 1.8 million nutrient tons by the end of the century. These amounts would represent applications of about 9 lbs. per cropped acre in 1965 and 29 lbs. per cropped acre in 1975. Table 6-1 sets out IACA's aggregate projections by crops. Compared with the experience during the period of the Second Five Year Plan, the rates of growth of fertilizer use implied in the IACA projections would appear to be rather conservative. As stated in Chapter I, the absorption of fertilizer during the Second Plan period, albeit from a very low base, grew rapidly at an average rate of about 22 percent per annum. Most likely the growth of fertilizer use would have been even higher had not changes in policy, as well as lack of adequate supplies, introduced constraints beyond the control of the farmers.

Various short-term projections of future fertilizer use in West Pakistan have been made in the past (see Annex 8). These projections tend to coincide at an offtake figure of about 370,000 nutrient tons by 1969/70, or a rate of growth of fertilizer use well above 30 percent per annum. 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) did not show a major increase over 1964/65, subsequent steps taken by the Government of West Pakistan would tend to support such an optimistic assessment. For fiscal 1966/67, the Planning and Development Department of the Government of West Pakistan hopes to have more than 250,000 nutrient tons (equivalent to about one million tons of nitrogenous fertilizer) available for distribution. An offtake of 80 percent of this amount in 1966/67 would represent a level of absorption of nitrogen approaching that projected by IACA for 1975, and would by far exceed IACA's general expectations.

TABLE 6-1

IACA's Projections of Total Fertilizer Requirements by Crops in West Pakistan

('000 tons nutrient)

	1965[a]		1975		1985		2000	
	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5
Wheat	7	—	100	64	248	147	338	211
Cotton	23	—	42	14	98	52	196	163
Coarse Rice	9	—	10	—	24	8	60	42
Fine Rice	—	—	10	4	23	10	45	26
Coarse Grains	—	—	8	3	35	23	84	50
Fodders	—	—	15	11	71	54	172	176
Sugarcane	49	—	22	4	36	12	63	25
Fruit	2	—	5	2	15	7	42	17
Other Crops	—	—	5	1	23	22	55	62
Total	90	—	217	103	573	335	1,055	772
Rate of Growth of Fertilizer Use: (% per annum)		13.5%		11%		7.5%		

[a] In the absence of any reliable information this is a very rough approximation.

The Study Group is satisfied that scope for the use of such quantities exists. 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. As an upper limit the Study Group considers that a target of about 350,000 nutrient tons (equivalent to about 1.6 million tons of ammonium sulphate fertilizer) would be feasible for 1969/70. This implies a rate of growth in fertilizer use of around 30 percent per annum, and would be about double the IACA estimate if their implied rate of growth were applied to the existing fertilizer consumption. The coverage and rates of application envisaged by IACA for 1975 are thus expected to prevail by the end of the Third Five Year Plan period.

During the period of the Fourth Plan (1970/71–1974/75), it may become more difficult to maintain a similar momentum in the absorption of increasing quantities of fertilizer. Assuming that the rate of growth of fertilizer offtake would drop to about 15 percent per annum, the level of consumption would reach about 700,000 nutrient tons by 1975. This would again be double the IACA estimate. While a high degree of uncertainty is necessarily inherent in all these projections, it should be possible for the West Pakistan authorities to reach these targets if appropriate arrangements are made for supplies and distribution. For the reference years thereafter (1985 and 2000), the Study Group would expect the increasing offtake of fertilizer to slow down considerably and approach the levels estimated by IACA (Table 6-1).

The Study Group's more optimistic assessment with regard to the future absorption of fertilizer is compared to IACA's in Table 6-2. In the Study Group's opinion, the estimates in the table would delineate the range within which future fertilizer offtake is likely to fall. Using the Study Group's estimate, the quantities of fertilizer (in terms of ammonium sulphate equivalents) would increase from 1.6 million tons in 1970 to 3.3 million tons in 1975.

TABLE 6-2
RANGE OF FERTILIZER OFFTAKE FOR REFERENCE YEARS
('000 tons of nutrient)

	1964/65	1970	1975	1985	2000
IACA:					
Nitrogen	90	120	217	573	1,055
Phosphate	—	55	103	335	772
Total	90	175[a]	320	908	1,827
Rate of Increase (per annum)	14%	13%	11%	5%	
Study Group:					
Nitrogen	90	250	470	620	1,100
Phosphate	—	100	230	330	700
Total	90	350	700	950	1,800
Rate of Increase (per annum)	30%	15%	5%	4.5%	

[a] IACA has made no estimate for 1970; the above figure is based on the implied average annual growth between 1965 and 1975.

The financial outlays implied in these estimates are considerable for the farming community, and for the public sector as well, if the rapid growth of offtake would continue to be supported by subsidies, at least through 1975. Assuming that present price levels would not change substantially, and that subsidies would continue at a rate of about 30 percent of the present price to farmers, the annual level of expenditures for fertilizer use as estimated by the Study Group, would be about as set forth in Table 6-3. These estimates may be too high since the costs of fertilizer production should be substantially reduced by the introduction of new technology. The expectation is that such reductions would diminish or eliminate the need for Government subsidy, while the price paid by the farmer would remain substantially the same. Also, the above costs and the quantities in the previous table are based on sulphate of ammonia equivalents. To the extent that urea is substituted for these, the physical quantities would be more than halved, resulting in reduced transportation and distribution costs. Care should, however, be taken to ensure that the prices to farmers do not rise substantially until such time as the use of fertilizer has become a well-established practice.

The expanding fertilizer use outlined above constitutes a very ambitious program in itself, requiring determined efforts by all concerned. Given proper support, the targets should be achievable. Such a program would warrant the highest priority, since the increased use of fertilizer is likely to be the most important single factor in bringing about rapid agricultural growth in the near future. To the extent that the Study Group's assessment of future fertilizer use exceeds that of IACA, it obviously carries implications for the projection of future agricultural production. These are dealt with in Chapter VIII below.

Seeds and Planting Material

A further agricultural input of the utmost importance is improved seed material of superior varieties, particularly of wheat, cotton, and rice. Important progress has recently been made in the case of wheat. West Pakistan, in collaboration with Mexican wheat-breeding experts supported by the Rockefeller Foundation, has been embarked on an active wheat improvement program since 1959. Several higher yielding varieties have been developed and are in various stages of progress from the research stations to commercial multiplication. Imported Mexican varieties (Penjamo and Lerma Rojo) are already being multiplied, while the locally produced Mexipak varieties have not yet reached the stage of distribution for commercial production.

The technical yield potential of these newly introduced varieties under Pakistan farming conditions, according to the wheat-breeding experts, is about 45 maunds

TABLE 6-3
GROWTH OF PRIVATE AND PUBLIC EXPENDITURES FOR FERTILIZERS
(at present prices and subsidy rates)

	Farmer Outlays	Public Subsidies (Rs. million)	Total	Annual Growth (%)
1964/65	84	36	120	—
1969/70	325	140	465	30
1974/75	650	280	930	15

per acre on average. This compares to an average of about 13 maunds per acre presently being obtained in the better farming areas of West Pakistan. The potential is thus considerable, and its realization will again depend on whether West Pakistan succeeds in implementing an efficient program of multiplication and distribution, providing adequate incentives, and supplying the associated inputs to farmers. The performance during the first year of commercial multiplication (1965/66 rabi season) on an area of about 12,000 acres distributed over the major agricultural regions of West Pakistan was very impressive indeed.[1] On the basis of harvesting data available for 5,000 acres, average yields ranged from 26 to 34 maunds per acre under actual farming conditions. Maximum yields exceeded 80 maunds per acre, 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.

The general shortfall of yields, as compared with the technical and biological potential, has been attributed mainly to five causes: (i) suboptimum moisture conditions of the seed beds; (ii) excessive depth of sowing, carried over from practices used with indigenous varieties; (iii) low seed rates which were only about 60 percent of the recommended seed rates for improved varieties; (iv) shortage of irrigation water, as well as insufficient number of waterings; and (v) deficient application of fertilizer. It is important to recognize that not any one single factor led to the shortfall, but that practically all major elements of efficient cultivation practices were lacking to some extent. The future success of the accelerated wheat improvement program is thus not only dependent on the availability of adequate quantities of improved seeds, but on an overall improvement of crop husbandry practices as well.

IACA assumes in its projections that the wheat acreage covered with improved Varieties would approach 50 percent by 1975, and 100 percent by 1985.[2] On the basis of the projected acreage under wheat by 1975 (15.2 million acres) and 1985 (15.4 million acres), and the recommended seed rates of about 100 pounds per acre, about 350,000 tons (9.4 million maunds) of improved wheat seed material would be required by 1975, and nearly 700,000 tons (18.8 million maunds) by 1985. Assuming that seed is produced by the best farmers at an average yield of about 30 maunds of seed material per acre (or 1.1 tons per acre), some 320,000 acres would have to be devoted to improved seed production in 1975 and 635,000 acres by 1985, compared to a current acreage of about 12,000 acres under improved wheat varieties. This would mean a 26-fold increase over the next decade, or a rate of growth in acreage devoted to the production of improved seed of nearly 40 percent per annum. In order to provide a base for this offtake, IACA estimates that the present 6,000 acres under Government seed farms should be raised to 25,000 acres for the production of Government-controlled foundation seed.

While IACA's projections imply an ambitious target with regard to the multiplication, distribution and acceptance of improved wheat varieties, the wheat-breeding experts advising the Government of West Pakistan on the accelerated wheat

[1] As reported in "Annual Technical Report, Accelerated Wheat Improvement Program West Pakistan, 1965/66," S.A. Qureshi and Ignacio Narvaez, Agriculture Dept. of West Pakistan, Lahore, August, 1966.

[2] IACA's Comprehensive Report, Volume 7, Annexure 9, Agriculture, page 85.

improvement program have predicted an even faster progress. Their estimate is that by the end of the Third Plan (1969–70) about six million acres of irrigated land would be sown with improved wheat seeds. This would require the availability of some 265,000 tons of improved seed material by 1969/70, and implies a target acreage for improved seed production of at least 250,000 acres, or a growth of more than 100 percent per annum over the remainder of the Third Plan period.

As desirable as the achievement of such ambitious targets undoubtedly would be, they do appear somewhat optimistic. 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 retain high germination rates, and an extensive and efficient distribution network. None of these aspects is well developed at present, nor are there, to the knowledge of the Study Group, any definite plans for such a comprehensive program. While the IACA estimates regarding the introduction of improved wheat varieties appear to be somewhat conservative in comparison with those of the seed specialists, their achievement would represent a very important advance in the development of West Pakistan's agriculture.

The widespread use of improved seed material is presently confined to cotton. IACA estimates that about 40 percent of the present cotton acreage is already covered with improved seed material, and that such use would become general practice by 1975. The problem with cotton seed is mainly one of maintaining the purity of seed material of individual varieties. To this end, a Cotton Control Act was passed in 1949 providing for the cultivation of specific staples in specified zones. Although initially limited to the Punjab and Bahawalpur, new legislation is now extending this control to the whole of West Pakistan, while simultaneously providing for stricter supervision of seed extraction and handling at the ginneries. However, a major source of intermixture of seeds, and an obstacle to adoption of improved varieties, is the continuing practice of retaining some cotton for hand-spinning on the farms. The poor quality cotton seed derived therefrom is frequently used for planting.

In IACA's option, the poor seed quality contributes to the low plant population commonly achieved under present farming conditions. IACA found in the watercourse studies[1] that the most frequent plant population for cotton ranged between 6,500 and 7,000 plants per acre, as compared to a recommended plant population of 16,000 plants per acre. The low plant population is not entirely due to poor quality seed, but also to low seed rates, emergence difficulties and post-emergence mortality. Thus, in conjunction with improving cotton seed quality, IACA proposes increasing seed rates and full plant populations to achieve the yield potential associated with improving levels of all inputs. By applying improved seed rates to the projected cotton acreage, IACA estimates future cotton seed requirements would be about 58,000 tons for 1975 and 95,000 tons for 1985. Seed is severely damaged by pests, and every effort should be made to control these pests and improve seed storage conditions in order to improve seed quality. The Study Group feels that effective pest control might reduce the seed requirements somewhat below these IACA estimates.

[1] IACA Comprehensive Report, Volume 10, Annexure 14, Watercourse Studies.

Important progress has been made with the development of high yielding dwarf varieties of coarse rice 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 to cover about one million acres with improved varieties by 1970. Assuming seed rates of about 20 pounds per acre, this would require about 90,000 tons of improved seed material, roughly equivalent to IACA's target for 1975. IACA expects improved rice varieties would be in common use by 1985, and require more than twice the above seed production per year.

There are further opportunities in the increased use of improved plant varieties of maize and sugarcane. In the case of maize, the development of so-called synthetics, as well as hybrids, holds considerable promise for West Pakistan. However, the introduction of hybrids requires considerable organizational and scientific support for maintenance breeding as well as large-scale planting in contiguous areas. Furthermore, it appears that the yield potential of good straight maize varieties has not yet been exhausted, and that considerable progress could be made immediately with a proper package of inputs applied to available varieties. The choice of sugarcane sets material needs improvement, as does the planting rate. At present, only about half the recommended number of sets is being planted. Most of these are two node sets, although IACA considers three node sets to be more desirable. However, the actual supply of new sugarcane varieties should not be a major problem, since the propagation is vegetative and there is no danger of varietal deterioration.

IACA believes an improvement in the general quality of sowing material would come from broad realization by farmers that improved seed has value to them, and from the development of seed supplying agencies, partly Governmental and partly private, which would supply tested and certified material.

The Study Group, in agreement with IACA, has no doubt whatever that improved quality seed could and should make an important contribution to the growth of agricultural production through higher yields. It is of the utmost importance that stimulation and support be given to the present efforts being made to develop varieties which would respond to the use of additional inputs, and to make them available on a commercial scale. In general, the Study Group would accept IACA's assessment of the probable progress and contribution to production from this source of growth as reasonable for planning purposes, but it retains the hope that IACA's projections may prove to be on the conservative side. Improved seed constitutes an influence which is extremely difficult to measure. It is not a specific term, and it could be quite meaningless to measure progress in terms of the amount of improved seed employed. In the past, many reports suggest that much of what has been called "improved seed" has been little, if any, better than farmers' own stocks. If, however, "improved seed" is interpreted as meaning seed of high genetic quality, produced and distributed under controlled conditions which provide a high degree of assurance that it would be true to type, free from adulterants and of high germination, then Study Group believes that IACA's estimates—for example, 50 percent of the wheat area sown with such seed by 1975 and 100 percent by 1985—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. If the authorities are successful in covering the areas estimated by IACA with improved seed of high quality, at appropriate seed rates, this would have an impact all down the line and lead to progressive improvement of the seed used on any areas remaining uncovered. The Study Group would attach the utmost importance to the development of the necessary institutional arrangements required to secure the widespread use of better seed.

The magnitude of the seed requirement for the present situation, and IACA's projections for the future for the three major crops, are shown in Table 6-4. The Agricultural Department and the ADC are already active in the provision of improved seed. Their distribution in 1964/65 for the three crops: wheat, 0.4 million maunds; cotton, 0.3 million maunds; and rice, 0.7 million maunds. These figures serve to indicate the magnitude of the problem and, with the exception of rice, the large gap between requirements and supply for these crops. In addition, coarse grains and fodder would require large quantities of improved seed. Kharif and rabi fodder together already require about 2.0 million maunds of seed at present, and under the IACA projections would require 6.0 million maunds in the year 2000.

IACA does not envisage a situation in which all seed would be drawn from either Government or registered private seed farms. They suggest a system of segregated zones in which there is strict Government supervision, and in which all farmers are required to use good quality seed supplies from seed farms or of known origins and standards. The principle is to flood the zone with good quality seed, renewed at regular intervals so that good seed replaces bad. The system would work better with cotton than with other seeds because Government supervision can be easily applied at the ginneries, and it would be possible to prevent ginneries from drawing their seed cotton from areas outside the zone where another variety may be being sown. There are, at present, 5,000 acres on cotton seed farms, and this area is sufficient, even at existing yield level, to serve a 90,000 acre segregated zone from which seed would be drawn for wider distribution.

Because wheat seed is freely available from local sources, the process of flooding an area with improved seed would be more difficult. The success would depend heavily on the attractiveness of the Government foundation seed and its controlled multiplication. In the case of the Mexican and Mexican-derived varieties, the superiority of the new seed may help achieve rapid saturation.

TABLE 6-4
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
Total	10.50	17.40	22.20	22.70

Plant Protection

The West Pakistan Government has been providing virtually free pest control to farmers through the agricultural extension services. While the provision of free plant protection service as a maximum incentive to establish the practice was a laudable intention, the actual achievements appear to have been very unsatisfactory. It is estimated that, at best, about 12 percent of the cropped area received some form of plant protection,[1] which may or may not have been effective. It is also estimated that about 15 percent of the potential yield of all cultivated crops is lost annually through pest damage. The personnel carrying out this service are generally poorly trained, treatments are usually 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 often appears to be the result of a particular landowner's influence rather than an objective assessment of the most pressing needs.

IACA considers that farmers do not pay much attention to the elimination of weeds which serve as host plants for pests. Destruction of crop residues immediately after harvesting, especially those of cotton and rice, is not practiced on a wide scale. Also, little attention has been given to the adjustment of planting dates in accordance with pest control needs, and the possibilities of pest and disease control through adequate cultural practices appears to have been largely neglected in the past.

Chemical pest control, though provided free by Government, has suffered from severe defects, including inadequate storage facilities which reduce the specific effective properties of chemicals, inadequate means for transportation and spraying, and indiscriminate use of insecticides which are potentially harmful to the beneficial fauna. It has furthermore diverted a substantial number of potential extension workers from important extension activities to plant protection with inadequate means.[2]

As farming practice improves and intensifies, plant protection would become increasingly important as a direct contribution to the improvement of yields and an essential ingredient to safeguard all other inputs. There appears to be an increasing awareness among agricultural authorities, technicians, and agriculturists that the provision of plant protection could be more efficiently organized through a transfer of these activities to the private sector. There does not seem to be very good grounds for the occasionally expressed fear that this might result in a decrease of the acreage under effective control. Plant protection as a private service industry would merge the interests of the supplier to render better service with the need of the farmer to get improved protection. While this may initially entail a continuation of some forms of subsidy, it is very likely that increasingly progressive farmers would become willing to acquire plant protection services at reasonable costs.

Both the ADC and the Department of Agriculture now aim to transfer the responsibility for plant protection to the farmer himself, while making education in pest identification and control an important part of extension. As IACA has

[1] Agricultural Department of West Pakistan, "Plant Protection: Recommendation for improving the effectiveness of plant protection research and field applications in West Pakistan." Hendivil, F. P., Lahore, October 1966.
[2] IACA's Comprehensive Report, Volume 8, Annexure 11, page 46.

pointed out,[1] there is usually a very short period during which pesticides are effective and the farmer's own interest in them is therefore critical for satisfactory control. With the exception of well-managed estates and fruit gardens, such a conversion from public services to the farmer's own control would be a slow and difficult process. Instruction, timely identification and remedial action, acceptance of the concept of paying for plant protection, and the problem of cost sharing between landlord and tenant are all serious constraints. Nevertheless, continued ineffective plant protection can greatly reduce the projected production from future investment in water development and other agricultural inputs.

In view of these observations, IACA does not foresee a growth in the use of plant protection similar to the growth in fertilizer use. It is not likely that the plant protection situation would improve much before there has been more general acceptance of the use of fertilizer and better husbandry, and therefore improvement in yields. In projecting the requirements for plant protection inputs, IACA has assumed a relatively small increase over the first decade in the acreage sprayed. Thereafter a more general use of chemical control is anticipated, and the desirable number of applications would be gradually reached. For the determination of the desirable number of applications under West Pakistan conditions, IACA has been guided by the experience of the University of Lyallpur, the Risalewala Research Institute, and by experimental results of private companies. Table 6-5 gives IACA's projection of the percentage coverage of crops by pesticides, by reference years, and a rough assessment of the situation presently prevailing.

IACA's cost estimates per acre treated are given in Table 6-6. Based on these projections of acreage covered, application per crop, and costs per acre, the aggregate costs of pesticides for reference years have been estimated by IACA to be about Rs. 65 million in 1975, Rs. 206 million in 1985, and Rs. 726 million in 2000. This does not include spraying equipment and labor. It is expected that mechanized spraying would expand *pari passu* with the expansion of mechanization described in the next section. Government help with aircraft for aerial spraying would continue to be necessary in the case of epidemic attack and the Government is already equipped with aircraft for use against locust attack. Depending

[1] IACA's Comprehensive Report, Volume 8, Annexure 11, page 46.

TABLE 6-5
IACA's Projection of Plant Protection Coverage
(percent)

	1965	1975	1985	2000
Rice Nurseries	20	45	65	90
Fine Rice	3	20	40	60
Coarse Rice	3	5	17.5	32.5
Cotton	5	20	40	60
Sugarcane	5	27.5	47.5	70
Fruit	25	25	45	65
Vegetables	10	15	35	65
Maize	3	7.5	27.5	60
Kharif fodder	—	5	17.5	20
Oilseeds	—	5	20	42.5
Wheat	—	—	10	25
Rabi fodder	—	—	—	20
Gram	—	—	—	20
Kharif pulses	—	—	10	30

TABLE 6-6
IACA's Cost Estimates of Insecticides per Acre Treated
(in Rs.)

Crop	1975	1985	2000
Rice Nurseries	27.00 (3)[a]	25.50 (3)[a]	24.00 (3)[a]
Coarse Rice	18.00 (2)	17.00 (2)	24.00 (3)
Fine Rice	18.00 (2)	25.50 (3)	24.00 (3)
Cotton	33.80 (3)	63.80 (6)	80.00 (8)
Wheat	— (–)	6.80 (1)	12.00 (2)
Maize	27.00 (2)	25.50 (2)	24.00 (2)
Oilseeds	13.50 (2)	12.80 (2)	24.00 (2)
Pulses	— (–)	9.30 (1)	17.60 (2)
Sugarcane	27.00 (2)	51.00 (4)	48.00 (4)
Fruit	16.20 (2)	30.60 (4)	43.20 (6)
Vegetables	14.40 (2)	20.40 (3)	19.20 (3)
Tobacco	9.00 (1)	17.00 (2)	24.00 (3)
Gram	— (–)	— (–)	17.60 (2)
Kharif Fodder	13.50 (1)	25.50 (2)	24.00 (2)
Rabi Fodder	— (–)	— (–)	24.00 (3)

[a] Numbers in parentheses refer to the number of applications of pesticides.

on the subsidy policy of the Government of West Pakistan, a decreasing proportion of the total costs is likely to come from the public sector. Excluding equipment, the foreign exchange component included in these cost estimates is assumed to be about 60 percent.

Mechanization and Agricultural Implements

Mechanization in West Pakistan covers a broad range of activities—from Government-operated tractor fleets for the colonization of virgin lands to the development of improved farm implements at the University of Lyallpur. Existing farm implements are adapted to local conditions, and most of them are manufactured from local materials. Improved hand tools and animal-drawn equipment are being popularized through Government subsidies. However, unlike the rapid spread of private tubewells, the improvement in tools and simple equipment appears to be progressing rather slowly.

The popularity of, and demand for, tractors and tractor-drawn equipment is expanding more rapidly, especially amongst the medium and larger size farms. There are currently about 6,000 tractors working on farms, and mechanized cultivation will become increasingly important and advantageous to farmers in the future. As cropping intensities rise, harvesting and land preparation activities tend to increasingly converge. There is a corresponding reduction in the time available for cultivation and planting, and distinct labor peaks occur at the end or, conversely, the beginning of each crop season. At higher levels of intensity mechanized cultivation is likely to become a prerequisite for dealing with such time schedules and labor peaks, while simultaneously reducing hired labor costs. To the extent that mechanized cultivation would substitute for animal power, it would also set free folder acreages for production animals or, alternatively, an expansion of cash crops. Mechanized cultivation would also enable better and more timely land preparation, thus providing for better crop performance. Since mechanized cultivation is not generally more expensive than bullock farming, IACA feels that such activity as land preparation, post-planting cultivation, harvesting, and threshing are likely to mechanize fairly rapidly, though largely limited to the farm size groups exceeding 25 acres per unit.

However, a rapid increase in mechanization is likely to be restrained by a number of socioeconomic factors. The farm size problem and its associated financial implications have already been mentioned above. Land fragmentation and the tenure and sharecropping system are likely to be other substantial barriers 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 an adequate supply of spare parts and mechanics. IACA points out that much research is still needed to select the right types of equipment, to adapt the existing equipment, and to develop equipment better suited for the local conditions.

The importance of mechanization is recognized in the Third Plan, which calls for an expansion in the distribution of improved implements at subsidized prices. Additional workshops and repair facilities for the Government-operated tractors are to be established at district levels in order to improve the efficiency of Government-operated machinery. The Plan also anticipates that the total number of tractors would increase, and the requirements of wheel tractors by private individuals would be met increasingly by local manufacturers.[1]

For projection purposes, 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 because mechanization is a progressive process. Initially, mechanization would be partial, concentrating on certain specific activities such as cultivation and land preparation. IACA has taken this into account in its approach, and has equated this with full mechanization on a reduced area. Table 6-7 shows the coverage and rate of mechanization by farm size groups, as projected by IACA for reference years. IACA has identified the components for a complete mechanization unit capable of serving an area of at least 100 cropped acres per annum.

[1] The projected assembly plant at Rawalpindi with an annual capacity of 1,500 tractor units is expected to supply a large part of local demand during the Fourth Plan period.

TABLE 6-7
IACA's Projected Rate of Mechanization

		1975		1985		2000	
Farm Size Group	Percent of Total Farm Area In Group	Percent Mechanization	Percent of Total Farm Area Mechanized	Percent Mechanization	Percent of Total Farm Area Mechanized	Percent Mechanization	Percent of Total Farm Area Mechanized
Farms above 25 acres	40	20	8	50	20	85	34
Farms 5–25 acres	50	4	2	10	5	30	15
Farms below 5 acres	10	—	—	5	0.5	10	1
Total	100		10		25		50

Such a mechanization unit would include a wheel tractor with tilling and mowing equipment, seed drill and thresher, and a trailer and miscellaneous equipment. It is estimated that such a unit would cost about Rs. 25,000. The area assumed to be mechanized in Table 6-7 would imply the use of approximately 33,000, 83,000, and 165,000 mechanization units for the respective reference years. The initial stock of spare parts and its continuous replacement over the life[1] of the equipment would amount to about 50 percent of the initial capital cost of a mechanization unit. Assuming a lifetime of nine years in 1975 and about eight years thereafter, the levels of annual expenditures for mechanization are shown in Table 6-8. The foreign exchange component of these expenditures is likely to decline as local manufacture provides an increasing portion of the mechanization package. The foreign exchange content by 1975 is estimated at about Rs. 75 million, increasing to about Rs. 200 million by 1985. This assumes that the proportion of locally assembled equipment would be about 40 percent in 1975 and 50 percent by 1985.

Although the projections of cost are based upon the acceptance of complete mechanization, there is little doubt that for some years to come mechanization is likely to be limited to tractor cultivation. It would seem reasonable to suppose that threshing would soon be recognized as a process which can be power-driven, and other operations are likely to follow. However, it is only when such operations as cane crushing and transport are mechanized that the working bullock can be increasingly replaced, thus enabling a larger number of milk and meat producing animals to be maintained on the fodder base.

The Study Group, along with the Government and IACA, recognizes the important role that mechanization must play in the progress towards more intensive and more highly commercialized agriculture and feels every encouragement should be given in the form of credit, advice on purchasing and suitability for particular conditions and purposes, instruction in operation, ensured supplies of machinery and parts, and adequate service facilities. In view of the preponderance of small farms, careful consideration should be given to the stimulation and support of contract services and cooperative use of machinery, and to the continued improvement of bullock-drawn equipment and hand tools.

[1] IACA estimates that initially the lifetime of a unit may be about nine years (10,000 working hours) but would decrease to about 7½ years by 1985 when cultivation activities become more intensive.

TABLE 6-8
ESTIMATED EXPENDITURES FOR MECHANIZATION
(at reference years)

	1975	1985	2000
Mechanization Units ('000)	33	83	165
Annual Expenditures for Mechanization Units (Rs. million)	90	260	520
Annual Expenditures for Spares (Rs. million)	40	130	260
Annual Level of Mechanization Expenditures (Rs. million)	130	390	780

Improvement of Livestock

Along with the increase in mechanized farming, IACA envisages a reduction in the proportion of draft animals in the cattle herds—a decline in numbers accentuated by a progressive increase in the work output of draft animals. The number of working draft animals (expressed in animal units) is expected to decline from 10.4 million in 1965 to 4.2 million in 2000, while the production herd is expected to increase from the current estimate of 9.6 million to 14.5 million by 2000. In view of the substantial contribution from animal husbandry, which IACA projects to increase over time, the rapid buildup of an improved cattle herd assumes special significance.

The principal change envisaged within the production herds is a change from buffalos to zebu cows as milk producers. This change is likely to be slow in coming about, and the number of buffalo cows is expected to begin to decline only after 1985. At the same time, up-graded zebus would become increasingly important. The buffalo is at present a greatly superior producer of milk, and it is only the anticipated upgrading of the present zebu cows which justifies replacement of the buffalo. To support the anticipated rapid progress in the development of quality stock, it is necessary to use the best bulls available to the fullest extent possible, and the use of carefully selected bulls on the scale required can only be done by an extensive program of artificial insemination. IACA proposes to upgrade the present zebu herds by a massive program of artificial insemination. The technique proposed is the repeated top-crossing of successive generations to selected Sahiwal or Red Sindi sires, leading to the progressive improvement of the national herd.

There is already a basic artificial insemination organization operating in West Pakistan under the Directorate of Livestock Farms. IACA projects that the number of artificial inseminations would reach five million per year by 2000, and that the organization would be self-financing. In order to sustain the livestock projections made by IACA, it would be imperative to develop the existing organization into a country-wide service. IACA's program and recommendations for artificial insemination are reproduced in Annex 9.

As discussed in Chapter II, the livestock sector is of such importance, and is so little understood, that the Study Group proposes it be the subject of a special comprehensive study to establish more accurately both its present status and the requirements for its development. This study should include a review of the IACA proposals to replace the Provincial buffalo herd by upgraded Sahiwal and Red Sindi cattle by the extensive use of artificial insemination. The study would seek to establish the practicality, and the genetic and economic desirability of the proposals, bearing in mind the large increases in milk and meat production which would certainly come about from the existing stock when feeding standards are improved and selection is applied under the more intensive systems of husbandry that should evolve. The present system of maintaining two separate classes of stock for the production of milk and working animals may well prove to be wasteful of resources. The study should investigate the effect of applying selection pressure to both buffalo and cattle herds to produce male stock capable of effective draft work from dams whose milk production will be at a sufficiently high level to maintain an economic dairy industry.

B. INSTITUTIONS AND ORGANIZATIONS

Introduction

The development and expansion of the organizational structure to stimulate and serve the rapid growth that is envisaged in the proposed program would be an extremely critical, as well as a very difficult, task. The problem has been studied in depth in recent years by the Food and Agriculture Commission (1959), the Provincial Reorganization Committee (1961), and in the so-called Revelle Report of the White House Panel (1962). In the course of this study, IACA reviewed the situation in the light of probable future needs and set out in an annexure to the Comprehensive Report[1] an analysis of the present situation, together with its views and recommendations.

This is a subject on which no finality can be reached. The Study Group does not feel able to do more than draw attention to some of the basic considerations that should be kept in mind, without being very specific as to solutions. One general observation would be that for some time to come any further major changes in the overall pattern of organization should, as far as possible, be avoided. The significant changes that have been made in the recent past, including the setting up of WAPDA, the ADC and the LWDB, require more time to prove their effectiveness. The emphasis should be on adjustment and improving coordination, rather than further radical change. Another would be that, to the extent practicable, the private sector be given maximum opportunity and encouragement to participate. The Study Group's observations on these and other points relating to the institutional framework are presented in the remaining portions of this Chapter.

Coordination of Planning and Services

Coordination of Planning. The Study Group would endorse IACA's view that effective coordination between the bodies responsible for planning (as well as implementation, including construction and operation of projects) is a prime necessity. At the present time, the responsibility appears divided amongst a number of technical agencies and departments. Also, ambiguities of jurisdictional boundaries between agencies occur, and a good deal of planning is done in isolation of the ideas and programs of other departments concerned. In addition to WAPDA and ADC, most of the line departments are concerned with planning, and the Agriculture and Irrigation Departments are particularly affected. All agencies and departments compete for shares in the available Government resources, and all have skills and experience that should make a contribution to planning. IACA reports that there have been occasions when two agencies have been engaged on plans for the same areas. Also, it seems clear that the Agricultural Department's has not had much influence on WAPDA's and the Irrigation Department's project planning for agricultural development. All too frequently there have been open differences of opinion between agencies on matters of responsibility and methods to be employed. The operational responsibilities for the preparation of sector and intersectoral plans must be assigned to particular bodies, but this should be done in a manner that ensures constant review and the incorporation of experience and views from all the interested line departments.

[1] IACA Comprehensive Report, Volume 8, Annexure 11.

At the Provincial level the logical place for coordination of these issues would appear to be the Planning and Development Department of the Government of West Pakistan, but this Department does not have enough professional staff to enable it to exercise an effective coordinating role. In the opinion of the Study Group, the situation should be carefully reviewed and arrangements made which would ensure effective coordination and afford full opportunity to the line departments and agencies concerned to make their contribution on a continuous basis.

Coordination of Services. The services offered by the line departments and agencies are all complementary, each making a contribution to the package required by the farmer. A high degree of coordination is necessary to ensure that the advice and the services provided are in keeping with policy and developmental objectives, and that supplies are available in the right quantities and at the right time. Observations on the individual services essential for the success of the program are made in succeeding sections. The concern here is with the machinery to ensure both inter- and intradepartmental coordination. Important considerations would include the establishment of the principles which govern the definition of jurisdictional boundaries, and continuous review of how policy is implemented in important matters such as procurement, deployment of scarce resources, project construction and operation, and management. Again, the Planning and Development Department would appear to be the logical body to play a key role in bringing about more effective coordination.

Policy for Water Distribution

Provincewide Allocations. As discussed in Chapter V-D, procedures for allocating water must be amended to allow for the changing conditions of the future. The canal system would be subject to major changes in operation when the alterations brought about by the Indus Waters Treaty become operationally effective. The increasing scale of new development projects would further add to the complexity of water and power supply problems. To meet this situation, IACA has recommended the setting up of an Irrigation Authority. This body would make basic policy decisions on barrage allocations, dam release patterns, and tubewell pumping policies with reference to both water and power considerations.

The Study Group believes that a Provincial Irrigation Authority is required in order to use the available water resources in the most efficient manner. Its responsibility for Provincewide water allocations, and its determination of overall policy regarding the operation of the system, would place it in an important policy-making position entrusted with decisions affecting the equitable and economical use of all West Pakistan's water resources. It should therefore be constituted at the highest level and equipped to take fully into account the whole range of administrative, legal, sociological and technical considerations to the extent that they affect policy and general principles.

Project Operation and Management. Closely related to future efforts to develop the water resources of West Pakistan is the question of which institutional mechanisms would assist farmers make the best use of new production opportunities. Earlier comments on institutional support[1] listed the range of institutions already established to promote agriculture, and cited Government's willingness to

[1] See Chapter I-D above.

introduce administrative innovations where these appeared necessary. In point of fact, there has been considerable experimentation with new administrative units, much of it in response to suggestions of non-Pakistani advisors and observers, but the end results have not always matched expectations. This has been partly due to personnel and administrative problems germane to Pakistan's present stage of development, as well as to the function and role of particular institutions which have been created. Because the organization of public projects for water resource development is critical to the program under review, the Study Group's observations on this aspect are presented in somewhat greater detail.

IACA has based its recommendations for project operation and management on certain major assumptions and policy positions: (i) surface water distribution and public tubewell operation must be under the same organizational control; (ii) the private sector should rapidly assume responsibility for supply and distribution of inputs such as fertilizers, plant protection, and improved varieties of seed; (iii) reclamation as such would not be as high a priority objective as in the past; and while it is important to unify control over sources of irrigation water, there is less need to integrate the supplying of water with agricultural extension activities and provision of material inputs.

Two organizations currently have responsibility for development activities in project areas in West Pakistan. One of these, the Agricultural Development Corporation (ADC), has jurisdiction over four barrage commands (Thal, Taunsa, Gudu, and Ghulam Mohammed), though not over the barrages themselves. Within the commands, the ADC has responsibility for water supply, for provision of agricultural inputs, and for extension activities related to implementation of project objectives. This semiautonomous agency thus fulfills all functions normally carried out by regular departments of Government, and does this in a unified, or integrated, way in the areas under its jurisdiction. Only one of the projects proposed by IACA falls within an area currently under the ADC, and IACA believes it would be logical for the ADC to assume responsibility for this project area. On the other hand, IACA does not favor ADC responsibility for any of the other proposed projects. IACA's proposed projects are smaller than complete canal commands, or cut across the boundaries of canal commands, which places the source of surface water to the project outside of the project area. ADC control over a project (other than the one noted above) would therefore result in a situation where the source of surface water could be separate from the use of all irrigation water, and control would be divided between two different agencies. This would run counter to the most important of IACA's working assumptions.

The second institution, the Land and Water Development Board (LWDB), is also a semiautonomous body and was organized specifically to promote development in the SCARP project areas. The Chief Secretary is *ex officio* Chairman of the LWDB, and the members include Secretaries of all Government departments concerned with agricultural development. The activities of the LWDB to date have been limited to the SCARP I area, where a Project Director has been placed 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 number of extension workers per unit of area is somewhat larger than in other parts of the Province, but in other respects the staffing is comparable to that provided elsewhere. The membership of the LWDB was designed to secure interdepartmental coordination at the highest levels, but meetings of the full Board are held only once every two months. The effect of this is to leave much of the coordination task to the Project Director. The LWDB participation in SCARP I has been relatively brief, and the project has run into problems unrelated to its administrative makeup (e.g., faulty screens in at least 100 public wells have required replacement). Nevertheless, IACA has concluded that the LWDB model is not well adapted to the project areas it has proposed.

Foremost among the reasons for this is IACA's assumption that unified control of surface water and groundwater supplies is essential to the successful operation of the projects. IACA therefore suggests that this responsibility be vested in the Irrigation Department. This Department already operates the canal system, and has acquired staff with experience in matters related to water supply and water use. Control and operation of water supply by a single agency would also be consistent with an overall integration of Basinwide water supply—an objective which IACA also considers of vital importance. Responsibility for agricultural extension and research would lie with the Agriculture Department, as it does now in nonproject areas. IACA also recommends that provision of fertilizers, improved seeds, and plant protection should become a private sector activity as soon as possible, with the ADC, the Plant Protection Service, and the Cooperatives necessarily continuing their present operations in these respects until the private sector has developed its capacity to meet farmers' needs.

IACA envisages a continuing role for the LWDB, but in a modified fashion. The new role would be a coordinating one at the former level (Secretaries of Departments), but without the present operational emphasis. Instead, an LWDB representative would be assigned to the project area to facilitate field coordination, working through a new administrative unit which IACA calls the Project Field Force (PFF). This representative would be an appointed chairman, at the level of Deputy Commissioner grade in the Civil Service of Pakistan (CSP), and would be preferably an administrator by training and experience rather than a technical man. The PFF would also include the ranking officers from the line departments in the project area, who would represent their departments, and a representative of the local district administration. The PFF would coordinate the activities of all departments involved in the project area, although the chairman of the PFF would have no direct authority over the officers of the departments. Problems which cannot be resolved through normal departmental channels would be referred to the LWDB for ultimate solution at the higher level. The PFF would also have responsibility for monitoring the performance of the project, and for keeping statistical records for later use in analyzing experience under the project. This summary of the IACA proposal[1] omits other lesser details, but in essence it would constitute a less integrated approach to project implementation than called for under the present ADC or LWDB arrangements, and would depend on contributions from the line departments much as they are now provided outside the ADC and SCARP I areas.

The Study Group has reviewed IACA's proposals and has been guided by two major considerations. The first of these is a belief that it may be desirable at this stage to call a moratorium on further major administrative reorganization related

[1] IACA's Report, Volume 8, Annexure 11.

to agriculture and water resource development. Frequent administrative reorganization can become counter-productive. Staff morale is affected, and if reorganization becomes a common solution to operational problems, each change gives reason to expect that further change would follow. Staff loyalty and identification with an organization must reflect this uncertainty in some degree. There is thus merit in giving any new organization time to achieve the level of performance expected of it—staying with an organizational decision until there is a clear reading on either its viability or its failure as an administrative concept. This may be the state of affairs with respect to the ADC and the LWDB, both of which have been in operation too short a time to provide an adequate test of their ultimate workability.

The second consideration relates to the need for an integrated project management. The Study Group feels strongly that in addition to efficient distribution the success of the water resource development program depends on emphasis going equally to efficient water use and to better farming practice and the use of more material inputs. Creating the environment which generates this dual emphasis would be a most demanding task, requiring a high degree of close cooperation and overall direction. Earlier sections of this report have dealt with the superior cumulative effects of proper combinations of water and other inputs, and the need to make the entire package accessible to the farmer. The Study Group agrees with IACA that it would be desirable to have the private sector assume a growing importance in the supply of agricultural inputs, but until the private system has developed the capacity to ensure timely and adequate supplies in the project areas there would have to be continuing promotion and distribution activity by authorities responsible for maintaining the development pace at projected rates. The Study Group feels that something along the lines of the ADC and LWDB concept, with a Project Director in full charge of all developmental activities and water supply, would provide this close supervision and integration which development requires, and could be consistent with growing private sector competence in meeting input supply requirements. This should not preclude minor changes designed to improve the efficiency of project direction, e.g., locating the Project Director's headquarters in the project area itself, ensuring continuity by long-term appointments to the Director's position, and making adequate budget allowances for planning and monitoring activities.

The Study Group's preference for integrated project management, in spite of the difficulties it would entail in relation to divided responsibility for surface and groundwater supplies, requires further qualification. Firstly, the line departments should continue to carry out their increasingly important functions in their respective fields, and care should be taken that the discharge of their responsibilities, especially in the nonproject areas, is not impaired by the withdrawal of key staff for project areas. Secondly, the Action Program, including the ongoing as well as the IACA projects, would bring more than 10 million acres under the direct responsibility of public tubewell project management over the next 10 years. While it is of utmost importance for the development period of each individual project that direct and undivided responsibility should rest with the project management, this responsibility should nevertheless be regarded as temporary. Once full development has been achieved, the routine operation of the project facilities should be handed over to a more permanent organization which has full farmer participation. Once the management responsible for the development of the project has withdrawn, the line departments should successively assume their responsibilities within the project areas. Some formal procedures would need to be established to determine when such transitions should take place. Consideration should furthermore be given to the possibility of establishing semiautonomous forms of management for the permanent operation of the tubewell fields. Such operations would be within the frame of natural resource exploitation policies and under the overall control of the Government, but with adequate representation of the farmers.

The monitoring function deserves special note because it has not been an integral part of the project operation thus far. The Study Group's review of the IACA Comprehensive Report has brought home forcefully the fact that planners have been handicapped by a lack of firm bench mark data. Moreover, the process by which farmers incorporate opportunities for change is not well understood, and has not been studied carefully under actual conditions of rapid technological and economic change. The watercourse studies of IACA and LIP are initial efforts in the right direction, but they have been limited in the coverage offered and the time which was devoted to the studies. The Study Group therefore strongly endorses the IACA suggestion that project management should include provision for continuous monitoring of progress, starting with the construction phase when benchmark data representing pre-project conditions could be gathered. Strong support for this type of study, and its incorporation into the institutional structure of project management, could produce data of immense value and importance to development in other countries as well as in Pakistan.

Operation of the System. A corollary to the Study Group's preference for something similar to the LWDB or ADC for project management purposes is that the Study Group does not see an overriding advantage in placing control of all project water supplies with the Irrigation Department. Granting that this Department does operate the canal system and that it has acquired experienced staff for this purpose, it does not follow that extending its jurisdiction to include project tubewells would bring more efficient water management to project areas. With Province-wide responsibilities and diverse activities (e.g., small dams, canal operation and maintenance, tubewell installation, etc.), it is unlikely that the Department would have the interest or the capacity to focus on project area problems to the required extent. Localized coordination through a body such as the PFF, where no authority rests with the PFF Chairman, may be difficult if major departmental interests are centered on departmental activities in other areas. The Study Group feels that successful projects would depend on responsible project management, wholly concerned with project problems and responsible to project needs. Within the project area, water supplies would be regulated in accordance with specific development requirements. The Study Group does not expect that the integration of surface and groundwater supplies would be a technically or administratively difficult problem within proposed project areas, once the Province-wide pattern of surface water distribution had been established.

Technical Support for Agriculture (Research, Education and Training)

Technical support for agriculture is essentially the responsibility of the Department of Agriculture. Although some of this support reaches farmers through other institutional arrangements, such as the ADC and the LWDB, the personnel involved are mostly drawn from departmental ranks. Efforts to strengthen the Department of Agriculture should therefore have beneficial results outside the Department itself. The discussion under this heading thus focuses largely, though not entirely, on the Department.

It is a truism that effective institutions require good personnel as a starting base. In this respect the Agriculture Department has operated under serious handicaps. Careers in agriculture have not carried much prestige in the past. Salaries have been low and opportunities for advancement have been limited. Working conditions have been poor—Field Assistants are expected to cover an area of 15,000 acres and the Agricultural Assistants supervising them are expected to cover 60,000 acres, but inadequate transport facilities are provided to enable them to do this effectively. Trained research personnel frequently find themselves in administrative posts, and this is, in fact, a more effective route for their personal advancement despite the waste of scarce technical training it entails. 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. The result of factors such as these is that it is extremely hard to attract some of the better students into agricultural careers. For those who are capable, opportunities in other Government services are much more promising in almost all respects. Where the basic raw material is drawn from candidates who may be below standard, training alone can go only so far in producing an improved agricultural service.

Personnel. Facilities to prepare personnel for agricultural careers currently include two agricultural colleges and one university, which turn out about 300 graduates annually at the B.Sc. and M.Sc. level. These graduates enter service at the level of Agricultural Assistant. An additional five colleges train field assistants, and have a capacity to produce 500 students at this level of training. IACA estimates there should be adequate numbers of degree graduates for Government purposes by 1976 or 1977 at the above rates of availability, but that the facilities, which are being improved with the assistance of IDA credits, could handle more than this number of students. The shortage of field assistants is considered more serious, however, and IACA recommends that the number of colleges for field assistant training be increased from five to 11. This would raise the annual turnout of field assistants from 500 to 1,100 men. The IACA estimates of manpower requirements for graduates and Field Assistants are shown in Table 6-9. If the

TABLE 6-9
IACA's Estimates of Manpower Requirements for Agricultural Services

	Graduates	Field Assistants[a]
1965	2,225[b]	3,900
1975	3,775	6,000
1985	4,800	9,300
2000	5,070	10,000

[a] Extension services only.
[b] Existing.
Source: IACA'S Comprehensive Report, Volume 8, Annexure 11.

additional colleges for field assistants come into operation between 1970 and 1975, there should be enough trained personnel to staff the Government's needs by 1980. IACA assumes that any surplus in graduates, relative to Government requirements, would be increasingly absorbed by the private sector as development brings a more commercially oriented agriculture to West Pakistan.

Although it appears possible to train the number of new personnel required to meet the IACA estimates of manpower needs in future years, the quality of the instruction to be offered is more open to question. The course length has recently been raised from one year to two years for field assistants, including six months of field work under supervision. This is a desirable direction in which to move, and there should be continuing efforts to make the training periods meaningful in the practical terms required for effective work with farmers. Proposals to increase the number of training facilities for field assistants should be studied with some care, however, for the important constraint in this type of expansion would be the quality of the faculty available to teach in the new institutions. Because of the limited attractiveness of agricultural service at present, the Study Group feels that it may be more strategic in the short run to concentrate on improving the quality of instruction than to become too preoccupied with turning out a given quantity of manpower.

A quantitative personnel deficiency in the technical support for agriculture is likely to occur in the engineering field. This would be primarily a problem for agencies other than the Department of Agriculture, but it may be mentioned here because finding a solution to it would be of obvious major relevance to future departmental activities. Current estimates are that the new graduates of engineering schools during the Third Plan period would be 3,200 fewer than required for all fields. Even allowing for the release of large numbers of engineers from the Indus Basin Project Works at the end of the Third Plan period, IACA estimates there would be an insufficient number of engineers for planning, construction, operation, and maintenance under programs falling within the jurisdiction of WAPDA and the Irrigation Department. The Irrigation Department alone would require 430 new graduates by 1970, and 1,000 new graduates by 1975. One way to meet this deficiency temporarily would be to continue the use of foreign consultants in positions of critical scarcity. 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. Foreign consultants could also be used to give specialized postgraduate training to new engineering graduates. The current difficulties arise because West Pakistan does not have a large pool of trained and experienced manpower to draw upon at a time when developmental activities are expanding very rapidly. In the long run, the supply of fully qualified engineers may become more nearly in balance with future needs as a consequence of the gradual expansion and improvement of educational facilities at all levels, but for immediate needs it appears necessary to supplement the supply with trained manpower resources available from outside Pakistan.

Research. The Department of Agriculture maintains research activities in three regions of West Pakistan. The need for a strong and well-supported research branch is self-evident in an area like West Pakistan where the technical problems of agriculture are numerous and new knowledge is essential to future development. It seems fair to say, however, that research cannot fulfill its vital role under the conditions which now prevail. Research in the agricultural sciences is beset with the difficulties noted earlier with reference to agricultural service in general. Career opportunities are more limited than in other fields, and while research personnel fare somewhat better than extension personnel in pay and allowances, IACA reports research facilities are neither adequate nor uniform in the different research centers.

An important objective of research in agriculture is to find solutions to farmers' problems, but the second stage of this is to bring the research findings to the farmers in a form which they can understand and use to advantage. This requires close and continuing cooperation between the research and extension branches of the Agriculture Department. Where there are several agencies concerned with agricultural development, as in West Pakistan, the scope for fruitful cooperation is wider than a single department. Research personnel are not only the source of information about their own research results, but they should be familiar with important research findings in countries abroad as well. Improved coordination should therefore result in increased contacts between research workers and the wide range of people connected with agricultural development. The exchange should be in both directions—the research branch would learn which problems most urgently need further investigation, and extension workers and farmers would learn what results have already been obtained by research in Pakistan and elsewhere.

Much of the research work currently undertaken is apparently of limited immediate practical application, and is sometimes more oriented toward publication in the scientific literature than toward solving day-to-day farm problems. The staffs of the research centers include some experienced and distinguished scientists, but much of the research is actually carried out by young and inexperienced research workers who need supervision to initiate and sustain meaningful experimentation. It is difficult to foresee substantial improvement in the agricultural sector without a dynamic research program to deal with such matters as continuing varietal improvement, more efficient treatment of insect infestation and plant disease, and better understanding of soil, crop, water and fertilizer relationships. Building an efficient and contributing research branch would not be a simple task, and would take more than the addition of a few more staff members or some new equipment. It would require dedicated leadership, generous financial support, patience and understanding of the uncertainties which are a necessary part of research, and the infusion of a spirit of service to the agricultural community. Without these elements, research is likely to remain mechanistic and unimaginative, isolated from its constituency, and therefore largely unproductive. Aside from pointing to the general deficiencies, the Study Group can only underscore the importance of building a strong research organization in support of West Pakistan's developmental needs, and urge that neither the role nor the requirements of research be underestimated.

Extension Services. The extension services afford the most direct point of contact between the Department of Agriculture and the farmers, but the available evidence indicates that, with some notable exceptions, this contact is generally of limited effectiveness. The reasons are, again, partly due to the general problems of recruitment, the low status of the extension staff, and the consequent poor morale of workers in the field. Added to these are the extension workers' difficulties in getting around the large areas for which they are responsible, for transport is totally inadequate for their task. 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 the plant protection activities which, according to IACA, are largely ineffective. The low status of the extension personnel, and the field assistants 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 poor 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.

These are only some of the problems confronting the extension services, but they are intended to be indicative of the present situation. The IACA Comprehensive Report[1] contains a number of suggestions on how extension activities can be improved, many of them similar to suggestions made earlier by the Food and Agricultural Commission and other groups who have studied this problem. The Study Group is not in a position to make specific proposals, but its general concern is evident in what has already been said. The agricultural and water development program being proposed for West Pakistan would require the rapid and widespread adoption of a variety of new agricultural inputs and improved farming practices. Without this, the expected rates of growth cannot be achieved. The primary vehicle for transmitting the new knowledge to farmers would be the extension services, and in their present state they simply would not be adequate for the task. The quantitative and qualitative improvement in the extension services is thus a critical link in the success of the program, and the measures adopted to bring about such improvement cannot be partial or half-hearted.

One important aspect of extension to which the Study Group wishes to draw attention is livestock management, because it touches directly on the program. The projections of agricultural production anticipate a very large expansion of the livestock component, and call for standards of animal husbandry far higher than have been generally achieved to date. This aspect of extension work would therefore assume increasing importance. Responsibility for extension activities relating to animal husbandry currently rests with the Directorate of Animal Husbandry within the Department of Agriculture. The functions of this Directorate are mainly limited to the prevention and control of disease, and farmers receive little advice on livestock management and improved feeding practices. IACA has suggested that advisory work on animal husbandry should be an integral part of agricultural extension, and that the Directorate of Animal Husbandry should be concerned solely with veterinary matters as it is, in fact, at the present time. The Study Group believes this point is well taken because livestock production would have to become increasingly coordinated with overall land use planning by farmers, and the agricultural extension personnel should be prepared to advise farmers on how to adjust to the changing production opportunities opened up by the proposed program. Plans for raising the standards of extension work in the future should therefore include provision for the training of extension officers in livestock management techniques.

[1] IACA's Comprehensive Report, Volume 8, Annexure 11, pages 60 ff.

Assistance to Private Water Development. Policy for water distribution in West Pakistan must also take into account the contribution which could be made by the private sector. This activity should be stimulated and assisted by organized institutional support. In particular, 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. This advice would have particular reference to small dams, watercourse alignment, and private tubewell installation, and should include assistance in organizing cooperative use of facilities. It may also be necessary to devise some form of licensing for private tubewells. The unexpected pace of private tubewell installation during the Second Plan period has been referred to elsewhere in this Report, and it now appears that the present rate of private development may be faster than public development (although coverage may be less complete and restricted to areas where groundwater conditions are most favorable).[1] To the extent that private resources can be marshalled for this purpose, this frees Government funds for investment in necessary projects which the private sector is unlikely to finance. It is also evident that the anticipated agricultural development would require continuing substantial private tubewell investments up to 1975, and probably beyond that date, even with the most optimistic assumptions about Government's capacity to complete irrigation improvements.

IACA agrees that it is desirable to encourage private sector investment in tubewells, even though it believes this investment would be eventually replaced by a system of public wells, and that public investment would generally be more efficient than private. IACA also states that it has allocated its public investment in a manner which would provide scope for private participation. The strategy in this respect is to encourage private investment along with public investment in a manner which maximizes the return to the combined capital invested by both sectors. This implies that public investment would not always be made where the internal rate of return is highest. If private investment would provide essentially the same service, even with some loss in efficiency, there could be a case for encouraging the private initiative. Government funds would then be diverted to other projects where private investment is unlikely to take place. Thus, the issues do not arise at a level of generality which contrasts total public and total private investment as the alternatives. The real questions concern the volume of private investment which should be encouraged, and how the private sector might react to governmental activities in the field of water development.

The selection of an area for public development is a strong deterrent to further private investment. If the area selected for public development is one where private investment might take place, but there is long delay between project identification and project completion, there could be a substantial loss of benefit from the private development which might otherwise have been in operation. The Study Group therefore feels that the public investment program should be drawn up with full realization of the consequences of either attempting more than can be readily achieved, or preempting areas which can be developed by the private sector. No

[1] IACA cites a "most favorable" forecast that a total of 8,000 public tubewells would be installed between 1965 and 1970 (equivalent to less than 32,000 cusecs capacity), as contrasted with a Planning Commission estimate that 8,000 private tubewells could be installed annually (equivalent to 8,000 cusecs) during the same period, or a total of 40,000 cusecs.

one can foresee with certainty the conditions which would attract private investment. The private tubewell installations to date have been heavily concentrated in a few areas of the Punjab, and there may be important social, economic and cultural differences between regions which account for the private sector activity, or lack of it. Nevertheless, the Study Group wishes to state its view that the initial formulation of groundwater projects should be confined to areas and situations where public investment has a clear advantage over private, and where private investment is not likely to be very significant in any event. With this in mind, the Study Group's review of specific IACA projects has examined the possibility of reducing project size, or deferring public investment in tubewells where there appeared to be reasonable prospects that private investment would be forthcoming in the absence of a public tubewell project. Since these project reviews can be only indicative, the Study Group has further recommended that when the detailed project feasibility studies are made they should include serious examination of whether, and to what extent, development might take place if all or part of the proposed project area were left largely to private initiative. In all circumstances where private development is appropriate, the Study Group would recommend strong institutional support to stimulate and assist progress.

Supply Services for Agriculture

General Framework for the Supply of Inputs. This Report has stressed the importance of providing farmers with material inputs to accompany the application of adequate water supplies following water resource development. The institutional means for this are now essentially governmental. This has been an obvious response to a situation where, historically, there has been scarcity of supplies resulting from a shortage of foreign exchange and other procurement difficulties, and the need to guard against abuses in such circumstances. Also, it must be recognized that the pressure for supplies has suddenly emerged in the wake of a vastly increased development program. Whether this reliance on Government for such services should be continued into the future is another question. IACA has suggested that the private sector be encouraged to participate in fertilizer supply, plant protection, and improved seed distribution, and has offered fairly specific observations on how this might be accomplished.[1] Experience in agriculturally developed countries supports this view, and indicates that conditions can be created in which these functions are efficiently carried out by the private sector. The Study Group substantially endorses IACA's suggestion and is strongly of the opinion that there would be advantages in having the private sector become an important element in the supply network for inputs.

Since the Government of Pakistan has taken a pragmatic approach towards private sector participation in general, it appears likely there would be little opposition in principle to a growing dependence on the private sector for agricultural input supplies. The transition from public to private supply would, however, be difficult, and would vary for different services. Increasingly the Government's role would become a supporting one. For some time to come it would have to retain overall responsibility for procurement and for the administration of subsidies, so long as the latter continue. Extension and research would continue to

[1] IACA's Comprehensive Report, Volume 8, Annexure 11.

be important Government activities, particularly with regard to varietal improvement, effective control of pests and diseases, improved fertilizer use, proper water application, and the like. It would also be necessary for the Government to maintain an effective supervisory role with respect to the quality of inputs offered to farmers, and the advice on use which private sellers give to farmers. While the transition from public to private supply may be a drawn-out process, the developmental priorities are immediate. The Study Group takes the view that maximum encouragement and opportunity should be given to private sector participation, but the timely provision of a sufficient quantity and range of inputs, at incentive prices and of assured qualities, is more important at this time than the particular institutional arrangements (public or private) by which this is accomplished. In the interest of assuring that material inputs and additional water would be available in all areas, it is probably realistic to assume that integrated supplies must depend heavily on Government initiative for some time to come.

Fertilizers. Distribution of chemical fertilizers is an activity which private enterprise could enter most readily. It did so briefly in the past (1964–65), but the Government resumed the distribution function when fertilizer shortages arose in 1965 and private dealers began selling at prices above the fixed Government retail price to farmers. There is also a good prospect that domestic manufacturers of fertilizer would sell directly to farmers through the manufacturers' own sales organizations. If the supply position improves to a point where prices can be stabilized at a price level fixed by the Government, the Study Group anticipates that fertilizers would again be sold through private channels. An important element in the Study Group's modifications of the IACA proposed agricultural and water development program is the projection of a larger use of fertilizers in the early years. The contribution of this input to agricultural production need not be delayed until the full water development program is completed, and there is therefore an immediate need to take the steps necessary to ensure the widest distribution. The Government would undoubtedly continue to provide some sales outlets through the ADC in the ADC project areas and the cooperatives in other parts of the Province. Overall supply permitting, the addition of private sales outlets to the Government's distribution activities would expand opportunities for farmers to obtain fertilizers, thereby enhancing the probability that the projected rapid rate of growth in fertilizer use would be realized.

Improved Seed. Private participation in the supply of seed of improved varieties is likely to be slower in developing than fertilizer distribution. Production of foundation stock would remain primarily a Governmental activity under the research branch of the Department of Agriculture and the seed farms of the ADC. Farmers have shown interest in obtaining new varieties, and the improved wheat varieties undergoing testing and multiplication have aroused great expectations. Past experience with the production and distribution of improved seed in West Pakistan, mainly under Government control, has not been very encouraging. While good progress has been made in the introduction and breeding of new and improved varieties, further progress is still heavily dependent upon research which is not yet entirely adequate. Also, it is contrary to experience to expect that, once available, improved varieties would spread from farmer to farmer without an intervening process of planned multiplication and improved organization to control purity. Interdepartmental rivalry has apparently been one factor discouraging the use of improved varieties, but it has also been very hard to establish effective controls against adulteration by growers and distributors. There would be many difficulties to surmount before achieving a smoothly functioning private distribution system. IACA suggests that competition between private seed suppliers and the ADC would introduce a check on adulteration, and would be particularly feasible for crops such as wheat. The Study Group agrees with this general view, but would point out that the full impact of new and improved varieties cannot be realized until supplies of uniformly high quality are widely available to farmers. Under the circumstances in West Pakistan, this situation is unlikely to occur rapidly or easily through a proliferation of independent suppliers, and it may require a large amount of Government supervision and participation for some time to come.

Farm Machinery. Although mechanization of agriculture has not progressed very rapidly thus far, it would become increasingly important as more irrigation water becomes available under the proposed program. Private enterprise could play a useful role in distributing and servicing farm equipment, but Government would 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. The required degree of mechanization would not occur if the initial experiences were unfavorable because of widespread inadequacy and inconvenience in obtaining necessary repairs. With this qualification, the Study Group agrees that private initiative should eventually replace Government in this supply activity. The rapid growth of domestic production and servicing facilities for private tubewells encourages the belief that private sector capacity would move into other areas of farm mechanization. Because individual ownership of farm machinery is not feasible at present for the majority of West Pakistan's farmers, the Study Group feels it may be useful to devote attention to ways in which private contractors can be encouraged to provide machinery services, and make the advantages of mechanization available to a larger number of farmers. Another potentially fruitful approach would be the encouragement of cooperative arrangements for sharing major pieces of equipment. An important function which Government should perform is to carry out an expanded research program to determine which kinds of equipment are most suited to West Pakistan conditions and which are the most economical for the farmers to use. Such information would enable farmers to purchase or rent farm machinery which best fits their particular needs, and could minimize the potential waste of resources which would result from the acquisition of inefficient or unsuitable types of equipment. Research should also be carried on which seeks continuing improvements in bullock-drawn equipment and simple hand tools, since these would be of immediate benefit to the many small-scale farms unable to adopt more expensive types of mechanized equipment.

Plant Protection. IACA and most other observers have agreed that the present arrangements for supplying free plant protection services are quite unsatisfactory. Providing this service imposes a large burden on the extension staff. Their numbers are small and they have limited ability to deal effectively with infestation problems. The result appears to be an absorption of much of the time of the extension personnel without significant benefits to the farmers. These circumstances have led IACA and others to conclude that adequate area coverage can come about only when the major responsibility for applying plant protection materials falls on the farmers themselves, because the departmental manpower resources are much too thin. This would also mean opportunities for private sector participation in the production, demonstration, and distribution of pesticides and the equipment used to apply them. The extension services would still be responsible for instructing farmers in control measures, and in safe methods for handling and storing plant protection materials. This would not be easily done on a large scale, in part because the extension workers themselves would have to become more knowledgeable on the complexities of effective plant protection measures. Still, the general trend toward direct farmer participation seems inevitable if the expected contribution of plant protection activities under the proposed program is to be realized. Placing the financial burden as well as the physical task of application on the farmers may create some problems of acceptance. However, if the prices of the materials are sufficiently low to provide incentives to use them, and the results obtained by farmers are visibly significant, the adoption of plant protection materials should pose no greater difficulties than would be true for the other material inputs. The Study Group feels that in a uniform ecological environment such as the Indus Plains, it may be possible to efficiently control some pests by rule-of-thumb methods evolved from experimental work designed to measure the effectiveness of different spraying programs. Such easy-to-understand spraying regimes would also possibly increase the rate of acceptance of plant protection methods by farmers where they prove successful. They would certainly ease the work of the extension staff. The Study Group therefore recommends that research effort be applied to spraying experiments, particularly on cotton. Such research would seek to ascertain the optimum stage of growth for commencement of spraying and spraying intervals, bearing in mind both adequate pest control and economy in the measures used as twin objectives.

Agricultural Credit

The Credit Need. At the beginning of 1959, the Government of Pakistan appointed a Credit Enquiry Commission to review the credit situation in Pakistan, and to make recommendations regarding measures to be taken to meet the credit requirements of a growing economy and to improve the channels of credit. The Commission, which presented its report in 1960, identified the three main problems:[1] (i) an effective credit system designed for the direct benefit of the primary producers has yet to be developed; (ii) there is a tendency for credit to gravitate towards the well-to-do elements in the community, and to be virtually denied to people who are most in need of credit; and (iii) the cooperative credit movement has become virtually stagnant at the primary level while the financing agencies above the primary societies have largely directed their fund to noncooperative purposes. Though some improvement appears to have taken place, by and large the situation reflected in these conclusions continues to exist.

Following the Credit Enquiry Commission, the Ministry of Finance established a Credit Advisory Committee, under the auspices of the State Bank of Pakistan, for consultation with, and coordination of, rural credit agencies.[2] It is expected that the work of this Committee would be continued and enlarged dur-

[1] Credit Enquiry Commission Report, Government of Pakistan, Karachi, 1960, page 183.
[2] The Third Five Year Plan (1965–70), Government of Pakistan, May 1965, page 439.

ing the Third Plan period. The Government sources through which credit is obtained by farmers are the Agricultural Development Bank and, to a lesser extent, the Cooperative Societies. In special circumstances loans have also been made available by the Revenue Department and the ADC. The small farmer—notably the sharecropper rather than the owner-farmer—still relies to a very great extent on private sources for credit, principally relatives, zamindars, merchants and shopkeepers. Rates of interest on such loans may be several times higher than the 5 to 9 percent per annum paid on loans obtained from official sources. Although an increase in the funds made available to credit organizations by Government is certainly needed, the procedures through which a farmer must go to obtain credit, especially short-term credit, are often both complex and slow. The result is that the farmers continue to be very dependent upon private sources.

In addition to the credit needs for working capital and for medium- and long-term investments in agriculture, there is an insistent demand for personal credit to meet social obligations. This latter demand has added substantially to the indebtedness of the farming community, but the institutional credit sources do not generally provide for this. Previous studies indicate that more than 50 percent of the indebtedness of farmers in West Pakistan has resulted from borrowings for family expenditures and social obligations not related to agricultural production.[1]

Several factors contribute to the chronic problem of agricultural indebtedness. Firstly, the size of the typical agricultural enterprise is very small, and often the cultivators are not the owners of the land. Secondly, the ordinary farmer has insufficient collateral to satisfy institutional credit requirements. In the absence of adequate warehousing facilities or assurances that the crops would be marketed through the credit agencies, the security of crops remains highly dubious in many cases. Land alienation legislation, introduced in conjunction with land reform and designed to prevent the transfer of agricultural land in foreclosure proceedings, may even make it difficult for the smaller owner to borrow from institutional sources because he cannot pledge his land as collateral. Thirdly, many farmers work holdings too small to maintain their families from the produce of the land itself at present yield levels, and they therefore remain in perpetual need of funds while at the same time they do not control dependable means of repayment.

These three conditions result in the perpetuation of noninstitutional sources of credit such as money-lenders, relatives and shopkeepers. In the absence of an institutional credit system to satisfy the described credit needs, the noninstitutional credit arrangements do fill a vital gap without which the public welfare functions would have to be greatly increased. However, this service is performed in many cases at exorbitant costs to the borrowers either through excessive interest rates or through manipulation of the prices of goods provided or commodities purchased.

While the Study Group is not in a position to suggest any ready solution to the chronic problem of agricultural credit, it should be realized that this problem consists basically of two distinctly different kinds of needs. There is the definite need to provide more funds for productive purposes on both a current and long-term basis, and there is the social need to provide transfers of purchasing power to the less advantaged. Since institutional credit is not usually available for the latter case, the borrowers achieve some credit standing with noninstitutional lenders by

[1] Credit Enquiry Commission Report, page 12.

repaying through a process of disinvestment. This adds to the growing rural poverty, which is already rapidly spreading as the high rate of growth of the rural population proceeds apace. This, however, is a problem of the economy at large, and neither the agricultural credit system nor the agricultural sector as such can, or should, be expected to carry such social welfare functions. It must be pointed out, furthermore, that this system has definite adverse side effects for agricultural development inasmuch as it tends to make productive credits from noninstitutional sources scarce and expensive, and may thus significantly impair the prospects of the small operators who, at reasonable credit costs, might otherwise be able to participate in the development of the agricultural sector.

IACA estimates that Government credit sources presently provide only about 5 to 10 percent of the working capital requirements.[1] The Credit Enquiry Commission estimated that the productive credit requirements, on the basis of the technology prevailing in the late fifties, must have been about Rs. 500 million for short-term seasonal credits only. The Commission also received representation that the credit requirements of the agricultural sector would at minimum be about 25 percent of total output or, on the basis of the value added for 1959/60, about Rs. 2 billion equivalent. This seems somewhat high for being representative of productive credit needs, and a rate of 15 percent of total output, roughly equivalent to 50 percent of the annual on-farm expenditures, may be more indicative of the true credit requirements. Even on this base, however, the credit requirements for 1965 and 1975, respectively, would be Rs. 1.3 billion and Rs. 2.2 billion. While these figures can only be indicative of general magnitudes, it would be unrealistic to expect that the Government could provide funds sufficient to support institutionalized credit on the scale required. The noninstitutional source of credit would thus have to continue to fill a vital gap in supporting agricultural development.

However, as IACA rightly points out,[1] insufficient attempts have so far been made to mobilize the rural savings potential. There are indications that substantial transfers from agriculture to urban activities take place annually. Furthermore, the rapid growth of private tubewell installations, with little Government support and little participation by institutional sources of credit, again suggests the availability of remunerative agricultural investments on a substantial scale. The Government should therefore explore the possibilities for mobilizing private savings and channelling them into the institutional credit system including the prospects for establishing depositories and actively campaigning to change the attitude of the rural community towards institutionalized savings.

The Agricultural Credit Institutions. The participation of the commercial banking system in the field of agricultural credit is largely confined to lending to other large farmers who can offer satisfactory collateral. The bulk of the institutional credit (excluding commercial bank sources) is provided by credit channels of the Government or by agencies receiving direct Government support. The Government's declared policy continues to be that the cooperative system remain the main institutional channel for the provision of short and medium-term credit, while the Agricultural Development Bank (ADB) should be primarily concerned with the provision of long-term credit. In addition, the Revenue Department under the

[1] IACA's Comprehensive Report, Volume 1, page 197.

West Pakistan Agriculturists' Loan Act of 1958 can provide advances (so-called *taccavi* loans) to farmers in distress resulting from natural calamities, as well as for private water development, preparation of land for irrigation, private drainage, reclamation and flood protection works.

The cooperative credit movement at the primary level has suffered from relative stagnation in the post-Partition period. This resulted partially from massive withdrawal of members and deposits in the course of Partition, and the exodus of experienced staff from the cooperative societies to other more profitable opportunities. Though the cooperative credit societies shifted in the wake of Partition towards multipurpose activities, the generally poor management of the societies led farmers to work increasingly through private marketing channels, where they could procure credit exceeding the low credit limits set for the cooperative system.[1] While there is some indication that the share capital of cooperative societies in West Pakistan has increased substantially, this apparent improvement must be regarded with caution because a portion of loans is sometimes withheld as share-money when these are granted to new members. Towards the end of the Second Plan period the credit outstanding was reported to be over Rs. 600 million, of which about one-quarter was apparently overdue.[2] The aforementioned Credit Advisory Committee is expected to further advise specifically on the operation and improvement of rural cooperatives, and especially to explore ways and means to implement supervised rural credit in conjunction with coordinated farm commodity storage programs tied to the provision of credit.[3]

The ADB was established in 1961 by merging the Agricultural Development Finance Corporation and the Agricultural Bank of Pakistan (ABP). The ADB has an authorized capital of Rs. 200 million, of which only Rs. 100 million has been paid up. This limited capital base has forced ADB to operate to a large extent on borrowings[4] and overdrafts from the State Bank; this factor, together with the large staff requirements for the administration of numerous small loans, has depressed the ADB's profitability. Nevertheless, since its establishment the ADB has almost tripled its lending volume in West Pakistan, from Rs. 33 million in 1960 to Rs. 95 million in 1965, while maintaining a rate of recovery of more than 75 percent.[5] This impressive progress in lending commitments may be difficult to maintain unless new capital resources are made available to the ADB in due course. An increase in the Government's share capital of Rs. 75 million has been provided for in the Third Plan period, but no action has been taken on this so far. Though mainly restricted to medium- and long-term credit, and oriented towards the creditworthy farmer, the performance so far achieved by the ADB in West Pakistan is indeed encouraging and worthy of continued and increased support.

State credits for agriculture (taccavi loans) in West Pakistan are made available at a level of nearly Rs. 15 million per annum, though with apparently rather unsatisfactory rates of recovery. The Credit Enquiry Commission pointed out in its

[1] The ceilings were raised in 1961 and "service" cooperatives, now being organized at Union Council levels, can provide credit in kind without specific limits.
[2] Andrus, J. R. and Mohammed, A. F., Trade Finance and Development in Pakistan, Stanford University Press, 1966.
[3] The Third Five Year Plan (1965–70), Government of Pakistan, May 1965, page 440.
[4] Including an IDA Credit of $ 27 million for mechanization and private tubewell development.
[5] This includes arrears inherited from the predecessor institutions.

report that there is no recourse but the Revenue Department for the provision of credit to new settlers and in cases of distress. However, there appears to be some overlap in the credit functions of the ADB and the taccavi system in the provision of funds for productive investment requirements. Consequently, the Third Plan stipulates that long-term taccavi loans should no longer be provided by the West Pakistan Government except in areas where no other institutional credit services exist, or where the special needs of settlement and land reform programs justify the provision of such loans. The Third Plan recommends further that a revolving fund for taccavi loans should be established on the provincial level which should eventually become self-sustaining, given the Plan allocation and the recoveries of outstanding loans. It is appropriately stressed that this would require a clear separation between any welfare functions still included in the taccavi system and the specialized credits for production purposes.

This summary description of the prevailing agricultural credit situation only serves to underline the complexities West Pakistan faces in developing an agricultural credit system which would efficiently support the anticipated transformation of the agricultural sector. The Study Group has no ready solution to offer, and can only stress the fact that any growing monetization in the rural areas would require a change in attitude toward credit by the majority of farmers. Only when farmers learn to look upon credit as a form of productive input which needs to be recovered by the lender, and makes the distinction between credit in its productive sense and relief grants, will it become possible to provide a larger volume of institutional credit on a commercial basis. Institutional credit arrangements alone may not provide a solution for agricultural credit problems, but there must be a serious effort to organize an effective rural credit system, as has been begun with the Credit Enquiry Commission. Even partial implementation of the Commission's recommendations requires the development of management expertise, and would therefore take time. To a large extent it would also depend on the increase in savings within the rural economy. In the meantime, the noninstitutional sources of credit are likely to remain a most important source of finance to the farmers.

VII

Financial Requirements of the Development Program

A. WATER DEVELOPMENT INVESTMENTS

Public Expenditures

The original Third Plan (1965–70)[1] included an allocation of public expenditures for water development in West Pakistan of Rs. 2,662 million. This allocation did not allow for the IBP Works, nor did it make any provision for the construction of Tarbela. Of the total provision of Rs. 2,662 million, about 52 percent, or Rs. 1,390, was allocated to the development of groundwater through public tubewells. A further 30 percent, or Rs. 793 million, was allocated to the further improvement and extension of surface irrigation, including small schemes outside of the Indus Basin and some multipurpose schemes. The remaining Rs. 479 million, or about 18 percent, were distributed over such items as drainage, flood protection and investigations. This allocation of funds is indicative of the continued emphasis that the Government is prepared to give to the development of groundwater resources.

The water development program IACA has proposed as a result of its studies and the revised IACA Program (see Chapter IV) could both be contained within the above amounts, but this would require some redistribution of funds within the total allocation (Table 7-1). IACA's proposals for the Third Plan period would result in a reduction in the public tubewell allocation of about 23 percent or some Rs. 324 million. The expenditures for surface drainage—mainly a start on the Indus Left Bank Outfall Drain and the Sukh Beas Scheme—would be increased by nearly 87 percent, or about Rs. 168 million. In addition, tile drainage pilot projects would require another Rs. 39 million. However, the total allocations for water development under the IACA proposals—excluding Tarbela—would be Rs. 2,365 million, or Rs. 297 million less (equivalent to 11 percent) than the allocations contained in the original Third Plan. This reduction in the allocation for water development is principally a reflection of IACA's assessment of what further physical works could reasonably be completed in the remaining four years. In

[1] Government of Pakistan Third Five Year Plan, May 1965. In December 1966 the Government of Pakistan revised the phasing of plan expenditures and the sectoral allocations. The original plan allocation for water development was reduced by Rs. 482 million or about 18 percent. The most drastic reduction was applied in the drainage reclamation and tubewell portion which takes partly into account the shortfall against physical implementation targets. Government of Pakistan Planning Commission, Revised Phasing, Sectoral Priorities and Allocation of the Third Five Year Plan, December 1966.

particular, it results from a deferment of some public tubewell construction until a later period.

Since the completion of the IACA studies, it has become even more obvious that the ongoing public tubewell program is falling behind schedule, and this is reflected in the revised public tubewell implementation program shown in Chapter IV. Based on IACA's estimates for ongoing tubewell projects, and including the Study Group's higher contingency allowance for new projects (see Chapter IV), the reduction of the public tubewell allocation contained in the original Third Plan period would be about Rs. 345 million under the revised program. Allowing for the costs of raising Chasma Barrage (Rs. 105 million before duties and taxes, the cost of the barrage itself being included in IBP works) the expenditures for surface irrigation would increase to Rs. 705 million, as compared to the Government allocation of Rs. 793 million. Overall, the proposed Action Program set forth in Chapter IV and the ongoing Government activities (other than IBP works and the construction of Tarbela) would require total allocations of Rs. 2,441 million during the Third Plan period, as compared to the Rs. 2,662 million allocated in the original Third Plan. This would be equivalent to a reduction of about 8 percent in the water development program. As stated above, however, the most recent revised allocation under the Third Five Year Plan calls for a reduction of 18 percent, leaving a total allocation of Rs. 2,180 million for water development activities in the Third Plan period. This would be a shortfall of Rs. 261 million against the requirement of the Action Program.

The financial requirements for Tarbela (including power facilities) during the Third Plan period have been estimated at about Rs. 1,414 million before duties and taxes and interest during construction. This would raise the total requirements for the Action Program during the Third Plan period to Rs. 3,855 million, or increase the original Government allocation by about 45 percent. The required allocations for the Third Plan period are compared in Table 7-1.

No Government estimates for the Fourth Plan water development expenditures were available for incorporation in this report. The IACA proposal would call for total allocations, excluding Tarbela, of about Rs. 2,602 million. This estimate, however, has been revised by the Study Group in the light of the revised public tubewells program (Chapter IV) and the addition of further flood protection estimates. In addition, as stated in Chapter IV, the Study Group has raised IACA's cost estimates for public tubewell installation by about 20 percent. The combined effects are compared in Table 7-2 against the IACA proposal. Five tubewell schemes, included in the Action Program and scheduled to start during the Fourth Plan period, as well as some Tarbela expenditures would continue into the Fifth Plan period (1975–80), and there would therefore be a carry-over commitment of about Rs. 130 million from the Action Program to be met in the first year of the Fifth Plan period. Excluding the Rs. 130 million, the total public financial requirements for the period of the Action Program are compared in Table 7-3.

In the absence of detailed cost estimates for all the works included in the above estimates, and because of increasing import substitution effects (especially in the case of tubewell equipment), only an indicative assessment of the foreign exchange component could be made. Assuming that tubewell projects would require about 40 percent foreign exchange, surface irrigation about 60 percent, and drainage and flood protection works about 15 percent, the foreign exchange requirements

TABLE 7-1
COMPARISON OF PUBLIC INVESTMENT REQUIREMENTS FOR WATER DEVELOPMENT DURING THE THIRD PLAN PERIOD

	Third Plan	IACA Proposal	Revised[a] Program
		(Rs. million)	
Public Tubewells	1,389	1,065[b]	1,044
Surface Irrigation	793	600	705
Surface Drainage	195	363	363
Tile Drainage	—	39	39
Flood Protection	73	74	74
Investigations	187	199	191
Miscellaneous	25	25	25
Subtotal	2,662	2,365	2,441
Tarbela	1,414	1,414	1,414[c]
Total	4,076	3,779	3,855

[a] The reconciliation of the IACA proposal with the proposed Action Program would consist of: (i) inclusion of raising of Chasma Barrage (Rs. 105 million), (ii) reduction of investigations included in tubewell allocation (Rs. 8 million), and (iii) rephasing of tubewell program deferring tubewell investments of about Rs. 21 million. There would thus be a net increase of about Rs. 76 million. For details see Chapters IV and V.

[b] Exclusive of electrical transmission and distribution.

[c] Investment requirements including power facilities as phased in investment schedule of Action Program.

for the period 1965/66 to 1974/75 would amount to about Rs. 4,150 million or about $874 million equivalent. To this should be added a sum of about Rs. 200-250 million ($42-$53 million equivalent) for investigations. Total foreign exchange requirements would thus be about $927 million equivalent, exclusive of the overrun of the Action Program into the Fifth Plan period of approximately Rs. 75 million or $16 million equivalent.

Private Expenditures

Private investment for water development activities would be concentrated on private tubewells and, to some extent, on farm drainage works associated with the Sukh Beas Scheme. IACA's projections of future private tubewell installations are considerably lower than those made by the Government and provided for in the Third Five Year Plan. The Study Group, anticipating some encouragement for private tubewell development in the Third and also the Fourth Plan period,[1] has taken a somewhat more optimistic view of the rate of growth of future private well installations. However, for the purpose of projecting private investment, the revised IACA estimates set forth in Chapter IV have been used, though with an allowance for some cost increases in private well construction. The higher rate of installation shown in these revised projections takes into account the deferment of some public tubewell projects, especially in the Bari Doab as described in Chapter IV.

[1] In the Third Five Year Plan, a provision is made for support of some 15,000 private tubewells by the Department of Agriculture.

TABLE 7-2
PUBLIC INVESTMENT REQUIREMENTS FOR WATER DEVELOPMENT IN THE FOURTH PLAN PERIOD

	IACA Proposal	Revised Program
	(Rs. million)	
Public Tubewells	1,310[a]	1,339[a]
Surface Irrigation	352	352
Surface Drainage	516	516
Tile Drainage	184	184
Flood Protection	—	75
Investigations	240	240
Miscellaneous	—	30
Subtotal	2,602	2,736
Tarbela	2,789	2,789
Total	5,391	5,525

[a] Exclusive of electrical transmission and distribution.

Allowing for investments in well replacement and also including on-farm costs for drainage works to be carried out by farmers in conjunction with the Sukh Beas Scheme, the estimates of private investments are compared in Table 7-4. Especially the estimates for the Fourth Plan period should be regarded as tentative and subject to upward revision. Any shortfall in the public tubewell program, or any decision to defer public developments because of active ongoing private investments in tubewells or lack of public funds, would tend to raise the estimate for the Fourth Plan period. Furthermore, the rate of private installation in the noncommanded areas, both within and outside the Indus Basin, is largely unpredictable and may be substantially above that projected in Chapter IV.

TABLE 7-3
PUBLIC FINANCIAL REQUIREMENTS FOR THE PERIOD 1965/66 TO 1974/75

	IACA Proposal		Revised Program		Variations
	Rs. million	%	Rs. million	%	Rs. million
Public Tubewells	2,375	26	2,383	26	(+) 8
Surface Irrigation	5,155	56	5,260	55	(+) 105
Surface Drainage	879	10	879	9	—
Tile Drainage	223	2	223	2	—
Flood Protection	74	1	149	2	(+) 75
Investigations	439	5	431	5	(−) 8
Miscellaneous	25	—	55	1	(+) 30
Total	9,170	100	9,380	100	(+) 210

TABLE 7-4
ESTIMATED PRIVATE INVESTMENTS IN WATER DEVELOPMENT DURING THE THIRD AND FOURTH PLAN PERIOD
(Rs. million)

	Government	IACA's Proposal			Revised Program		
	Third Plan	Third Plan	Fourth Plan	Total	Third Plan	Fourth Plan	Total
Private Tubewells	300	352	236	588[a]	428	321	749[a]
Drainage	—	—	—	—	—	13	13
Total	300	352	236	588	428	334	762

[a] Including replacement investments.

B. AGRICULTURAL DEVELOPMENT EXPENDITURES

Public Sector Program

The allocation of public funds for agricultural development in the original Third Five Year Plan amounted to a total of Rs. 1,999.4 million. An additional provision of Rs. 554.2 million in the Central Government's development allocations for agriculture in West Pakistan increased total allocations to Rs. 2,554 million.[1] This represented a more than threefold increase over the Second Five Year Plan allocation. The aggregate provision did not include allocations for other sectors supporting agriculture, such as industry, transportation, power, and agricultural education.[2] Most of the allocations for agriculture would be for recurrent expenditures of Government services, and to support measures designed to encourage agricultural development.

The largest single item in the original allocations was for fertilizer subsidies (Rs. 678 million). The three items of fertilizer subsidy, plant protection provided as a free service to farmers, and seed multiplication and distribution accounted for Rs. 1,026 million, or 40 percent of the total allocation, which indicates the emphasis the Government is prepared to place on these three strategical inputs. Another Rs. 500 million, or about 20 percent, was allocated for extension, research, mechanization and soil conservation. The remaining Rs. 746 million covered such activities as animal husbandry and range management, colonization, forestry and fisheries, and such institutional factors as cooperatives and the ADB.

In the course of the recent revision of the phasing, sectoral priorities and allocations of the Third Five Year Plan,[3] the plan allocations for West Pakistan's Agriculture (before provision from the Central Government[4]) were reduced to Rs. 1,622 million. As discussed in Chapter VI, most of these reductions were applied

[1] Government of Pakistan, The Third Five Year Plan (1965–70), May 1965, page 460.
[2] The original Third Five Year Plan included an allowance for manpower development in agriculture of Rs. 67.2 million.
[3] Government of Pakistan, Planning Commission, Revised Phasing, Sectoral Priorities and Allocations of the Third Five Year Plan (1965–70), December 1966, especially page 17.
[4] Allocated for use by the Central Government in the field of agriculture were Rs. 372 million for both Provinces. No separate allocation of these funds to West Pakistan was available to the Study Group.

to expenditures on fertilizer subsidies, plant protection, mechanization and extension services. In the Study Group's assessment, the fertilizer subsidies have been reduced (in keeping with the lower rate of subsidization) from an original level of Rs. 678 million to Rs. 500 million (see next paragraph). The Government's revised allocation would make available no more than about Rs. 400 million. The Study Group believes this large a reduction is not in accord with the ambitious offtake targets for fertilizers projected for the remainder of the Third Plan period. Similarly, the Study Group feels that allocations for the extension services are of sufficiently high priority to be maintained at the original level. The Study Group has no means to assess the relative merits of the selective cuts made under other headings, but would recommend that any reductions of allocations to agriculture (beyond those prompted by revised phasing) be carefully reconsidered in the light of their impact on the use of nonwater inputs, and consequently production.

As stated in Chapter VI, the Study Group would attach high priority to the accelerated introduction of nonwater inputs, especially fertilizer and seeds, but increasingly also to plant protection and mechanization. On the basis of the most recent experience with fertilizer procurement and distribution, the Study Group has increased the IACA projections of fertilizer consumption for the Third Plan period (Table 6-2). Assuming a continuing subsidy rate of about 30 percent, and employing the higher offtake projection of the Study Group, the subsidy requirement would amount to approximately Rs. 500 million. The Study Group also feels that all costs associated with the provision of plant protection services free of charge to farmers should be regarded as development expenditures, and thus charged in full.

No Government estimates of public development expenditures for agriculture are available for the Fourth Plan period. IACA has placed a global assessment of requirements at Rs. 3,700 million, including fertilizer subsidies of Rs. 155 million, plant protection costs of Rs. 100 million, and extension and research expenditures of Rs. 260 million.[1] While it may be possible to reduce the rates of subsidization as assumed by IACA, the allocation for these three items would appear to be on the low side. The size of the fertilizer subsidy is again due to a rather low fertilizer offtake projection for the Fourth Plan period, as well as reduction in the subsidy rate.

While the Study Group has no basis for making a detailed estimate of public development expenditures for agriculture during the Fourth Plan period, its more optimistic expectations would tend to call for increased allocations for fertilizer subsidies and plant protection. Assuming that a further reduction in the rate of fertilizer subsidization (e.g., from the present 30 percent to about 20 percent) would become feasible as a result of reduced procurement costs, and that there would be no substantial increase in the cost of fertilizers to farmers, the total subsidy requirements for the Fourth Five Year Plan period would still amount to some Rs. 700 million based on the Study Group's offtake projections. Although the Study Group would expect increasing participation by private enterprise in the provision of plant protection services, this would be a slow process and not likely to relieve public sector expenditures to the full extent during the period 1970 to 1975. As stated before, plant protection in West Pakistan is presently

[1] IACA's Comprehensive Report, Volume 1, page 161.

very inadequate, even though allocations have been considerably increased. In the future, substantially higher levels of production per unit of land would need to be protected, and IACA has estimated[1] that on-farm expenditures for plant protection in the irrigated area of the Basin would average about Rs. 10 per acre by 1975. This would be roughly equivalent to Rs. 300 million in the year 1975. Assuming a gradual increase in the level of outlays for plant protection from about Rs. 100 million in 1970 to about Rs. 300 million in 1975, total plant protection expenditures for the Fourth Plan period would amount to about Rs. 1.0 billion. Allowing for private participation to the extent of about 50 percent, the required public allocation would still amount to Rs. 500 million, or around Rs. 100 million per annum.

The Study Group's tentative estimate of total public development expenditures for agriculture during the Fourth Plan period would thus exceed the IACA estimate by about Rs. 950 million, equivalent to an increase of about 25 percent over the IACA figures. The various estimates of required public sector allocations for the Third and Fourth Plan periods are given in Table 7-5. For the period of the Action Program (1965/66 to 1974/75), total expected public development expenditures for agriculture would thus range from about Rs. 6.0 billion to Rs. 7.0 billion. This compares to Rs. 9.5 billion for water development alone (see Table 7-3).

[1] Ibid., Volume 7, Annexure 9, page 134.

TABLE 7-5
COMPARATIVE ESTIMATE OF PUBLIC DEVELOPMENT EXPENDITURES FOR THE THIRD AND FOURTH PLAN PERIODS

	Government	IACA Estimate		Study Group's Provisional Estimates	
	Third Plan[a]	Third Plan	Fourth Plan	Third Plan	Fourth Plan
		(Rs. million)			
Fertilizer Subsidies	678 (395)	340	155	500	700
Plant Protection Subsidies	300 (184)	88	100	300	500
Extension and Research	182 (49)	180	260	180	260
Mechanization	214 (123)	214	2,835[c] (Mechanization through Others)	214	2,835[c] (Mechanization through Others)
Soil Conservation	105 (95)	105		105	
Animal Husbandry	112 (90)	112		112	
Colonization	117 (94)	117		117	
Forestry and Fisheries	304 (171)	304		304	
Others	364 (363)	364		364	
Subtotal	2,376	1,824	3,350	2,196	4,295
Capital Liability[b]	178 (58)	178	350[d]	178	350[d]
Total	2,554	2,002	3,700	2,374	4,645

[a] Revised allocation (see text) net of those from Central Government shown in brackets.
[b] On Government account: Cooperatives, ADB, and taccavi loans, revised figure for cooperatives only.
[c] IACA's global estimate, based on original Third Plan.
[d] IACA's estimate.

The foreign exchange requirements of the above outlined public expenditure program would vary considerably, depending on the degree of local manufacture involved. IACA estimates total foreign exchange requirements of about Rs. 378 million, equivalent to about 20 percent, for the Third Plan period. No estimate is available for the Fourth Plan period. However, foreign exchange requirements for fertilizer and mechanization should not increase substantially because of increasing local production capacity of these items. Chemicals for plant protection would, however, continue to be imported. In the absence of any assessment of foreign exchange requirements for the Fourth Plan period, the Study Group assumes these expenditures to continue at about the present level of about Rs. 400 million. The foreign exchange requirement for public development expenditures in agriculture under the Action Program would thus be about $164 million equivalent.

Private Sector Expenditures

The Third Plan[1] envisages total private investments in the agricultural sector, net of those for private tubewells, of about Rs. 1.9 billion. This would include such items as private development of lands, private improvements of irrigation facilities other than private tubewells, additions to farm buildings and implements, and increases in the livestock herd. This estimate is, however, a very general figure, based on some rural surveys in 1963/64 to which an average annual increase of about 5 percent has been added. No attempt has been made to detail the estimate, or to allocate it to specific production activities. It is, however, meant to exclude recurrent production expenditures for such items as fertilizer, seeds, etc.

While IACA has not been able to substantiate the above estimate, it has retained it in view of the recent rapid growth of private investment in agriculture. IACA further assumed that, along with the increase in public investments, the private sector investments in agriculture would also double in the Fourth Plan period, amounting to about Rs. 3.8 billion for the five-year period. Total private investments in agriculture for the period 1965 to 1975 would thus amount to about Rs. 5.7 billion.

The above estimates would require average annual levels of private investment of about Rs. 380 million during the Third Plan period, and Rs. 780 million during the Fourth Plan period. Assuming that 90 percent of this investment would occur in the irrigated areas of the Indus Basin, it would represent investments of about Rs. 11 per acre and Rs. 23 per acre respectively. On average, this would be considerably less than 10 percent of the gross production value per acre, and would thus appear to be within the realm of possibility. Conceivably, the rate of growth of private investments would be significantly influenced by such factors as rural electrification, the development and availability of improved implements, and credit availability. A wide margin of error would therefore be inherent in the above estimate. In the absence of any better evidence, the Study Group has adopted the assessment outlined above. This may need to be revised in the light

[1] Government of Pakistan, Third Five Year Plan (1965–70), May 1965, page 103.

of efforts by the Central Statistical Office to provide firmer estimates of private investment activities in agriculture.

It would be desirable to stimulate the rate of private investment in the interest of local resource mobilization. Important in this respect would be the increased availability of capital goods, which may partially depend upon a more liberal import policy, repair and service facilities, and credit. In the long term it should be possible to achieve a rate of private investment in agriculture of around 10 percent of gross value added. For the year 1975, this would be equivalent to approximately Rs. 1.3 billion per annum.

C. TOTAL FINANCIAL REQUIREMENTS

The estimates of financial requirements for both public and private investments during the decade 1965–75 should be regarded as preliminary, and would need further verification by the findings of more detailed investigation and surveys. The amounts shown in Table 7-6 would, however, be indicative of the magnitude of finance required for the implementation of the Action Program together with other ongoing activities in the field of agricultural and water development. This table indicates the need to increase the financial allocations for the revised program in the Fourth Plan period by about 67 percent above requirements of Third Plan, but with increasing emphasis on agricultural development expenditures in both the public and the private sectors.

TABLE 7-6
FINANCIAL REQUIREMENTS FOR THE DEVELOPMENT OF IRRIGATION AND AGRICULTURE DURING THE THIRD AND FOURTH PLAN PERIODS

	IACA's Estimates			Revised Program		
	Third Plan	Fourth Plan	Total	Third Plan	Fourth Plan	Total
			(Rs. million)			
Public Sector:						
Water Development	3,779	5,391	9,170	3,855	5,525	9,380
Agricultural Development	2,002	3,700	5,702	2,374	4,645	7,019
Subtotal	5,781	9,091	14,872	6,229	10,170	16,399
Private Sector:						
Water Development	352	236	588	428	321	749
Agricultural Development	1,900	3,800	5,700	1,900	3,800	5,700
Subtotal	2,252	4,036	6,288	2,328	4,121	6,449
Total:						
Water Development	4,131	5,627	9,758	4,283	5,846	10,129
Agricultural Development	3,902	7,500	11,402	4,274	8,445	12,719
Total	8,033	13,127	21,160	8,557	14,291	22,848

On the basis of the revised program, total water development investments are expected to increase by about 38 percent, with nearly 95 percent coming from the public sector. Total agricultural development expenditures would increase by about 98 percent, with 55 percent contributed from public sources. Thus, even in the Fourth Plan period, the public sector would still have to provide the financial support for irrigation and agricultural development to an extent of more than 70 percent of the total. Such a distribution of the financial burden of agricultural development would appear necessary where the prevailing rural per capita income is low. It also indicates a lack of incentives for investment in agriculture which is probably compounded by the limited access to institutional credit facilities. No reliable estimates of the savings transfers from the rural to the urban sector are available, but a recent tentative estimate[1] indicates that such transfers may be as high as Rs. 3.6 billion per annum for both Provinces. This would indicate that at least Rs. 1.0 billion per annum would find more attractive uses in West Pakistan either in consumption or nonagricultural investment. To the extent that agriculture is likely to continue to be the main contributor to GNP, it would be highly desirable to redirect this flow of funds and eventually reach a position where the private sector would make a substantially larger contribution to capital formation in agriculture.

The above outlined physical program for water development leaves little room for accelerated private investments—the public projects would have exploited most of the attractive opportunities during the decade 1965 to 1975. Only the further deferment of public tubewell projects could lead to increased direct private investments in this sphere. Such a possibility should be kept in mind if available public financial resources for water development should fall short of requirements during the Third and Fourth Plan periods. While considerable opportunities for private investment in agriculture proper appear to exist, their realization would in turn depend on the relative profitability of such investments. It would therefore be imperative that the Government, through appropriate economic policy, would provide an economic environment within which private savings would find an attractive use in agriculture. Basic to this would be price policies and measures to ensure a fair distribution of income within the sector.

As pointed out earlier, the estimates of foreign exchange requirements can only be indicative. On the assumptions made in Parts A and B above, and allowing for IACA's estimate of foreign exchange requirements in the private sector, the total foreign exchange requirements of the revised program would be about as given in Table 7-7. The development program for irrigation and agriculture as outlined in this report would thus require, on average, foreign exchange availability of about $100 million equivalent per annum during the Third Plan period, and about $165 million equivalent per annum during the Fourth Plan period. It should be stressed, however, that this assessment would need to be reviewed from time to time as more detailed information becomes available and as specific decisions on the program content would be taken.

[1] Griffin, K. B., Financing Development Plans in Pakistan, the Pakistan Development Review, Volume V, No. 4, Karachi, 1965.

TABLE 7-7

INDICATIVE ASSESSMENT OF TOTAL FOREIGN EXCHANGE REQUIREMENTS FOR IRRIGATION AND AGRICULTURAL DEVELOPMENT DURING THE THIRD AND FOURTH PLAN PERIODS

	Third Plan Period	Fourth Plan Period	Total
	(Rs. million)		
Public Sector:			
Water Development	1,700	2,450	4,150
Agricultural Development	380	400	780
Subtotal	2,080	2,850	4,930
Private Sector:			
Water Development	70	50	120
Agricultural Development	270	1,000	1,270
Subtotal	340	1,050	1,390
Total:			
Water Development	1,770	2,500	4,270
Agricultural Development	650	1,400	2,050
Total	2,420	3,900	6,320
$ million equivalent @ 4.75:	509	821	1,330

VIII

Comparison of Supply and Demand

A. GROWTH OF PRODUCTION

Having previously examined the IACA proposals from several points of view, this Chapter deals with the growth of production that would be expected to take place if the recommended programs were carried out as scheduled, and the quantities of nonwater inputs were utilized as projected. This means focussing here on the aggregate result to be expected from the contributions of the various proposals embodied in the program. Any projection of this kind is an extremely difficult undertaking, dealing as it does 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. It should therefore be clear that projections with respect to such an area can only be indicative at best, and must necessarily reflect the judgment of those who have prepared them.

To arrive at estimates of the levels of production at the reference years, IACA has analyzed the prospects in each of the canal commands in considerable detail. Starting from an estimated level of production based on an average of the later years of the Second Plan period (approximately the 1965 level), IACA applied its respective yield projections for each year to the estimated cropped acreage in each canal command. These yield projections, as explained in Chapter II, are based on the assumption of full delta irrigation and the application of other inputs. The levels of input use would increase in accordance with the IACA assumptions described in Chapter VI. In applying these yield projections (incorporating full delta and increasing inputs), IACA has adjusted the resulting production on the basis of its judgment with respect to the constraints likely to be operative at any given time. For areas in the canal commands where underwatering would continue in the early years (until more water would become available under the program), IACA has estimated production by first reducing the actual cropped acreage to the equivalent acreage which could be cropped at full delta. IACA then applied its full delta yields to this reduced acreage to estimate production, and this quantity of production was assumed to have come from the larger actual acreage. The resulting implied yields are thus lower than full delta yields, and the difference reflects IACA's approximation of the effects of underwatering on yields. As explained in Chapter II, to make some allowance for the additional production associated with underwatering, IACA added about 10 percent to the production of minor crops. Intensity growth in each canal command was also projected as described in Chapter II. The first increment of additional irrigation water was assumed to fill the gap between the degree of underwatering prevailing and full delta. Further increments of water were assumed to bring about increases in intensity at full delta at rates conditioned by the salinity status, the estimated farming constraints, and the cropping pattern prescribed for the particular agricultural zone. The additional cropped acres resulting from increased intensity were assumed to have a yield growth as set forth in IACA's yield projections, but modified in each canal command by the degree of salinity assumed to prevail at any particular time.

The result of this detailed compilation by canal commands is a set of estimates for the total acreage cropped and total crop production at the reference years. As shown in Table 8-1, the cropped acreage would rise by 42 percent, from 39.12 million acres in 1965 to 55.61 million acres in 2000. The production of major crops is proportionately greater, however, because yields per acre would also be rising. The significance of these production estimates can best be seen in connection with estimates of demand, and this comparison is further discussed in Part B of

TABLE 8-1

IACA's Projections of Cropped Acreage and Production in West Pakistan, 1965–2000[a]

	Cropped Acres				Production			
	1965	1975	1985	2000	1965	1975	1985	2000
	(million acres)				('000 metric tons)			
Kharif:								
Coarse Rice[b]	2.84	2.74	2.17	2.47	1,381	1,651	2,422	4,141
Fine Rice[b]	0.68	0.89	1.08	1.29	442	709	1,311	2,070
Cotton[c]	3.71	4.50	5.72	8.07	1,097	1,634	3,553	6,618
Maize	2.16	2.33	2.71	2.89	838	1,197	2,072	3,155
Fodder	2.93	3.77	4.46	5.56	21,880	35,194	62,356	102,175
Pulses	0.49	0.72	1.06	1.24	92	171	360	636
Groundnuts	—	0.04	0.17	0.56	—	26	174	706
Others	0.16	0.02	—	—	41	16	—	—
Tobacco[d]	0.03	0.03	0.03	0.04	13	16	26	32
Jowar/Bajra	3.01	2.33	2.20	2.31	680	672	738	939
Oilseeds	0.02	0.00	0.01	—	6	1	9	—
Rabi:								
Wheat	12.71	15.21	15.42	14.60	4,659	7,408	11,212	12,870
Fodder	3.26	3.92	4.30	4.79	47,501	67,561	100,630	136,444
Oilseeds	1.78	1.92	1.87	1.87	360	464	651	869
Gram	2.93	2.92	1.94	2.89	711	857	1,055	1,275
Maize	—	0.21	0.67	0.85	—	120	629	1,171
Pulses	0.73	0.62	0.59	0.61	133	129	141	165
Others	0.06	0.01	—	—	18	9	—	—
Green Manure	—	0.33	1.64	2.59	—	—	—	—
Perennials:								
Sugarcane[e]	1.21	1.21	1.31	1.51	1,495	1,840	3,085	4,755
Fruit	0.30	0.41	0.69	0.92	814	1,162	3,199	5,680
Vegetables	0.11	0.22	0.42	0.55	510	1,158	3,005	4,937
Total:	39.12	44.35	48.46	55.61				

[a] For the implied average yields, see Chapter II, Figure 2.3. [b] Unhusked rice. [c] Seed cotton. [d] Cured leaf tobacco. [e] Gur.

this Chapter. IACA's projection of cropping patterns anticipates some shift would take place in the acreage devoted to different crops. For example, fine rice is projected to become relatively more important than coarse rice, and the acreage in jowar/bajra, gram, and rabi pulses would decline. The acreage in oilseeds would become only slightly larger than in 1965. Wheat acreage would rise at first, but would be declining by 2000. In all these examples, production would rise despite smaller, or nearly constant, acreages. Substantial acreage increases (in addition to the fine rice mentioned above) would come 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.

Comparison of the percentage change in acreage and in physical production of important crops and livestock products is another indicator of the relative emphasis given in the IACA projections to the growth of different kinds of agricultural output. Among crops, cotton is shown as having 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, is projected to have the smallest percentage increase of physical production among the major crops. Its overall rate of growth is, in fact, only slightly greater than the projected rate of population growth. The largest increase of all would come in meat production, which is expected to increase sevenfold by 2000. Supporting this is the growth of fodder acreage and fodder production, which together with increased crop residues and grazing would provide the TDN necessary to maintain the production animals required for this level of meat production. Indices for acreage and production for the major crops and livestock products, based on IACA's projections, are shown in Table 8-2, in descending order of production growth.

TABLE 8-2
CHANGE IN ACREAGE AND INCREASE IN PHYSICAL PRODUCTION OVER 1965 PRODUCTION LEVELS—IACA PROJECTIONS

	1965		1975		1985		2000		Annual Growth Rate 1965–2000	
Crops	Acreage	Production	Acreage	Production	Acreage	Production	Acreage	Production	Acreage	Production
					(percent)					
Cotton	100	100	121	149	154	324	217	603	2.2	5.3
Fine Rice	100	100	131	160	159	297	190	468	1.8	4.5
Fodder (kharif)	100	100	129	161	152	285	190	467	1.8	4.5
Sugar (gur)	100	100	100	123	108	206	125	318	0.6	3.4
Coarse Rice	100	100	96	120	76	175	87	300	(−) 0.4	3.2
Fodder (rabi)	100	100	120	142	132	212	147	287	1.2	3.1
Wheat	100	100	120	159	121	241	115	276	0.4	2.9
Livestock:										
Meat	—	100	—	212	—	351	—	702	—	5.7
Milk	—	100	—	149	—	234	—	381	—	3.9

Source: IACA's Comprehensive Report, Volume 7.

TABLE 8-3
IACA PROJECTIONS OF AGRICULTURAL OUTPUT VALUE
Gross Production Value

	1965		1975		1985		2000	
	Rs. bill.	% of Total	Rs. bill.	% of Total	Rs. bill.	% of Total	Rs. bill.	% of Total
GPV Crops	5.38	61.8	7.59	56.8	13.44	58.1	20.57	52.7
GPV Livestock	3.32	38.2	5.77	43.2	9.70	41.9	18.47	47.3
Total GPV	8.70	100.0	13.36	100.0	23.14	100.0	39.04	100.0

Growth Rate Per Annum
(percent)

	1965–1975	1975–1985	1985–2000	1965–2000
GPV Crops	3.5	5.9	2.9	3.9
GPV Livestock	5.7	5.3	4.4	5.0
Total GPV	4.4	5.7	3.6	4.4

Source: IACA's Comprehensive Report, Volume 1, page 203.

Converting these estimates of production into value terms, IACA has projected the GPV from crops and livestock for the period 1965–2000. The prices used were IACA's estimates of 1964/65 farm-gate prices, and were kept constant except for rice and meat.[1] The GPV from livestock has been calculated by assuming certain yields of milk, meat, and animal by-products from production animals. The size of the production herds was placed at levels biologically consistent with estimates of available TDN, which include fodder production, crop residues, and an allowance for grazing. Further, the quantities of TDN consumed per Animal Unit were increased over time because it has been assumed that animal husbandry practice would be gradually improving, and the estimated conversion rates were made increasingly more favorable. The projections of GPV, resulting from IACA's input data described earlier in this Chapter, are given in Table 8-3. By the year 2000, cotton would make the greatest contribution to GPV of any crop. Wheat, which ranks highest in 1965 in terms of GPV, would drop to second place. It should be noted that IACA expects livestock to make an increasing contribution to total GPV, reaching nearly 50 percent of the total by the end of the projection period.

In order to relate the projected growth of agricultural production to the proposed water development program, the Study Group requested IACA to divide the aggregated canal command production data into areas affected by different types and phasing of development activities. Some error is inevitably introduced in a reallocation of production among areas in this manner, but it provides another view of the projected growth pattern. A distinction between four areas of activities was made:

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.

[1] IACA has assumed decreasing prices for rice because of shifts in consumption patterns, and increasing prices for meat reflecting improvement in quality.

IACA Project areas—CCA within the Indus Basin covered by the groundwater projects recommended in the IACA Comprehensive Report.

Deferred Project areas—CCA within the Indus Basin not scheduled for public groundwater development projects before 1975, but within which portions would benefit from private tubewell installations.

Outside areas—noncommanded areas. This includes noncommanded land outside the Indus Basin, as well as noncommanded land interspersed with the CCA within the canal system. Some portions of this category are scheduled for public development and some would benefit from private tubewell development.

Table 8-4 shows the resulting allocation of GPV as projected by IACA.

The annual rates of growth in cropped acreage and in GPV per cropped acre, inherent in the total GPV projections shown in Table 8-4, are as indicated in Table 8-5, again disaggregated into the four areas of activities.

The figure given in the foregoing tables reflect the concentration of public tubewell projects in the Basin, and the rapid growth in production expected by IACA in the early years (1965–85) after their completion. Opportunities for such rapid growth are assumed to be largely exploited by 1985, and in subsequent years additions to agricultural output would be more difficult to obtain. The Outside areas are projected to have low rates of growth in cropped acreage, but yield growth (as measured by the growth rate in GPV per cropped acre) is expected to be better than in the commanded areas. This is because the starting base is lower for the Outside areas and also because the yield-improving benefits from increased use of material inputs and better husbandry practice should become widespread throughout West Pakistan during the period covered by the projections, but it is mainly due to the dominating contribution of livestock production attributed to the Outside areas (see Annex 10).

The IACA Project areas have higher growth rates than either the Ongoing Project areas or the Deferred Project areas in these projections. The highest rates occur in the period 1965–75 when the projects are being completed and additional water supplies are assumed to result in increased cropped acreage and increased yields. Because these growth rates are calculated between reference years, they mask IACA's assumption of very rapid and spontaneous yield growth in conjunction with increased water availability. The projected growth of GPV declines only

TABLE 8-4
IACA's Projections of Agricultural GPV, by Development Activities

	Value (Rs. billion)				Growth Rate per Annum (percent)			
	1965	1975	1985	2000	1965–1975	1975–1985	1985–2000	1965–2000
Ongoing Project Areas	1.17	2.10	3.65	5.31	6.0	5.7	2.5	4.5
IACA Project Areas	1.20	2.40	4.35	6.40	7.3	6.2	2.6	4.9
Deferred Project Areas	4.40	6.09	10.95	20.18	3.3	6.1	4.2	4.5
Outside Areas	1.93	2.77	4.19	7.15	3.7	4.3	3.7	3.8
Total West Pakistan	8.70	13.36	23.14	39.04	4.4	5.7	3.6	4.4

Source: Prepared by IACA at Study Group's request.

TABLE 8-5
IACA's Annual Growth Rates in Cropped Acreage and GPV per Cropped Acre, 1965–2000
(percent per annum)

	1965–1975		1975–1985		1985–2000		1965–2000	
	Cropped Acres	GPV/ Acre	Cropped Acres	GPV/ Acre	Cropped Acres	GPV/ Acre	Cropped Acres	GPV/ Acre
Ongoing Project areas	3.1	2.9	1.7	4.0	—	2.5	1.4	3.0
IACA Project areas	2.8	4.3	2.0	4.0	—	2.6	1.4	3.5
Deferred Project areas	0.8	2.5	1.1	4.8	1.6	2.5	1.2	3.2
Outside areas	0.5	3.2	0.6	3.6	0.4	3.3	0.4	3.4
Total West Pakistan	1.3	3.1	1.2	4.5	0.8	2.7	1.1	3.3

Source: Prepared by IACA at Study Group's request.

slightly during the next decade, but after 1985 further increases in GPV are expected to come only from increases in yield.

The two major export crops of cotton and fine rice are projected to have the greatest percentage increase in physical production by the year 2000. IACA has made estimates of foreign exchange earnings from cotton and rice up to 1975, and these assume increases of 43 and 85 percent respectively in the volume of exports. IACA states that the foreign exchange earnings from these crops, plus the earnings from hides, skins, and wool, would be three times greater than the foreign exchange requirements for the IACA development program in the Third Plan period. Agricultural exports would also provide more than the amount of foreign exchange required for the IACA program during the Fourth Plan period (ending in 1974/75), but with a somewhat smaller margin of surplus over these requirements than is the case for the Third Plan period projections. These projections are summarized in Table 8-6. In value terms, export production would thus grow at a rate of about 3.5 percent per annum.

The Study Group has made a separate, and much cruder, estimate of future production incorporating some modifications of the IACA assumptions. These modifications result in a higher growth rate in the period 1965–75 and involve points which have been discussed in previous chapters, and also Annex 10. They may be summarized as follows:

1. An important part of the Study Group's review of IACA's Report has been a detailed examination of the 12 public tubewell projects which IACA has proposed. In the course of this review, the Study Group has made changes in the projected rates of growth in yields and cropped acreage, and these changes result in a more balanced growth path during the preproject and immediate postproject periods. These revised production estimates for reference years for the IACA Project areas have been incorporated in the Study Group's estimates of total agricultural production.

2. Because IACA revised its original estimates of livestock production to account for increased availability of TDN, the Study Group estimates for the IACA Project areas have been adjusted upward accordingly for the purpose of this analysis.[1] The Study Group, however, retains reservations about the rapid rate of

[1] In the project reviews cited above, estimates of livestock production have not been revised upward.

TABLE 8-6
IACA'S ESTIMATES OF FOREIGN EXCHANGE EARNINGS

	1965		1975	
	Quantity ('000 M. tons)	Value (Rs. mill.)	Quantity ('000 M. tons)	Value (Rs. mill.)
Fine Rice	100	140	185	185
Coarse Rice	40			
Cotton (raw equivalent)	175	570	250	820
Total		710		1,005

Source: IACA's Comprehensive Report, Volume 1, page 207.

increase in livestock production projected, particularly in the early periods. For this reason, the Study Group has recommended that a thorough study be made of the special problems and requirements related to improving livestock production. In the meantime, livestock projections used in this Report should be regarded as containing a wide margin of error.

3. The Study Group has assumed that the growth rates which are expected in the IACA Project areas would be equally feasible to attain in the Ongoing Project areas. Since the Ongoing Project areas are at a more advanced stage of planning and implementation, the Study Group's estimates of expected yields in the IACA Project areas have been applied in the Ongoing Project areas five years earlier.

4. The Study Group has assumed that the use of fertilizers by farmers in 1970 and 1975 would be about double the amount assumed by IACA, although the two projections become similar from 1985 onwards. The full explanation for this assumption is given in Chapter VI above, but briefly, it rests on the expectation that fertilizer use would increase rapidly between 1965 and 1975 if it is available in adequate quantity.

5. The Study Group has used a higher CCA acreage for 1965 than IACA has used for the Ongoing Project areas (SCARP I to IV plus Khairpur). These estimates, totalling 5.53 million acres CCA, are still less than the 5.67 million acres reported by WAPDA, but larger than the 4.86 million acres used in the IACA projections.

6. The Study Group, reflecting prevailing farming practice, has incorporated a modest extension of cropped acreage at earlier points in time because it assumes a higher cropping intensity at a lower level of water application. This would be underwatering by IACA's full delta standards, but would result in more cropped acres and also in higher production per unit of water, as discussed in Chapter II. The Study Group has also assumed some relaxation of IACA's rigid cropping calendar in order to facilitate water distribution and enable the achievement of higher cropping intensities.

7. The Study Group has assumed higher rates of yield growth independent of increased water availability because it projects a greater use of material inputs. This assumption has its main impact in the early years, before much of the increased water availability occurs, and in areas not scheduled for water development. The converse is true for the period immediately after additional water becomes available, for the Study Group then expects a more gradual yield growth than IACA.

8. Estimates of private tubewell installation, 1965–75, used by the Study Group are slightly higher than those used by IACA. The result is a somewhat larger cropped acreage and production, particularly in the Deferred Project areas.

Including the foregoing changes in assumptions, the Study Group's estimates of GPV and a comparison with IACA's estimates are given in Table 8-7. These projections represent what the Study Group believes to be a more likely growth path of agricultural production resulting from the developmental efforts. In supplying an alternative set of production estimates, the Study Group does not wish to imply that these are necessarily more reliable or accurate than those of IACA. However, they reflect the Study Group's best judgment on what growth of agricultural production would occur if the developmental efforts postulated in this Report were implemented as scheduled. The Study Group has projected the GPV per acre cropped as an indicator of general agricultural development, and has not attempted to make revised projections for individual crops.

The above aggregate estimates would be equivalent to the levels of GPV per cropped acre shown in Table 8-8 for the different areas of activity. It will be noted that the Deferred Project areas as a whole, including the portions covered by private tubewells, have a higher GPV per cropped acre than the IACA Project Areas in the early periods. This would be consistent with current conditions in West Pakistan, for the Watercourse Studies[1] indicated that the average GPV per cropped acre in 1965 was Rs. 409 in private tubewell areas. The figure of Rs. 236 per cropped acre used by the Study Group therefore seems well within the range for an area which includes the bulk of probable future private tubewell development.

In brief, the changes made by the Study Group have resulted in an overall rate of growth of 5.2 percent in GPV during the period 1965–75, against a rate of 4.4 percent projected by IACA. Although the growth rate for the entire period 1965–2000 is rather similar for both projections, the total GPV is higher under Study Group assumptions. This is mainly because of the assumed higher growth in the Deferred Project areas. The Study Group believes that increasing awareness of the availability of fresh groundwater supplies, plus supporting efforts by the Government to stimulate private investment, would carry forward the vigorous private tubewell investment which is already underway. The Study Group also feels there are short-term incentives to farmers to use less water per cropped acre than called for under IACA's full delta level, and that the cropped acreage resulting from both

[1] IACA's Comprehensive Report, Vol. 10, p. 393.

TABLE 8–7
COMPARISON OF IACA'S AND STUDY GROUP PROJECTIONS OF GPV
(Rs. billion)

	IACA			Study Group		
	Crop	Livestock	Total	Crop	Livestock	Total
1965	5.38	3.32	8.70	5.37	3.33	8.70
1975	7.59	5.77	13.36	8.80	5.61	14.41
1985	13.44	9.70	23.14	14.11	9.79	23.90
2000	20.57	18.47	39.04	21.40	19.37	40.77

TABLE 8-8
STUDY GROUP'S ESTIMATES OF GPV PER CROPPED ACRE

	1965	1975	1985	2000
	(Rs. per cropped acre)			
Ongoing Project Areas	261	375	551	760
IACA Project Areas	227	299	469	760
Deferred Project Areas	236	330	469	760
Outside Areas	156	215	305	494

private and public tubewell activity would be higher in the early periods of projection than assumed in the IACA projections. This should not lead to declining yields per acre because complementary efforts to expand the use of other inputs, particularly fertilizers, should be at least sufficient to maintain yield growth at about the present rate. Thus, the Study Group is somewhat more optimistic than IACA with regard to future private tubewell development, the acreage covered, and the future of fertilizer offtake by farmers in West Pakistan. This would obviously call for the utmost continuing effort on the part of all those concerned with agricultural development in West Pakistan, and would require firm decisions on policy, acquisition of the means to implement policies and continuity in policy execution. Provided these efforts are forthcoming, the Study Group feels its projections are consistent with the response to incentives already shown by West Pakistan farmers, and with the technical agricultural possibilities in West Pakistan. Nevertheless, such growth would require a substantial improvement over the performance of the Second Plan period described in Chapter I. It should also be stressed again that this more optimistic assessment by the Study Group is mainly the result of the assumption that much higher levels of nonwater inputs could, and should, be used in conjunction with the water availabilities projected over time. The Study Group thus places considerably more reliance than IACA on the response to inputs and the initiative and skills of the farmers—factors which should operate not only under existing conditions, but with increasing force as more irrigation supplies become available. The attainment of the above growth projections would require, however, that the Government continues to give high priority to agricultural development and supports it by appropriate policies.

Under the Study Group's projections, per capita GPV would rise from Rs. 228 in 1965 to Rs. 327 in 1975, and would reach Rs. 698 by the year 2000. This latter figure would be about three times the 1965 level. A comparison between these projections and the IACA projections of per capita GPV is given in Table 8-9. It should be noted that these per capita GPV projections relate to the total rural population, and not only to the portion directly engaged in agriculture. The effect

TABLE 8-9
COMPARISON OF RURAL PER CAPITA GPV PROJECTIONS

	1965	1975	1985	2000
IACA GPV Projection (Rs. billion)	8.70	13.36	23.14	39.04
Per Capita GPV (Rs.)	228.00	303.00	459.00	668.00
Bank Group GPV Projection (Rs. billion)	8.70	14.41	23.90	40.77
Per Capita GPV (Rs.)	228.00	327.00	474.00	698.00
Rural Population (millions)	38.1	44.1	50.4	58.4

of the Study Group revisions in the early period, 1965–75, is again visible. The difference between the two per capita projections diminishes by 1985, and by the year 2000 the difference is only slightly greater than it is for 1975. The earlier difference is because the IACA growth rates for 1975–85 reflect the IACA assumption that significantly higher growth rates would not occur in the Deferred Project areas until after 1975.

The GPV projections given earlier have been translated into Gross Value Added (GVA) for the agricultural sector in Table 8-10. The assumptions and procedures employed by the Study Group are explained in Annex 10.

The general pattern of growth in terms of GVA is similar to that in the GPV comparison. The growth rates implicit in the Study Group's projections are higher than IACA's in the first decade, 1965–75, and are lower during the second decade, 1975–85. The Study Group estimates result in higher absolute values of GVA in all reference years for two main reasons: (i) the basic production estimates are higher because of the assumptions described earlier above; and (ii) an upward adjustment in the GVA has been made to correspond with the official prices used in national accounts (which average about 5 percent higher than IACA's prices), and to make allowance for nonreporting areas in West Pakistan.

The projections of GVA permit some comparison with official Government figures for 1964/65, and with growth rates based on Government data for the period prior to 1964/65. The following summarize the main points relating to the Study Group's revision of IACA's projections:

1. The Study Group's adjustments of IACA data have resulted in a smoother growth path in GVA over the entire 35-year period 1965–2000. This embodies the firm belief, repeatedly expressed in this Report, that the rate of progress in agricultural development in West Pakistan is not entirely determined by the completion of extensive public irrigation projects, but is rather a function of a judicious combination of additional water supplies and other inputs, together with agricultural policies which provide incentives to use them. Not only does this appear more realistic in the light of general experience, but it accords with the pressures for increased agricultural production likely to be present in Pakistan during the foreseeable future.

2. Under its more optimistic assumptions, the Study Group estimates that growth in GVA between 1965 and 1975 would be 4.5 percent per annum, compared to 3.8 percent for the agricultural sector over the Second Plan period. This would, in fact, be a performance rarely matched by countries at a similar stage of develop-

TABLE 8-10

COMPARISON OF IACA'S AND STUDY GROUP'S PROJECTIONS OF GROSS VALUE ADDED BY AGRICULTURAL SECTOR, EXCLUDING FORESTRY AND FISHERY

	Gross Value Added			Annual Average Growth Rate	
Year	IACA	Study Group	Period	IACA	Study Group
	(Rs. billion)			(percent per annum)	
1965	7.90	8.46	1965–75	3.5	4.5
1975	11.21	13.17	1975–85	5.4	4.9
1985	18.94	21.31	1985–2000	3.4	3.5
2000	31.34	35.44	1965–2000	4.0	4.2

ment. Nevertheless, by 1975 per capita GVA for the rural population would still be only about Rs. 300.

3. Having noted this, it is also necessary to point out that many agriculturists would benefit substantially. The progressive farmers with medium-scale farms or larger should find their production opportunities greatly enhanced, and would be the leading contributors to West Pakistan's increasing agricultural output. It therefore seems reasonable to expect that the execution of the developmental programs would lead to the emergence of a growing number of progressive farmers producing for the market.

4. Farmers with small holdings would be less able to make the investments necessary to take full advantage of the production opportunities afforded by the program. Further, even with larger returns per cropped acre, the small-sized holdings of a large proportion of farmers would continue to limit total net incomes to a relatively low level. The long-run solution to this type of rural poverty would appear to lie outside agriculture under West Pakistan conditions. It would require deliberate efforts to create greater opportunity for employment outside agriculture, and to reduce the rates of population increase among rural families. If the landowners and tenants with the smallest holdings are to get only small additions to their holdings, or if land reform measures only perpetuate a pattern of very small holdings through further land distribution to those now without land, the rate at which people would feel it necessary to leave the agricultural sector might be slowed down somewhat. However, it cannot and, in the long run, should not forestall the necessity for a large population movement out of agriculture and into other occupations.

5. Although the projections show lower rates of growth after 1985, this should not be interpreted as an implication that continuation of high rates of growth is in any sense impossible. It does mean that foreseeable growth after 1985, with techniques and inputs now known, would depend largely on improvements in yields, and these may be increasingly difficult to obtain once the levels projected for 1985 have been reached. On the other hand, this period lies far in the future; much can change during the intervening years and advances in agricultural technology could open vast opportunities for increased production which, at this point in time, are not contemplated.

6. For the more immediate future, however, it should be clear that meeting West Pakistan's agricultural requirements from its own soil would be an extremely demanding task. Differences in the rates of growth under various projections, or in the bases on which these projections rest, are of less consequence than the major import of the message which runs strongly throughout this Report. This message is that achieving and maintaining any acceptable rate of growth in agriculture would entail a much more vigorous, sustained, coordinated, and comprehensive effort on the part of all connected with agriculture than has ever been exercised in West Pakistan before. The Study Group has been impressed with the priority accorded, and the steps being taken by the Pakistani Authorities to support agricultural development. The continuation and strengthening of these policies are of the utmost importance.

B. SUPPLY AND DEMAND FOR AGRICULTURAL PRODUCTS

The proposed program of agricultural and water development has been drawn up with its focus on agricultural production. This choice was deliberate because it was the Study Group's intention that the program as a whole should be properly related to farming conditions and based on cropping patterns, cropping intensities and yield projections which were agriculturally feasible and compatible with the projections of irrigation water availability. The program has thus been oriented towards providing a technically sound and broadly flexible capability for increasing agricultural production, and was not designed to meet production targets fixed in terms of specific crops or groups of crops. Nevertheless, estimates of future effective demand for agricultural production, including both domestic demand and the demand for Pakistan's exports, were made to provide the base for an external check on the relative consistency and adequacy of the production projections outlined in Part A of this Chapter. A comparison of the somewhat separately devised supply and demand estimates is presented in this part of the Chapter. Because of a continuing situation of production deficit, demand targets as such were not a major influence in the formulation of the production program. The demand estimates are necessarily very rough approximations of what domestic and foreign purchasers would require in future years.

The reference points for this comparison of future demand and supply are the estimates of current production, trade, and apparent consumption of agricultural products which IACA has made for West Pakistan.[1] These magnitudes, designed to give some idea of the "normal" levels for 1964/65, are summarized in Table 8-11.

By converting these estimates to a per capita basis, and deducting losses for seed and waste, IACA has concluded that the current (1964/65) nutritional intake in West Pakistan averages 1,973 calories and 58.7 grams of protein per day. This diet is comparable to the low levels of calorie supply and protein found in Far Eastern countries generally, but it seems to contain a relatively high consumption

[1] IACA's Comprehensive Report, Volume 2, Annexure 2.

TABLE 8-11
IACA'S ESTIMATES OF PRODUCTION, TRADE AND APPARENT CONSUMPTION OF AGRICULTURAL PRODUCTS IN 1964/65 IN WEST PAKISTAN
('000 metric tons gross weight)

	Production	Import	Export	Feed	Human Consumption
Wheat	4,950	1,100			6,050
Other Grains	1,425			535	890
Rice (clean)	1,250		290[a]		960
Sugarcane	16,800			3,360	13,440
Gram and Pulses	995			150	845
Potatoes	135				135
Vegetables	1,050				1,050
Fruit	750				750
Milk	6,007				6,007
Meat (carcass weight)	395				395
Eggs	14				14
Fish	95				95
Oils and Fats	175				175
Cotton (lint equivalent)	400	10[b]	185[b]		225[c]

[a] Including 150,000 tons inter-Province deliveries.
[b] Including lint equivalent of yarn and textiles.
[c] In contradistinction to other products: for the whole of Pakistan.
Source: IACA's Comprehensive Report, Volume 1, page 39.

of sugar (as a source of calories) and milk (as a source of protein and fat). Consumption of foodgrains provides about 60 percent of the daily per capita calorie intake. Average per capita fruit and vegetable consumption is very low.

The determinants used to estimate future demand for agricultural products have been limited to two factors: population growth and per capita GPP, the latter being adjusted for a rising average savings rate. The possible effects on demand due to changing price relationships between the various agricultural products, between agricultural and nonagricultural products, and possible changes in income distribution, have not been taken into account. For the purposes of this analysis, IACA has assumed that the present price relationships would continue essentially unchanged. There is some allowance for increasing urbanization over time, because the demand elasticity coefficients used by IACA have been based on FAO international comparisons which allowed for some "normal" degree of urbanization to accompany economic development. However, expected urbanization rates in West Pakistan were not specifically provided for in the IACA demand coefficients.

The population estimates used by IACA fall slightly below the "high" population growth projections made by the Planning Commission for 1985, which assume that family planning programs would not begin to bring about significant change in the rate of population increase before 1985. On the other hand, after 1975 the IACA estimates are higher than the Planning Commission's "low" estimates. All three sets of estimates are shown in Table 8-12. It is evident from the table that the "low" population estimate, which is the one officially adopted by the Planning Commission, would result in more favorable per capita production and consumption projections after 1985 than the IACA estimates. The Study Group feels, however, that IACA's conservative approach to the population question may be the more realistic. In any event, in projecting the more adverse alternative they tend to draw attention to the consequences of failure to achieve the family planning program objectives implicit in the official Planning Commission estimates.

In order to indicate a range of possible effective demand, IACA has applied expenditure elasticity coefficients to two different growth paths of per capita GPP. The "high" path for GPP is based on growth rates anticipated in Pakistan's Perspective Plan. The "low" path is derived from the growth in agricultural production as projected by IACA and IACA's assumed growth rates for the remaining sectors of the West Pakistan economy. In this exercise, the proportionate contributions of agriculture and all other sectors are the same as in the Perspective Plan for the period 1965–85, but for years beyond 1985 (which extend past the

TABLE 8-12
POPULATION PROJECTIONS FOR WEST PAKISTAN
(in million persons)

Year	Planning Commission "Low" Estimate	IACA[a]	Planning Commission "High" Estimate
1965	51.2	51.2	51.2
1975	66.0	66.0	67.0
1985	84.0	87.0	88.0
2000[b]	112.0	124.0	126.0

[a] IACA's Comprehensive Report Volume 1, page 41.
[b] IACA's estimates based on extrapolation of Planning Commission estimates for 1985; IACA's Comprehensive Report, Volume 2-A, Chapter I.

Perspective Plan) IACA has assumed a declining relative importance for agriculture.[1] Savings rates in future years were assumed to be the same for both growth paths, so the relationship of per capita Gross Provincial Product to per capita expenditures was also similar in both cases. The use of two such alternative growth path estimates has the advantage of tracing the limits within which effective demand is likely to fall. These two alternative growth rates for Gross Provincial Product are shown in Table 8-13.

The coefficients of demand (expenditure) elasticity used by IACA to project future effective demand are modifications of coefficients of income elasticity estimated for all Pakistan by the FAO.[2] Demand estimates based on per capita expenditures generally employ higher coefficients than those based on per capita income, but in this case the FAO coefficients pertain both to an earlier time period than the IACA starting year and also to all of Pakistan. They were thus deemed not directly suitable for the purpose at hand. In fact, IACA has used coefficients based on expenditures which are generally lower than FAO's, which are based on income. The IACA coefficients decline markedly over time for cereals, but generally exhibit much less decline for the higher valued items of diet. They also vary with the two GPP growth paths. For given future years, the coefficients tend to be higher for the "low" growth path, and the reverse for the "high" growth path. For more details, see Annex 10.

Estimation of future export demand has been restricted to the two export crops of current importance—cotton and rice (Table 8-14). In the case of cotton, Pakistan's export market prospects have been assessed by reference to the varying future needs for fiber and textiles in developed and developing countries, and the assumption that Pakistan would be able to increase its share in world markets. IACA has used "high" and "low" estimates to mark the range within which export demand might fall, and has projected a minimum cotton export increase of about 80 percent by the year 2000, and an upper limit of about 145 percent. IACA notes that there is possibility that future exports could exceed its "high" estimates. Pakistan's exports of cotton in the early 1950's were larger than present export volumes, and declined because its growing domestic textile manufacturing capacity now consumes an important part of domestic cotton production. Increases in future exports would thus represent a recovery of, and some addition to, Pakistan's

[1] IACA's Comprehensive Report, Volume 2-B, Annexure 2, page 14.
[2] Agricultural Commodities Projection for 1970, FAO, 1962.

TABLE 8-13
PROJECTED ANNUAL GROWTH RATES OF GROSS PROVINCIAL PRODUCT IN WEST PAKISTAN

Year	Growth Rates "High"	Growth Rates "Low"	IACA Agricultural Sector
	(% p.a.)	(% p.a.)	(% p.a.)
1965–75	6.3	4.25	3.5
1975–85	6.7	6.5	5.4
1985–2000	7.0[a]	5.0	3.4

[a] Derived by IACA by extrapolating Perspective Plan growth rates.
Source: IACA's Comprehensive Report, Volume 2-B, Annexure 2, page 14.

previous share in world market sales. The share of the US in world cotton markets could also change. The US presently supplies a large and relatively stable volume of exports, partly due to internal price support and subsidy policies, and exercises a significant influence on world market conditions. If these policies undergo gradual change in a direction which reduces the US supplies available for export, Pakistan and other cotton-producing countries could expect increasing export opportunities in the world markets. Considerations such as these are obviously only speculative, but even if they appear remote from the perspective of the present time, they serve to indicate that the "high" estimates are not necessarily fixed upper limits to future export possibilities. The estimates actually used by IACA were based on assumptions of a growth in demand of 1 to 2 percent per year in the major cotton-importing countries, and slightly higher growth rates in the remaining countries. These estimates were further modified to include a 25 percent increase in Pakistan's share in world markets over the next few years, which IBRD commodity specialists agree may be possible to achieve.

IACA estimates that rice exports would increase more slowly than cotton, although predictions for this commodity also pose difficulties because of the many uncertainties which are present. Among the uncertainties would be the future role of Mainland China in world markets and the outcome of efforts by other exporting countries to increase production. Estimates of population growth indicate substantial increase in world food requirements by the latter part of this century, but how much of such requirements would represent effective demand for imported foodstuffs has yet to be assessed.

When the demand projections based on the "low" growth path for GPP (i.e., the path which incorporates IACA projections of growth in the agricultural sector) are set against IACA's estimates of physical production, the expected increase in production appears adequate to meet demand. The fact that the IACA expenditure elasticity coefficients applied to IACA's projections of per capita GPP provide demand estimates approximating the anticipated total domestic supply of agricultural products does not validate the realism of the coefficients as a basis for prediction, but it does indicate they are compatible with the growth estimates used. It further indicates that the assumption of constant prices does not grossly distort the results. In making these comparisons, IACA has allowed for seed and losses by reducing the physical production assumed available for consumption. The seed and loss allowances used by IACA appear reasonable, but it should be noted that IACA

TABLE 8-14
IACA's Cotton and Rice Export Projections
('000 metric tons)

Year	Cotton				Rice[a]			
	"High"[b]	Index	"Low"[b]	Index	"High"[c]	Index	"Low"[c]	Index
1965	175	100	175	100	290	100	290	100
1975	285	163	250	143	385	133	335	116
1985	360	205	285	163	450	155	370	128
2000	430	246	320	183	565	195	405	140

[a] Includes deliveries to East Pakistan.
[b] In terms of lint cotton equivalent for all cotton exports.
[c] Net exports of clean rice after deduction of allowance for seed and loss.
Source: IACA's Comprehensive Report, Volume 2-B, Annexure 2, pp. 20–21.

allowances are higher than those used by the Planning Commission. They also appear higher than figures used for other countries. IACA has added allowances for losses at the wholesale and retail levels, whereas the Planning Commission estimates apparently apply only to on-farm losses. The comparison between IACA and Planning Commission allowances is given in Table 8-15.

Within the total demand and supply projections of IACA there are imbalances for specific commodities. Foodgrains (e.g., wheat and coarse grain), in particular, exhibit a tendency to be in short supply relative to projected demand. The shortage is estimated to be about 11 percent of effective demand in 1975 and 1985, and about 18 percent by the year 2000.

Surpluses are also forecast, but, with the exception of oilseeds and fodder, these would not occur to an important extent before 1985. Rice projections show eventual surpluses, but a shortage is estimated for 1975 equal to about one-half the current gross tonnage exports of that commodity. By 1985 and 2000 small surpluses are general, and occur for all crops except foodgrains and gram and pulses (the latter in 2000 only). Foodgrain deficits, however, would continue to be substantial. The IACA comparisons of demand and supply, based on the "low" growth path for GPP, are given in Table 8-16. These estimates of the magnitude of surpluses and deficits should be taken as incidental to an approach under which production projections were drawn up with little reference to demand estimates. With such an approach it would be totally unexpected if supply and demand showed a balance for each commodity. The assumption of constant prices, consistent with the focus on the technical aspects of the development proposals, rules out production shifts in response to changing market incentives. In any event, predictions of the direction and size of price changes over a period of 35 years would be no more realistic than the assumption of constant prices for the same period. Prices would, however, presumably change in the face of imbalances such as those projected by IACA, and these changes would bring about increased production of some agricultural products and reduced production of others. Some indication of the potential for flexibility can be inferred from the IACA estimates of surpluses and deficits in production and acreage in different reference years. Assuming that (a) water availability would be identical to IACA projections, and (b) with the exception of rice and perennials, crop water requirements would be essentially similar for all crops grown in the same season, most deficit crops could be substituted for surplus crops within the same season and without adverse effects

TABLE 8-15
ALLOWANCE FOR SEED AND LOSSES, AS PERCENTAGE OF GROSS ANNUAL SUPPLY

Commodity	Planning Commission	IACA			
		1965	1975	1985	2000
Wheat	8.6	12	11	10	9
Rice	4.5	7	7	7	7
Maize	5.0	9	9	9	9
Jowar	4.5	9	9	9	9
Bajra	3.7	9	9	9	9
Barley	11.3	9	9	9	9
Sugar	10.0	16	16	16	16
Gram	6.7	11	11	10	9

resulting from differing crop water requirements. Even in the case of rice and perennials, acreage could be shifted from these crops to others under the projected water availability, but the substitution could not be reversed (i.e., from other crops to rice and perennials).

Using the year 1975 as one example, the IACA Comprehensive Report shows a foodgrain deficit of 1.32 million tons.[1] At yield levels projected by IACA for

[1] The terms "surplus" and "deficit" in the following illustrations refer to the difference between estimated production ("low" growth path) and projected demand.

TABLE 8–16
IACA COMPARISON OF AGRICULTURAL PRODUCTION WITH PROJECTED DEMAND
(low income growth path, 1975, 1985 and 2000)

Product	Demand	Production	Surplus (+) or Shortage (−)	Surplus (+) or Shortage (−)
		('000 mill. tons)		('000 cropped[b] irrigated acres)
			1975	
Wheat	8,405	7,405	−1,000	−1,430
Coarse grain	2,145	1,990	− 155	− 310
Rice	1,740	1,575	− 165	− 330
Sugarcane	18,315	18,395	+ 80	+ 5
Gram and Pulses	1,100	1,140	+ 40	+ 130
Vegetables	1,555	1,160	− 395	− 65
Fruit	1,165	1,160	− 5	−
Oilseeds[a]	355	515	+ 160	+ 530
Cotton (lint)	615	545	− 70	− 540
Green Fodder TDN	10,900	12,860	+1,960	+ 935
				−1,075
			1985	
Wheat	12,460	11,210	−1,250	−1,250
Coarse grain	4,440	3,440	−1,000	−1,110
Rice	2,405	2,490	+ 85	+ 105
Sugarcane	28,695	30,840	+3,145	+ 130
Gram and Pulses	1,545	1,550	+ 5	+ 10
Vegetables	2,660	3,005	+ 345	+ 50
Fruit	1,945	3,200	+1,255	+ 270
Oilseeds[a]	595	905	+ 310	+ 690
Cotton (lint)	1,000	1,185	+ 185	+ 925
Green Fodder TDN	18,900	20,730	+2,030	+ 725
				+ 545
			2000	
Wheat	18,010	12,935	−5,075	−4,230
Coarse grain	5,955	5,285	− 670	− 480
Rice	3,320	4,140	+ 820	+ 745
Sugarcane	45,875	47,550	+1,675	+ 55
Gram and Pulses	2,590	2,075	− 515	−1,290
Vegetables	4,960	4,935	− 25	− 5
Fruit	3,765	5,680	+1,915	+ 310
Oilseeds[a]	1,225	1,870	+ 645	+1,075
Cotton (lint)	1,730	2,205	+ 475	+1,585
Green Fodder TDN	26,100	30,940	+4,840	+1,385
				− 850

[a] Excluding cotton seed, including groundnuts. [b] At IACA yield projections for selected reference years.

Source: IACA's Comprehensive Report, Volume 2-B, Annexure 2, pages 22–23.

1975, 2.07 million irrigated acres would be required to remove the deficit. At the same time, surplus fodder, oilseeds, and gram and pulses occupy about 1.6 million acres and all are crops which are grown in both seasons. If the acreage planted in these surplus crops were divided about equally between the kharif and rabi seasons, 0.8 million acres would be available for wheat in the rabi season. At the implicit yield rates for 1975, this acreage could produce nearly 0.6 million tons of wheat. On a similar basis the remaining 0.8 million acres in the kharif season could produce 0.4 million tons of coarse grains. The total increase in foodgrains from these acreage substitutions would thus be about one million tons, leaving a more manageable deficit of around 0.3 million tons.

There would actually be more flexibility than the above implies. Further substitution involving oilseeds, gram and pulses might make up the remaining deficit. The reduction in fodder production would not affect the TDN available to meet livestock requirements because the fodder acreage shifted to foodgrain production would be surplus to estimated livestock needs, as given in the demand projections. In fact, fodder acreage could be reduced below the levels set by the demand projections because the shift to foodgrain production would yield additional crop residues for livestock feeding. Much would depend also on the yield levels reached by 1975. An increase in average wheat yields of one-half maund per acre would increase wheat output by more than 250,000 tons on the projected 1975 acreage under wheat.

Because the IACA projections for 1985 show an overall surplus of 545,000 irrigated acres, the prospects for shifting crops to meet the foodgrain shortage appear even better than in 1975. Surplus rice, amounting to 85,000 tons, would probably substitute directly for wheat as a foodgrain, reducing the deficit in wheat from 1.25 million tons to 1.17 million tons. The surplus acreage in fodder and oilseeds totals 1.42 million acres. If one-half of this, or 0.7 million acres, were shifted to wheat in the rabi season, it should be possible to increase wheat output by 0.7 million tons at projected 1985 wheat yields. A further shift of the estimated surplus cotton acreage (0.93 million acres) to coarse grains would approximately match the deficit in that category. Similar kinds of substitution in the year 2000 would also result in near balance for all crops.

The foregoing does not imply that the necessary shifts would come about in precisely this manner, but it does indicate the flexibility within the IACA proposed program. The Study Group recognizes that the Government seeks to attain self-sufficiency in basic foodstuffs, and has therefore made efforts to clarify the nature of the "deficits" which have been projected. The Study Group is reasonably certain that adequate flexibility exists in the proposed program to allay fears over major shortfalls in foodgrain production, but would add that Government price and marketing policies would have to be fashioned in ways which encourage the shifts in cropping patterns needed to eliminate surpluses and deficits. Such policies should permit price incentives to play a constructive role in allocating agricultural resources.

Demand based on the "low" growth path estimates, without reference to the availability of supplies to meet it, would lead to the average per capita daily consumption of calories and protein shown in Table 8-17. Bearing in mind that these are based on "high" population growth estimates, they project some improvement in the average diet. To the extent that population growth after 1975 is less rapid than IACA has projected, this picture would improve correspondingly.

IACA has not examined export possibilities other than cotton and rice, but certain surplus commodities, e.g., fruit and oilseeds, might eventually have export prospects. East Pakistan has been a market for oilseeds in the past. Other export possibilities could arise as new comparative advantages emerge in the course of the proposed agricultural and water development program. Livestock is one such example, where it may become more economical for some farmers to use their lands for the support of livestock rather than for the more traditional crops. Development of an export-oriented livestock component would require major changes in the marketing, grading, and processing arrangements which exist, but there are no fundamental reasons for ruling out potential export of livestock products. The Study Group has not made a special study of the inherent comparative advantages in the production which has been projected, but wishes to call attention to this further element of flexibility in the program. The desire for self-sufficiency in food is understandable, but this could also be achieved with higher levels of productivity through stimulation of agricultural exports based on West Pakistan's comparative advantages. Even without adding new export commodities, if new export markets could be developed for commodities projected to be in surplus supply in West Pakistan under IACA assumptions, some part of the projected foodgrain deficits could be met by imports. The cropping patterns which IACA has used in its Basinwide analysis would be more justified if such export possibilities were actually developed.

Larger deficits arise when demand is based on the "high" income path assumed in the Perspective Plan, and matched against the agricultural production which IACA expects to result from the proposed water and agricultural development program. The IACA Comprehensive Report only summarizes this deficit, and expresses it in terms of shortages of cropped irrigated acreage. The shortage would be 6.1 million acres, equal to 21 percent of the Basin cropped acreage in 1975. This would drop to 2.2 million acres in 1985, but would again rise to 6.6 million acres, equal to 15 percent of the Basin irrigated cropped acreage by 2000. It follows that if IACA's agricultural production projections are the more accurate, there is serious doubt that the Perspective Plan growth targets can be achieved. Put in a slightly different way, if the Perspective Plan overall growth targets are achieved instead, either the IACA water and agricultural development program would not meet West Pakistan's future agricultural requirements, or IACA estimates of production potential are less optimistic than the Perspective Plan.

The Study Group projections of production anticipate more cropped acreage in reference years than the IACA projections. The comparison is summarized in Table 8-18.

TABLE 8-17

PER CAPITA CALORIE AND PROTEIN INTAKE IN WEST PAKISTAN BASED ON IACA'S DEMAND PROJECTION AND POPULATION ESTIMATES

	1965	1975	1985	2000
Calories per day	1,973	2,183	2,524	2,787
Proteins (grams per day)	58.7	64.3	74.2	83.1
Animal Protein (grams per day)	15.9	18.4	23.4	29.1

TABLE 8-18
ESTIMATES OF CROPPED ACREAGE

	1975	1985	2000
		(million acres)	
Study Group's Estimates	47.84	54.30	58.68
IACA'S Estimates	46.19	51.88	58.59
Additional Cropped Acreage Under Study Group's Estimates	1.65	2.42	0.09

With the demand expected under the "low" growth path assumptions, there is apparently sufficient flexibility within the IACA projections to adjust to shortages which are likely to occur. The effect of the Study Group's revision is to add still further flexibility under these same demand assumptions because more acreage would be cropped, as shown in the previous table. Including both acreage and yield differentials, the additional flexibility can be more comprehensively illustrated in monetary terms. The monetary value of the total deficit in crops for 1975, the reference point when shortages would be most severe in terms of acreage, would be Rs. 531.7 million. This is derived as illustrated in Table 8-19, which is a summation of IACA estimates of surpluses and deficits in 1975, excluding fodder, valued at IACA prices. As shown in Part A of this Chapter, the Study Group's estimate of GPV crops in 1975 is Rs. 8.80 billion before seed and loss allowances, as compared to IACA's estimate of GPV crops for that year of Rs. 7.59 billion. The difference, or Rs. 1.21 billion, is more than twice the value of the deficit in crops shown above for the "low" growth path. The implication is again that under Study Group assumptions there would be greater flexibility to adjust to the deficits of the size projected by IACA.

If the Study Group's projections were realized, however, the GVA in the agricultural sector would be higher than IACA's estimate, and therefore the GPP

TABLE 8-19
VALUE OF IACA'S ESTIMATES OF DEFICIT IN CROPS
1975

Commodity	Price per M. ton (Rs.)	Surplus (+) or Deficit (−) ('000 M. tons)	Value of Surplus (+) or Deficit (−) (Rs. mill.)
Wheat	348	−1,000	−348.0
Coarse grain	294	− 155	− 45.6
Rice	508	− 165	− 83.8
Sugarcane	49	+ 80	+ 3.9
Grain and pulses	428	+ 40	+ 17.1
Vegetables	294	− 395	−116.1
Fruit	294	− 5	− 1.5
Oilseeds	615	+ 160	+ 98.4
Cotton (lint)	802	− 70	− 56.1
			−531.7

would be higher than assumed under the "low" growth path. Although the Study Group has not attempted to estimate a new growth path based on its agricultural sector projections, it clearly would fall somewhere between the "low" and "high" growth paths and thus generate a higher demand than that used in the comparison. It does not reach the growth path of the Perspective Plan, but in 1985, for example, the additional cropped acreage under Study Group projections is approximately equal to the deficit expected under the "high" growth path demand. The deficit for 1975 is more serious, and a substantial difference remains between the Study Group's and the "high" growth path estimates of supply and demand. An equally large deficit would arise in 2000 under the "high" growth path, but for reasons explained at the end of Part A of this Chapter the estimates beyond 1985 are extremely speculative at this time.

In reviewing these various possibilities, the following conclusions seem warranted.

1. It should be possible to meet deficits in specific crops likely to arise if Provincial economic growth follows the "low" growth path.
2. Study Group projections of GVA in the agricultural sector indicate consistency with a somewhat higher overall Provincial Growth Rate than IACA has assumed, although still lower than the Perspective Plan in 1975. The Study Group regards its projections as realistic, but requiring the most demanding efforts.
3. In the Study Group's opinion, the agricultural sector may perform somewhat better than anticipated by the IACA projections. However, the Study Group's estimates would still be sufficiently below the levels of the Perspective Plan to justify the caveat expressed by IACA—namely, higher growth rates in the non-agricultural sectors than now assumed in the Perspective Plan could raise the demand for agricultural commodities well beyond domestic supplies, and thus require continuing dependence on imports of basic food items.
4. To the extent that the inconsistencies of demand and supply require adjustments in the projected production pattern to meet policy objectives, the Government should give increased attention to the possibility of influencing aggregate, as well as specific, production through price incentives. This would appear to apply with particular force to the price for wheat, which may need to be brought more in line with world market prices (including allowances for real foreign exchange costs) in view of the decreasing dependability of PL 480 supplies.

The achievement of the rates of growth of agricultural production contained in the Study Group projections would represent a most commendable performance. Agriculture will continue to be the single most important sector in the West Pakistan economy for the foreseeable future, and the growth of the West Pakistan economy as a whole would therefore depend to a large extent on agriculture's performance. It is thus imperative that the agricultural sector receive the attention and support recommended throughout this Report. Although higher levels of production than projected by the Study Group may appear technically feasible, it is the Study Group's opinion that, within the given economic, social, and institutional environment, it would be unrealistic to expect growth of production considerably beyond that projected in this Report.

IX

Summary and Conclusions

Introduction

The Province of West Pakistan covers almost 200 million acres, and has a present population of about 54 million people. Within this vast area lie the Indus Plains, where the largest irrigation system in the world commands some 33.5 million acres with water drawn from the Indus River and its major tributaries. 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 West Pakistan. The importance of the irrigated Plains is therefore predominant, and for that reason this area has received the primary emphasis throughout Volume II of the Study Group's Report, which deals with irrigation and agriculture in all of West Pakistan.

The Study Group has conducted the Indus Special Study with the aid of five international consulting firms. Three of these formed an association, the Irrigation and Agricultural Consultants Association (IACA), and worked exclusively in the fields of irrigation and agriculture. The other two firms worked on surface water storage and power aspects. At all stages, the Study Group has maintained close contact with, and has benefitted from the full cooperation of, the Government of West Pakistan, its agencies, and its consultants.

Throughout the Study and in this Report, the Study Group has endeavored to maintain a proper balance in emphasis between the agricultural aspects of improvement and development (i.e., better farming, employing more agricultural inputs) and further water development. The Study Group has therefore stressed the need to apply better farming practices to the existing production potential simultaneously with the projected investment in water resource development which would expand the agricultural base. Inevitably, there tends to be a preoccupation in a Study of this kind with projects and investments, but other important features of development, including such aspects as institutions, organization, and recurrent expenditures, have not been overlooked in the Study Group's concern that all relevant developmental factors be taken into account.

Background to Water and Agricultural Development

The frame within which this Report rests is the actual performance of West Pakistan's agriculture over the past several years. The gross value added by crops grew at an annual rate of 4.7 percent over the Second Plan period (1960–65), and the growth rate for the agricultural sector as a whole was 3.8 percent per annum. Comparison with prior trends indicates that a different set of forces was at work during this time, bringing sustained increases in the acreage cropped and crop yields. Increased water availability was an important factor in this, with public projects adding about 5.5 million acre feet (MAF) to the existing irrigation supplies. More striking was the unanticipated contribution of about 6.0 MAF from private tubewell installations—an encouraging development which has continued into the Third Plan period at rates equal to, or higher than, those achieved in the Second Plan period. There was also evidence of increased use of other agricultural inputs, notably fertilizer. The quantities of such inputs used did not reach levels which account for any significant portion of the most recent growth, but the rate of increase in use by farmers is a favorable sign for future agricultural development. The Government has moved in a positive way to provide the institutional arrangements necessary to carry out a full program of agricultural development, and its broad economic policies have, on the whole, tended to encourage agricultural production. The setting is thus one in which there is some evidence of apparent readiness by farmers to adopt the means to advance agricultural development, and intent on the part of the Government to promote development by appropriate policy decisions and an adequate allocation of the available resources.

There are other favorable factors to take into account. The Indus River and its tributaries offer a supply of surface water for irrigation which is currently greater than can be utilized by the existing system. Of an annual mean discharge of 167 MAF from rivers entering the Indus Plains of Pakistan, about 76 MAF, or nearly half, is unused and discharges into the Arabian Sea. Seepage from these rivers and the canal system over time has created huge underground reservoirs of water, a large proportion of which is sufficiently fresh to use for irrigation. Usable groundwater underlies a gross area of 18.8 million acres, or over half the recorded commanded culturable acreage (CCA) of the Indus Basin. The consultants have estimated that at full development it would be possible to pump 44 MAF per year from usable groundwater sources without exceeding the annual recharge to the aquifer. The soils of the irrigated plains generally provide a satisfactory medium for plant growth, and there is no evidence that soils, as such, impose a serious constraint on future development. Salinity and alkalinity, often associated with waterlogging, pose problems in some areas which must be overcome and carefully guarded against in the future. Climatic variations occur throughout the Province, and these affect the selection of crops which can be grown well. But aside from the scarcity of rainfall—which forces the dependence on irrigation—climatic factors do not impose a serious constraint. Finally, a large majority of the farms are below five acres in size, and the average holding in the Province is only 10.1 acres. Sharecropping is widely practiced, with its attendant ills of insecurity of tenure, inadequate investment in production facilities, and limited rewards to the actual cultivators. Nevertheless, there is little to indicate that conservatism and resistance to change would prove to be major obstacles to development, and the productivity of tenant farms appears at least equal to that of the smaller owner-operated farms. The large investment in private tubewells which has already been made is a further sign of initiative at the farm level, albeit largely confined to the owner-operators of the medium and larger scale farm units.

The Key Elements in Program Formulation

In assessing the opportunities to stimulate agricultural development in West Pakistan, the Study Group studied data on a wide range of agricultural factors. These included 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 limitation inherent in a complex system 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, and used in the formulation of a development program, are summarized here under two broad categories, agricultural and water resource factors.

Agricultural Factors. The increased use of agricultural inputs other than water would have a beneficial effect on yields at levels of existing irrigation application. From this, two conclusions can be drawn: programs to stimulate the use of nonwater inputs by farmers need not be delayed until the supplies of irrigation water are increased, since such inputs would bring economic benefits under present conditions; until the level of farming practice improves to the point where it matches the level of water availability, farmers are likely to respond to increased irrigation supplies by expanding the acreage cropped at less than full delta water applications, rather than increasing the water applications to full delta on the existing cropped acreage.

Development of water resources should receive high priority in the short run. This is necessary in order to reduce the uncertainty of water supply which characterizes the present system, and the provision of additional and regular irrigation supplies is a prerequisite to increased cropping intensities and full use of other inputs. Farmers are familiar with irrigation water as an input, and are therefore likely to use additional supplies as soon as they become available. Finally, increased and reliable irrigation supplies should stimulate the use of nonwater inputs by farmers because water and other inputs are complementary in their contribution to increased yields. Additional cropped acreage also opens opportunities for increased use of nonwater inputs, even under conditions of underwatering as noted above.

The Study Group is in general agreement with the yield levels projected by IACA for the year 2000, which are generally two to four times higher than in 1965. Because of the assumptions above, however, the Study Group has smoothed out the growth path for yields. Thus, because it believes that increased use of nonwater inputs could be beneficial under present conditions, the Study Group projects a higher growth in yields during the period 1965–75 (before the water development projects become fully operative) than IACA. At the next stage, 1975–85, the Study Group projects a growth in yields less than IACA. This is because the Study Group does not assume that increased supplies of water would be applied immediately to bring applications to the level of full delta, or, to the extent that they are used in this way, that the increase in yields due to increased delta alone would be as rapid as IACA has assumed. For the period 1985–2000, both projections are very similar.

An overall average cropping intensity of 150 percent should be assumed to be a reasonable indicative target for development in the Indus Basin. Attempts to raise this average level would face difficulties primarily because of the incompatibility of certain crop successions, the expense of reclaiming saline land within the projected CCA, and limitations on farmers' capacity to shift rapidly from one crop to another with the equipment, labor, and animal power at their disposal.

The main deficiencies in the present irrigation system are: water availability in rabi and late and early kharif seasons is unreliable and inadequate to sustain optimum crop production; canal capacities in some areas are inadequate to achieve optimum kharif intensities; distributary and watercourse flows are inflexible; crop growth is affected, directly or indirectly, by lack of subsurface drainage; lack of surface drainage causes crop losses and yield reductions in the upper northern and lower southern regions.

Water Resource Factors. The mean combined flow of the Indus, Jhelum, and Chenab Rivers, after full implementation of the Indus Waters Treaty, has been estimated to be 142 MAF per year. Compared to the present average canal head diversions of 79 MAF per year, this indicates considerable potential for future surface water conservation and use in West Pakistan.

Fresh groundwater, containing less than 1,000 ppm TDS, is assumed to lie under 14.2 million acres CCA, and groundwater, which requires mixing with fresh surface supplies before being used for irrigation, is assumed to be found under an additional 4.6 million acres CCA. The current usable recharge to the aquifer is about 30 MAF per year, but this would increase to 44 MAF in the future as more surface water is absorbed by the canal system.

Heavy emphasis is placed on tubewell development in usable groundwater areas because the potential increase in demand for water is so large, particularly during the rabi months, that it would exceed the feasible rate of new surface water development works over the next 10 years. On the basis of the estimated feasible rates of installation, operational efficiency, and cost, no other mode of water development can compete with tubewells where usable groundwater is available on the land. Tubewells have the advantage of delivering water directly to the farm watercourses, and thus they overcome the constraining effect of the present limitations on canal capacity. They also provide a mode of development in which individual land owners or farmers can participate, and to this extent they assist in overcoming the present serious constraints on finances and implementation capacity. In the usable groundwater zones, they not only provide water quickly and cheaply, but also simultaneously provide water table control. The Study Group assumes that private tubewell installation would continue during the 1965–75 period, and that a total of 55,500 private tubewells would be in operation by 1970 even if the public tubewell program maintains the schedule called for under the Action Program. Under these conditions, this estimate of total private tubewells would drop only slightly to 52,500 by 1975. The Study Group also believes, however, that the private sector could sustain a higher installation rate than this and would do so if public tubewell projects were not going forward in certain areas of the Basin. If the public program should lag behind the Action Program schedule, the Study Group anticipates that private installation would be greater—possibly as many as 66,500 private wells in operation by 1970.

The Study Group recommends that surface water storage at Tarbela will be available as scheduled, and will be in operation for the rabi crops of 1974/75. The Study Group also accepts IACA's finding that canal remodelling during the period covered by the Action Program would be limited to one million acres where it would be designed to remove constraints in the mixing and saline groundwater zones.

Public and private tubewells would provide an important part of the need for subsurface drainage in the process of adding water for irrigation but in saline groundwater zones a separate and specific drainage system would be required. In this latter case, the selection of either drainage tubewells or horizontal drainage would depend on the type of drainage problem existing in different areas.

Damage from flooding would become increasingly important as the state of agricultural development improves, and this would require some flood protection measures. However, the relative importance of this problem, and the costs required for flood protection, appear quite small in comparison with the Action Program as a whole.

The findings concerning the quantities of water likely to be available for development lead to the further working conclusion that it would be more efficient and economical to use these foreseeable water supplies to intensify farming and develop new areas within the existing CCA, rather than to extend the canal system into new land. Within this guiding principle, the Study Group has not regarded the IACA estimate of 29.5 million acres CCA as a fixed limit, since it may prove feasible and advantageous to use available water supplies on parts of the existing CCA not included in this 29.5 million acres marked for intensive development. The Study Group believes that such decisions should be based on conditions existing at some future time when alternatives may come under consideration, but the acreage limitation must be kept prominently in mind when planning for development.

The Action Program

The Study Group's Report presents an Action Program for the period 1965–75 which builds upon these findings and considerations. This Action Program is the first stage in long-term planning for water resource and agricultural development consistent with West Pakistan's resource base, and incorporates proposals which are technically and operationally feasible under West Pakistan conditions. Many elements in the program require further detailed engineering study and economic evaluation before final decisions can be taken. Further, relative priorities and the specific inclusion or deferment of projects depend, to some extent, on the future course of events, for it is expected that constant review in the light of changing circumstances would result in modifications of the program as it is now conceived. While the development program as a whole applies to the period up to the year 2000, the Study Group has been particularly concerned that the Action Program relating to the period 1965–75 be achievable within the constraints likely to be operative, and not be merely an expression of goals which are feasible in a technical sense. The program is not intended as a prediction of what will be, but rather as a projection of what could take place if the development of irrigation and agriculture receives the high priority it deserves, and if the required resources are allocated and efficiently and effectively deployed.

There is emphasis in the early period of the program on development of tubewell installations to supply irrigation water. This emphasis stems from the availability of large underground supplies of water, the comparative cost advantage, and the fact that future expansion in surface supplies would increase the recharge and therefore the potential withdrawal from the groundwater reservoirs. Clearly, either public or private tubewells would serve to tap these underground sources of irrigation water, but for the long term some form of coordinated control would be required. This is because it would be necessary to integrate control over the groundwater table with the supply of surface water (which comes from sources already under public control), and because private development alone may not provide the coverage which would permit all farmers to benefit from groundwater supplies where these are exploitable. It is therefore desirable that public development continue to the extent public projects can be successfully and efficiently implemented. On the other hand, there are limits to the rate at which public groundwater development can proceed, and the existing willingness to expand private tubewell installations should therefore be utilized to bring development where the incentives are greatest to do so. The Study Group's approach to groundwater development over the next 10 to 15 years is thus a flexible one, seeking to take advantage of both public and private initiative and thereby accelerating the rate of exploitation of groundwater resources.

There are five main elements of water resource investment in the Action Program—the ongoing public groundwater development, Tarbela Dam, the public tubewell projects formulated by IACA, the Sukh Beas Drainage Scheme, and private tubewell installation. The ongoing public groundwater development portion consists of public tubewell development projects which are in some stage of construction or project preparation at the present time. These call for a total of 10,118 public wells in five SCARP (Salinity Control and Reclamation Project) areas, of which some 2,900 have been completed in SCARP I and II since the start of construction in 1959. The West Pakistan Water and Power Development Authority (WAPDA) has scheduled the balance of about 7,200 wells for completion by 1971/72. In addition to these, WAPDA has proposed that it begin implementation of one more area (SCARP V) in 1967/68, which would provide 2,300 public wells in the Lower Rechna Doab.

The Study Group believes, on the basis of WAPDA's performance to date, that completion of the ongoing projects as scheduled is far from assured. There are certainly pressing needs for improved procedures and increased financial allocations to the executing agency, for removal of constraints on electrification, and for the urgent establishment of management cadres capable of putting tubewell fields into operation immediately upon completion. There would thus be little room for additional new projects for implementation during the Third Plan period. Because of this, the Study Group feels that a portion of the tubewell development included in the Action Program and scheduled for SCARP IV (amounting to 1,010 wells out of a total of 3,270) should be deferred until after 1973. This is suggested because of the implementation problems just noted, and also because the area of Rechna Doab where SCARP IV is located is currently undergoing extensive development by private tubewells. This private activity alone may be sufficient for development of the area in the early years. The Study Group further recommends that the SCARP V project, noted above, be deferred on the same grounds, and SCARP V has not been included in the Study Group's Action Program. Areas within SCARP V where waterlogging and salinity are major problems would be included in a separate project within one of the IACA public tubewell project proposals. Despite the apparent constraints on actual implementation, project preparation for projects to be carried out in the Fourth Plan period should nevertheless be vigorously pursued during the remaining years of the Third Plan period.

Construction of the Tarbela Dam is the main element of the Action Program for the further development of gravity irrigation. The dam should provide an initial live storage availability of 8.6 MAF at a drawdown level of 1332 feet, but siltation over a 50-year period would reduce this to about 1 MAF by the end of that time. Under the present construction schedule, the full 8.6 MAF cannot be impounded by 1974/75, but there should be about 5 MAF impounded during the flood season of 1974—equal to the storage requirements expected during the rabi season 1974/75. In quantitative terms, the regulating effect of Tarbela should increase the rabi flows of the Indus from mid-October to mid-April by about 65 percent. Other contributions of the dam include the fact that it would be a further step in exploiting the huge water resources of the Indus which presently flow to the sea partially unused. It would increase the reliability of irrigation supplies for rabi crops (particularly wheat), would enable an extended utilization of the link canal system by diversion of storage releases through the links for use in the central parts of the Indus Basin, and would increase the recharge to groundwater and thus add to the recoverable recharge in usable groundwater zones.

On the other hand, the construction of Tarbela Dam generates consequences for other aspects of water resource development which must be taken into account under the other parts of the Action Program. For example, there must be sufficient control of the groundwater table before additional surface water from Tarbela storage can be admitted to seriously waterlogged areas. The location and timing of tubewell projects must therefore be decided in the light of the existence of Tarbela storage by 1975. The need for canal enlargement is related to the increase of surface water supplies at critical months. Although existing capacities are designed largely to meet kharif needs, and are generally underutilized during rabi, increased surface supplies during rabi would also require additional deliveries during the months when kharif and rabi requirements overlap. In some cases, this condition is likely to exceed the current canal delivery capacities, and would call for some canal remodelling. If, however, surface deliveries are integrated with groundwater development, concentrated pumping during the overlap months could relieve this constraint in the earlier years of increased surface availability. Finally, the timing of groundwater development in areas where mixing with fresh surface water is required would depend on when such fresh surface supplies would be available from Tarbela storage.

The ongoing public groundwater projects and Tarbela Dam are thus the parts of the Action Program already under either preparation or construction. IACA has identified and formulated an additional 12 public tubewell projects for inclusion in the Action Program which would further contribute to the irrigation water supplies, drainage, and groundwater table control. These 12 projects are concentrated principally in the three regions of the Bari Doab, the Sutlej Left Bank, and the Lower Indus. IACA has proposed 11,403 tubewells, of which 4,867 would have a capacity of about four cusecs and 6,536 a capacity of about three cusecs. These would cover about 5.8 million acres CCA, of which 4.1 million acres would be in fresh groundwater zones. With the exception of the Sukkur Right Bank project, all would eventually absorb additional surface supplies after the completion of Tarbela Dam, most of this during the rabi season. The total net increase in irrigation water supplies from groundwater and additional surface water in these 12 projects areas would be 13.28 MAF by 1985. If carried out as scheduled, groundwater development projects under the entire Action Program would add some 18,600 tubewells, providing supplementary irrigation water to approximately 12 million acres of culturable area.

The Study Group has determined priorities for the 12 new tubewell projects from the preliminary information available. These priorities were derived intially from an examination of the water requirements associated with attainment of optimum cropping intensities under the agricultural and technical constraints believed to be present. This examination resulted in a set of water budgets, one for each canal command, subsequently aggregated into a comprehensive water budget for the system as a whole. The priorities followed from consideration of the technical feasibilities of providing the water requirements stipulated in the budgets. These priorities were then checked against two economic evaluations—one a ranking which resulted from considering of the costs and benefits of different water development activities in analytical units based on groundwater quality zones, and the second a linear programming exercise which employed a more comprehensive model based on whole canal commands. The priorities which emerged under these three different approaches were similar for the most part, and the minor differences between them were resolved largely to accommodate technical problems which were involved.

The 12 projects seem sufficiently justified to merit consideration for the period up to 1975, but highest priority has been given to eight of the projects. The additional four projects, all in the Bari Doab, have only marginal advantages over the alternative of continued private development of the same areas, and may be deferred in the light of factors discussed below. Their evaluation is discussed in Annex 7. The major characteristics of these project areas are summarized in the next table (Table 9-1).

Although all 12 projects have been included in the Action Program, the Study Group suggests that public groundwater development efforts should be concentrated first in fresh water areas where thus far there has been little private tubewell development. The latter four projects noted above are situated in the Bari Doab where there has been substantial private development, and the indications are this would probably continue in most parts of these project areas in the absence of public projects. The Study Group also feels that private wells would provide sufficient drainage effects to enable the introduction of additional surface supplies, and therefore suggests that public development in the Bari Doab be generally deferred until after 1970 except in the Wagah area and possibly parts of the Upper Dipalpur Command. By that time private initiative would have demonstrated its capability more clearly, and it may be determined whether it can provide the necessary groundwater table control. Decisions can be taken at that time whether

TABLE 9–1
GROUNDWATER DEVELOPMENT PROJECTS IDENTIFIED AND FORMULATED BY IACA

Project	CCA ('000 acres)			Number of Wells			Installed Capacity	Depth to Water Table (% of project area)		Groundwater Pumped at Full Development	Ultimately Attainable Cropping Intensity
	Fresh-water Zone	Mixing Zone	Total	4 Cusec	3[a] Cusec	Total		Less than 10′	More than 10′		
							(cusec)	(percent)		(MAF)	(percent)
Rechna Doab:											
Shorkot Kamalia	222	72[b]	294	370	56	426	1,650	78	22	0.61	149
Bari Doab:											
Dipalpur Above BS Link	344	28	372	580	50	630	2,460	55	45	0.76	150
Dipalpur Below BS Link	362	249	611	473	377	850	3,020	28	72	1.01	150
Ravi Syphon-Dipalpur	257	338[b]	595	440	340	780	2,600	30	70	0.98	150
Shujaabad	303	76	379	576	149	725	2,730	74	26	0.98	149
Sutlej Left Bank:											
Fordwah Sadiquia	237	122	359	495	170	665	2,420	56	44	0.86	145
Bahawal Qaim	335	187	522	618	306	924	3,290	7	93	1.22	146
Panjnad Abbasia	716	162	878	1,315	308	1,623	6,110	83	17	2.37	148
Lower Indus:											
Rohri North	451	147	598	—	1,580[c]	1,580	4,210	40	60	1.21	145
Rohri South	400	128	528	—	1,500[c]	1,500	3,730	5	95	1.14	130
Begari Sind	349	—	349	—	880	880	2,640	90	10	0.72	150
Sukkur Right Bank	160	113	273	—	820	820	2,120	97	3	0.72	150
Total:	4,136	1,622	5,758	4,867	6,536	11,403	36,980	49	51	12.58	150

[a] The capacities of wells included under this category would vary from 2 to 3 cusec.

[b] Including some saline areas for which tile drainage proposals have been made by IACA.

[c] Including tubewells required on remodelling.

to initiate detailed project preparation, or to defer such action even further. This would require close monitoring of private development in the Bari Doab.

A fourth element in the Action Program is IACA's revision of a drainage project originally formulated by the Government of Pakistan and known as the Sukh Beas Nallah Drainage Scheme. As revised, this project would utilize a 327-mile alignment, mainly of the old Beas River bed. The catchment area would be about 3.3 million acres, with a design discharge capacity of 462 cusecs at the head and 2,263 cusecs at the tail. This area borders the Dipalpur, Pakpattan, and Mailsi canals on the east, and Lower Bari Doab main canal on the west, and the project would provide drainage for an area of West Pakistan where existing levels of agricultural production are amongst the highest in the Province. The drainage project would support both private tubewell development and the public tubewell projects proposed for the latter part of the period 1965–75. To the extent that reduction in prolonged flooding of large agricultural areas would reduce the recharge to the groundwater aquifer, the drainage project would also contribute to the control of the water table in large parts of the Bari Doab.

Finally, the Study Group anticipates continuing private tubewell development throughout the period of the Action Program. This is essential to the growth in agricultural production because the contribution to growth from the public portions of the Action Program (which is considered to be the maximum feasible) would be inadequate for West Pakistan's needs. The Study Group therefore strongly suggests that Pakistan Authorities implement policies conducive to rapid private tubewell development as a matter of urgency.

Although private diesel-powered wells are the most expensive form of groundwater exploitation for the farmers because of their high fuel costs, they have the advantage of being independent of electric power supplies. This could provide an interim solution in areas not yet electrified, as well as added reliability in areas where power is available but not always dependable. A comparison of public and private electrified wells indicates negligible cost differences per unit of water pumped on the land. Although private wells may be pumped at lower rates than public wells, this generally reflects a pumping pattern directly related to farmers' actual water requirements, and therefore constitutes a more efficient use of the groundwater pumped. The Study Group has accepted the IACA proposals for public development as scheduled in the Action Program, but would urge the Government to continuously observe the relative performance of public and private development efforts. The emphasis on public or private groundwater exploitation in usable groundwater zones may be changed from time to time, depending on the availability of public funds and the relative advantages of the two approaches as these emerge more clearly with increased experience.

The Action Program assumes that a total of at least 52,500 private tubewells would be operating by 1974/75, of which 38,500 wells would be in the canal-commanded area. The contribution to irrigation supplies from these private wells and the public wells included in the Action Program, as well as a comparison with the groundwater quantities utilized in the Sequential Analysis, appears in the next table (Table 9-2). This Sequential Analysis involved a 20-year sequence, and was undertaken to demonstrate how the system at large would meet the water requirements of each irrigation unit under the year-by-year conditions of development. It was thus an attempt to test the operational feasibility of the integrated irrigation system which the program calls for. The following table shows that the Action Program, as now proposed, would essentially meet the irrigation water requirements calculated by IACA in its Sequential Analysis for reference years over this period. The table also illustrates another point of significance for the strategy to be followed during the period 1965–75. This point is that private groundwater exploitation is clearly dominant throughout the Third Plan period, and continues to make an important contribution to irrigation water availability up to 1975. The Study Group believes that the public tubewell program constitutes a maximum number of wells likely to come on flow. Private installations have been projected at a declining rate of increase, which may understate the potential. It is therefore important that private development be given every encouragement until the successful implementation of consecutive public well fields appears ensured.

A Summary of Conclusions in Regard to the Action Program is offered below:

1. The Study Group recommends an Action Program for 1965–75 which would be the first stage in long-term planning for water resource and agricultural development.

2. Ongoing public tubewell projects in five SCARP areas should be completed as scheduled, with the exception of SCARP V and portions of SCARP IV. Public programs in the latter two areas should be deferred because of the constraints on public sector implementation capacity, and because rapid private development in those project areas appears most likely in the coming decade.

3. Tarbela Dam should be completed in time for impounding water during the flood season of 1974.

4. Additional surface storage would generate a need for some canal remodelling to accommodate increased flow during the overlapping of kharif and rabi seasons. However, concentrated pumping from tubewells during the overlap months may relieve this constraint during the early years of increased surface water availability.

5. The 12 public tubewell projects proposed by IACA appear justified, but the Study Group feels that four of them located in the Bari Doab could be deferred

TABLE 9-2
GROUNDWATER PUMPED UNDER THE ACTION PROGRAM

	1965/66		1969/70		1974/75	
	Canal Commanded Area	Outside Area	Canal Commanded Area	Outside Area	Canal Commanded Area	Outside Area
No. of Tubewells in Operation:						
Public	2,900	—	9,600	—	20,700	—
Private	29,000	5,000	46,500	9,000	38,500	14,000
Estimated Annual Pumpage in MAF:						
Public	2.7	—	10.2	—	21.7	—
Private	7.0	1.0	9.0	1.8	8.5	2.8
Total	9.7	1.0	19.2	1.8	30.2	2.8
Private as percent of Total:	72%	100%	47%	100%	28%	100%
Groundwater pumped in the Sequential Analysis:	9.6	—	21.7	—	31.0	—

beyond the Action Program period because they show only slight advantages over the alternative of private development in the same areas.

6. The Sukh Beas Drainage Scheme should be implemented during the period of the Action Program, and would serve an area of 3.3 million acres along the old Beas River.

7. Private groundwater exploitation would be clearly dominant throughout the Third Plan period, and would continue to make an important contribution to irrigation up to 1975. Success of the total program thus depends heavily on a continuing exercise of private initiative in tubewell installation, and this should receive every encouragement so that it can make the full contribution expected from it.

Long-Term Development Proposals

As noted earlier, the Action Program for 1965–75 places heavy emphasis on tubewell development of the usable groundwater areas throughout the Indus Plains because tubewells provide the most rapid and cheapest means of making additional irrigation water available on the land, in addition to affording flexibility in construction and use. Surface water storage developments for this period are very largely predetermined by the completion of Mangla Dam in 1967, a small amount of storage at Chasma Barrage scheduled for completion by 1971, and the work on Tarbela Dam. Canal enlargement before 1975 is limited to about one million acres because of resource constraints, limitations in the capacity of link canals to bring extra supplies of water to the headworks of enlarged canals, and the general shortage of river flow at critical times of the year prior to the time the surface storage facilities are completed.

Planning beyond 1975 for irrigation development in the Indus Basin becomes more complex. The various methods of irrigation development—surface supply, tubewell supply, subsurface drainage, and canal remodelling—together with agricultural constraints on the intensification of farming, all become more closely interrelated. The additional water deliveries and flow regulation provided by Tarbela and Mangla, superimposed on the large tubewell developments expected by 1975, would create a situation where irrigation supplies could be matched to the water requirements of crops instead of, as at present, to the natural flows of the rivers. Thus, after 1975, supplies should be adequate to meet the assumed needs of an increasing cropped acreage at full delta, including the conversion of areas from nonperennial to full perennial cropping where this has not been achieved by tubewells alone. Details are given in Chapter V. During the decade 1975–85, public tubewell fields would be extended over the outstanding usable groundwater area, and full integration of groundwater and surface water supplies would be achieved. The improved irrigation supplies and the control of the water table would enable the canal enlargement program to be greatly accelerated at this stage, and this would take the leading role in further water development. By the end of the century, there should be complete enlargement of the canal system serving some 16 million acres CCA, in addition to major works enlarging existing link canals and providing some new ones.

Some of the more urgent work of canal enlargement would be undertaken before 1975, but only in canal commands where it does not involve additional link canal capacity. As stated above, this would affect approximately one million acres. The major emphasis on canal enlargement, however, would not come until around

1980. By that time a new canal should connect the Chasma Jhelum link eastward across the Punjab with the main canals of the Chaj, Rechna, and Bari Doabs. At about the same time (1982), the Sehwan Barrage and the Sehwan-Rohri Feeder should be completed in the Lower Indus as the first stage of the Sehwan-Nara Feeder.

The extent and nature of the canal remodelling would vary with the different sections of the Indus Basin according to needs and the specific water situation in each. The details are provided in Chapter V, but a few general comments may indicate some essentials of the overall program in addition to the background sketched above. Remodelling would take place in the Punjab in those portions where there are extensive saline areas, or where the anticipated tubewell development would not provide enough irrigation water to meet the crop requirements at full delta. Most of this would have to wait until the west-east link across the Punjab was nearing completion. Canal enlargement in the Lower Indus hinges essentially on the Sehwan Barrage project which would act as a diversion dam to command a major feeder canal to the Rohri and Nara commands, and would also provide about 1.8 MAF useful storage capacity. 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 longer term program envisages that public tubewells would virtually supersede private tubewells within the canal commanded areas by about 1985. It should be noted at this point, however, that the Study Group is less certain about what relative weights should be given to the contributions from public and private tubewells over the longer term. Any firm judgments made at this time may well be based on sound principles, but at best can only rest on inadequate evidence as to what the relative advantages would actually be under West Pakistan conditions. For these reasons, the Study Group would prefer to see such an important judgment made in the light of careful analysis of performance after, say, five years' time.

As the program now stands, the initial emphasis after 1975 would be on the completion of public tubewell programs in usable groundwater zones, and the progressive substitution of public for private wells. This 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 of well fields in the long term. The actual phasing of public tubewells after 1975 can be regarded only as a broad indication of priority because much is based on judgment which must be checked by further investigations and analyses. By 1980 only a few areas of usable groundwater would remain undeveloped by public wells, notably Upper Swat, part of Pakpattan and part of Ghotki and Warsak. As this part of the tubewell program nears completion, the resources engaged in such work would be diverted to the drainage of saline groundwater areas to make possible the further intensification of irrigation by canal enlargement. Some of the more urgent saline areas with shallow water tables would be tackled at an early date, particularly those in the Panjnad Abbasia and Rohri commands. From 1980 onwards there would be a steady program of tubewell installation in saline areas amounting to about 500 tubewells per year.

The largest single drainage work for the long term, the Left Bank Outfall, would actually be started during the period of the Action Program. It is the first stage of

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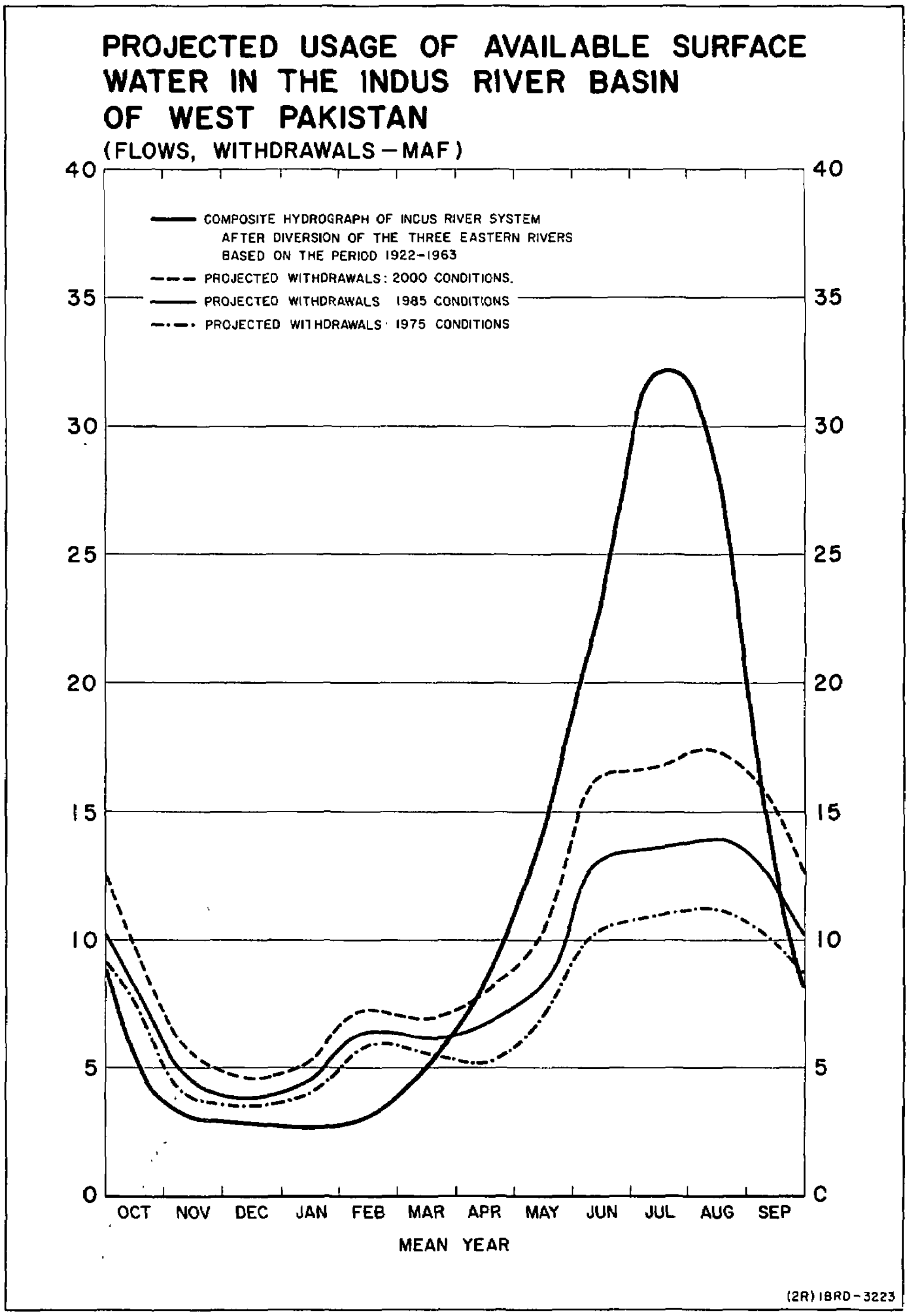
FIGURE 91



a large drainage complex proposed by the Lower Indus Project (LIP) consultants for the Sind, and would have the objectives of removing saline subsoil drainage water from the greater part of the Indus Left Bank south of Sukkur to the sea and providing surface drainage in areas south of Nawabshah. The drain would have an overall length of 267 miles, stretching from near Khairpur to the Rann of Kutch, and would provide a maximum discharge of 15,000 cusecs. The massive scale of the works in this project requires a construction period of 16 years, and it was therefore scheduled to begin in 1968. This meant that a rapid program of studies and site investigations had to be undertaken. The other major surface drainage work would be the Lower Indus Right Bank Outfall Drain. This would serve the Gudu and Sukkur Right Bank areas, and would drain their affluent into the Indus downstream of the proposed Sehwan Barrage. The drain represents the main feature of the final stage of the LIP consultants' drainage proposals, and is scheduled for completion by about 1990.

In order to determine the Action Program for 1965–75, and to set it in perspective with a longer term indicative development program for the Basin, it was necessary to analyze the patterns of water use over time in relation to the potential availability. Three reference years were used for detailed analysis—1975, 1985, and 2000—and in addition each year from 1965 to 1985 was analyzed against historical and synthetic sequences of river inflow. The water distribution and use analyses were undertaken in three stages: (a) the calculation of water use within canal commands, (b) routing the demands from canal commands to the river rim stations and reservoirs sites for each reference year, and (c) the operation of the reservoirs to correspond with the scheduled supplies from all sources. The sequential analysis, mentioned earlier, was added to test the operational feasibility of the program over its crucial period, 1965–85. In addition, a number of reservoir operational studies were carried out for Mangla and Tarbela reservoirs to determine their behavior for both irrigation and power purposes. See Figure 9.1.

These water distribution analyses were the means by which various alternatives were tested. They were not intended to provide detailed operational estimates for specific water allocation or distribution patterns, but nevertheless they form a useful framework upon which to build up detailed studies of future system operating procedures and rules. Such distribution studies must embrace all the new situations set up by the introduction of Mangla Dam and the link canals built under the terms of the Indus Basin Treaty, and their new transfers of water to the eastern Punjab. These and other aspects of the redistribution of surface water, including the implementation of tubewell programs, water substitution opportunities, and integration of surface and groundwater supplies, involve a number of agencies. These would include the Agricultural Department, Agricultural Developing Corporation, and the Land and Water Development Board as well as WAPDA and the Irrigation Department. The procedure for bringing together the views and experience of the various agencies and applying them to a study of water distribution is essentially a domestic one that can only be decided by the Government, but the Study Group attaches great importance to this matter and it has made some suggestions regarding its implementation. The need to proceed with these detailed studies of system operation is urgent.

A summary of long-term conclusions is offered below:

1. The long-term program anticipates that irrigation supplies should be adequate after 1975 to meet the needs of increased cropped acreage at full delta, and that full integration of groundwater and surface water supplies would be achieved during the decade 1975–85.

2. Although some of the more urgent canal remodelling work would start before 1975, the major emphasis would not come until about 1980. This activity is related to the construction of new link and feeder canals, and is phased to enlarge the capacity of existing canals at times when increased surface supplies would be available to them.

3. The Study Group anticipates eventual coordinated control of groundwater exploitation, but is reluctant to assign fixed weights to the relative contributions from public and private tubewells over the long term. Since there are uncertainties over the development pace which public sector tubewell projects can maintain, the Study Group would prefer to leave decisions on the timing and form of eventual coordinated control until there is a larger body of experience on which to base judgments.

4. The Left Bank Outfall, possibly the largest single drainage work in the world, should have been begun before the 1970's, preferably in 1968; it will continue over a construction period of 16 years. A second major work, the Right Bank Outfall, would constitute the final stage in the drainage program and is scheduled for completion by about 1990.

5. The Study Group recommends that detailed studies of the operation of the irrigation system be started as soon as possible, since the efficient operation of the system calls for understanding of the new situations being created by the various elements in the development program.

Program Requirements

Agricultural Inputs. The program advocates the simultaneous development of improved water supplies and improved farming practices. Improved farming, which includes better farm methods and the use of physical inputs such as fertilizer, better seed, and plant protection, is assumed to come about at rates which are considered feasible in West Pakistan. The Study Group considers there is greater scope for increased productivity within prevailing conditions of water supply than does IACA. It recognizes the inherent difficulties in achieving an agricultural breakthrough, but believes this can only be accomplished if water development is matched with a corresponding increase in the use of other inputs. It also believes there is a tendency to overstate the importance of further public water development, and to understate the importance of improved farming employing more and better inputs. Unreliability of water supplies is, in all probability, a greater deterrent to investment and enterprise by farmers than the absolute quantity of water available. The Study Group would therefore place as much emphasis on efforts required to bring about better operation of the system and better farming as it would on further public water development. It would emphasize that no single input, be it water, fertilizer, seed, or anything else, can have its full impact when used in isolation. The various inputs must be applied in the right balance, at the right time, and in the appropriate manner—all of which depend on the skill and judgment of the farmers. The need to impart such knowledge to farmers underscores the importance of effective research and extension services. The Study Group believes that, given proper support, the IACA projections of input use could be exceeded, and therefore looks upon these projections as a minimum requirement needed to support agricultural growth. In its estimates of production, the Study Group has adopted IACA assumptions on input use, with the notable exception of fertilizer where Study Group assumptions are markedly more optimistic than those used by IACA.

The Study Group considers that an offtake target of about 350,000 nutrient tons, equivalent to about 1.6 million tons of ammonium sulphate, would be feasible by 1969/70, or an increase in fertilizer use of about 30 percent per annum over the Third Plan period. It may become more difficult to maintain a similar rate during the Fourth Plan period, and therefore a 15 percent per annum increase has been projected. The target for 1975 would thus be about 700,000 nutrient tons. Both of these targets are approximately double the IACA estimates of offtake for these years. While a high degree of uncertainty is inherent in all such projections, it should be possible for the West Pakistan Authorities to reach these targets, provided appropriate arrangements are made for supplies and distribution, and the costs to farmers are kept at acceptable levels. For the years after 1975, the Study Group would expect the rate of increase in fertilizer use to decline and gradually approach the levels estimated by IACA, i.e., 1.8 million nutrient tons per annum by the year 2000.

Improved seed material, particularly of superior varieties of wheat, cotton, and rice, constitutes a second important agricultural input. West Pakistan has embarked on an active wheat improvement program, in cooperation with Mexican wheat-breeding experts, and imported Mexican varieties and locally developed Mexipak varieties are currently being multiplied and distributed. The technical yield potential of these varieties appears more than three times greater than the average yields obtained in the better farming areas of West Pakistan. The Study Group has assumed that about 50 percent of the wheat acreage would be covered with improved varieties by 1975, and 100 percent by 1985. This implies an ambitious target in terms of multiplication, distribution and acceptance of the improved wheat varieties, but wheat-breeding experts advising the Government have predicted much faster progress. The Study Group estimates thus appear somewhat conservative in comparison with those of the seed specialists. While the Study Group is impressed with the apparent initial successes, it still feels that achievement of its projections would represent a very important advance in the development of West Pakistan's agriculture.

High-yielding dwarf varieties of coarse rice, developed at the International Rice Research Institute in the Philippines, are being tested in West Pakistan with apparently good results. It has been assumed that enough seed would be available for one million acres by 1975, although the Agriculture Department is planning for this much coverage by 1970. The program assumes that improved varieties would be in common use by 1985, and would require more than 180,000 tons of seed annually. Hybrid and synthetic maize varieties also hold much promise for West Pakistan.

The Study Group generally accepts, for planning purposes, the above assessment of the probable progress and contribution to production from improved seed material, but it retains the hope that these projections may prove to be on the conservative side. Improved seed represents an influence which is extremely difficult to measure. It is not a specific term, and to measure progress in terms of the amount of improved seed employed could be quite meaningless because much depends upon the complementary improvement of other practices, and on institutions responsible for production, multiplication, and supervision of the distribution of improved seed material.

Chemical pest control has been provided free to farmers by the Government, but it has suffered from declining importation of pesticides, inadequate storage facilities reducing the specific effective properties of chemicals, and inadequate means for transportation and spraying. It has furthermore diverted a substantial number of potential extension workers from important extension activities in order to provide plant protection service. Nevertheless, plant protection should make a direct contribution to improvement of yields as well as safeguarding the contribution of all other inputs, and this would become increasingly important as farming practice improves and intensifies. This is particularly true for the cotton and rice crops.

The program does not make allowance for plant protection to develop as rapidly as fertilizers, and regards it as unlikely that protective measures would improve much before the use of fertilizer and better husbandry are more generally applied and yields are improved. Accordingly, a relatively small increase in the acreage sprayed has been projected for the first decade (1965–75), after which more general use of chemical control would occur and the number of applications would gradually reach desirable amounts. Mechanized spraying would increase along with the expansion of farm mechanization, but the Government would have to continue aerial spraying against epidemic attacks such as from locusts. 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. This may entail an initial continuance of some form of subsidy, but increasingly the progressive farmers should become willing to acquire effective plant protection services at reasonable costs. The Government should initiate research programs designed to develop simple, practical procedures which can be readily employed by the farmers.

At higher levels of intensities, mechanized cultivation is likely to become a prerequisite for dealing with tight cropping schedules and peak labor requirements, as well as for reducing hired labor costs. To the extent that mechanized cultivation would substitute for animal power, it would also free fodder acreage which could then be used for an expansion of cash crops. Mechanized cultivation would also enable better and more timely land preparation, and thus contribute to yield performance. Since mechanized cultivation is generally no more expensive than bullock farming, land preparation, post planting cultivation, harvesting, and threshing are likely to be mechanized fairly rapidly, although this would be largely limited to the larger farms. Even here, though, rapid adoption would depend greatly on satisfactory service facilities and an adequate supply of spare parts and mechanics. On the smaller farms, land fragmentation and the sharecropping system are likely to be a substantial barrier to rapid mechanization.

The Study Group recognizes the important role that mechanization must play in the progress towards more intensive and more highly commercialized agriculture, and feels every encouragement should be given in the form of credit, advice on suitability for particular conditions and purposes, instruction in operation, ensured supplies of machinery and parts, and adequate service facilities. In view of the preponderance of small farms, careful consideration should be given to the stimulation and support of contract mechanization service and cooperative use of farm machinery, and to the continued improvement of bullock-drawn equipment and hand tools.

IACA has projected a substantial contribution to agricultural production from animal husbandry, and the rapid build-up of an improved cattle herd thus assumes special significance. The principal change in the long term would be from buffalos to zebu cows as milk animals, but the number of buffalo cows is not expected to decline before 1985. To support the anticipated rapid progress thereafter in the development of quality stock, it is necessary to use the best bulls available to the fullest possible extent. IACA had proposed that the upgrading of present zebu herds be done by a massive program of artificial insemination. The technique proposed is the repeated topcrossing of successive generations to selected Sahiwal or Red Sindi sires, leading to the progressive improvement of the national herd. The livestock sector is of such importance to both present and future growth, and is so little understood, that the Study Group suggests that it should be the subject of a special comprehensive study to establish more accurately the sector's present status, and to provide a detailed basis for deciding the requirements for future development.

A summary of conclusions in regard to inputs is offered below:

1. The Study Group feels strongly that development requires the simultaneous improvement of farming practices and irrigation supplies. It also believes there has been a tendency to overstate the importance of further water development and understate the importance of improved farming, including the use of more and better inputs.

2. Study Group projections of fertilizer use are approximately double those of the consultants for the period up to 1975, reflecting the Study Group's belief there is much scope for an increased use of agricultural inputs even under prevailing conditions of water supply.

3. Improved seed material, particularly in wheat, cotton, and rice, constitutes a second major agricultural input likely to have significant impact within the next decade. The Study Group has projected somewhat lower rates of adoption than currently estimated by advisors to the Government, but realization of these more conservative projections would constitute a major advance for West Pakistan. The actual impact of improved seed varieties depends on complementary development in practices and institutions affecting seed distribution and use.

4. Plant protection is not expected to improve as rapidly as fertilizer use and the introduction of improved seeds. The present program should be thoroughly evaluated, and steps taken to shift the major burden of this service from the extension personnel who now provide it.

5. Mechanized cultivation should become more prevalent as timely land preparation becomes necessary under conditions of larger and more reliable water supply. Mechanization is more likely to be adopted on the larger farms than on the fragmented smaller farms, but contract service and cooperative use of machinery could help to bring some of the benefits to the smaller farms. Government should also initiate research on improved animal-drawn equipment and hand tools.

6. The livestock sector is of such importance to agriculture, and yet is so little understood, that the Study Group suggests that it be 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.

Institutions and Organizations. The implementation of the development program outlined herein requires an organizational structure capable of stimulating and serving the rapid growth which is envisaged. The development and expansion of such a structure is an extremely critical and difficult task to which the Government should give immediate and careful attention. The Study Group does feel, however, that for some time to come any further major changes in the pattern of organization should be avoided as far as possible. Emphasis should be on adjustment and improving coordination, rather than further radical change. A second observation is that, to the extent practicable, the private sector should be given maximum opportunity to participate. Aside from these general points, the Study Group noted a number of areas of special concern.

Because the services offered by line departments are complementary, coordination is required to ensure that the advice and services provided to farmers are in keeping with development objectives, and that supplies are available in the right quantities and at the right time.

There is need for more effective coordination between governmental bodies responsible for planning and implementation of projects in order to avoid duplication of effort, and to afford full opportunity to departments and agencies to make their appropriate contributions to the development effort on a continuous basis. The Planning and Development Department appears to be the logical body to exercise the coordinating function for both planning and service objectives.

A Provincial Irrigation Authority is required to make basic policy decisions on barrage installations, dam release patterns, basin-wide water allocations, seasonal distribution, and tubewell pumping policies with reference to both water and power considerations. It should be constituted at the highest level to take fully into account the range of administrative, legal, sociological, and technical considerations related to water resource policy.

As mentioned before, the Study Group feels strongly that the success of the water resource development program depends on emphasis going equally to efficient water use and to better farming practices and the use of more material inputs. Creating the environment which generates this dual emphasis would be a most demanding task, and would call for a high degree of close cooperation and overall direction. The Study Group therefore favors the retention of an integrated project management approach during the development period of projects, despite the difficulties this might entail in relation to divided responsibility for surface and groundwater supplies. In keeping with its belief that further radical reorganization may be counterproductive, the Study Group feels that there are existing project management institutions, such as the Agricultural Development Corporation and the Land and Water Development Board, which could be strengthened and improved, and initially could serve the institutional needs of project areas. When the major changes associated with the project have been accomplished, the project management would withdraw in favor of a more representative body and the line departments would resume their normal functions in the area. The Study Group strongly endorses the IACA suggestion that project management should include provision for continuous monitoring of progress in project areas, starting with the construction phase when bench mark data representing preproject conditions could be gathered. Such monitoring should pay particular attention to the hazards of salinity and alkalinity.

Shortages of engineering personnel, relative to the needs of the water resource development program, are likely to continue for the foreseeable future. Efforts should be made to provide new graduates with further advanced training on-the-job, and to also train promising young men without formal engineering education for appropriate supervisory positions, again while on-the-job. The prospects for training adequate numbers of agricultural personnel for program needs are somewhat better, but the quality of instruction should be improved. As a general rule, the Study Group feels it may be more strategic in the short run to concentrate on improving the quality of agricultural personnel than to become too preoccupied with a rapid expansion of numbers.

It is difficult to foresee substantial improvement in the agricultural sector without a dynamic research program to deal with such matters as continuing varietal improvement, more efficient treatment of insect infestation and plant disease, and better understanding of soil, crop, water, and fertilizer relationships. Building an efficient and contributing research branch requires dedicated leadership, generous financial support, understanding of the role of research, and the infusion of a spirit of service to the agricultural community. Without these elements, research is likely to remain mechanistic and unimaginative, isolated from its constituency, and therefore largely unproductive.

It seems unlikely that West Pakistan can induce a rapid and widespread adoption of a variety of new agricultural inputs and improved farming practices without an informed and active extension service to conduct the necessary educational programs. The extension services need drastic improvement. Training, noted above, is part of this process, but this branch has suffered from its inability to attract and hold highly qualified personnel. Better career opportunities in agriculture, involving more status, better pay, better working conditions, and improved means for carrying out responsibilities appear to be part of the requirements. Quantitative and qualitative improvement of the extension services is thus a critical link in the success of the program, and the measures adopted to bring about such improvement cannot be partial or half-hearted.

The potential contribution from the private sector should be drawn into participation in agricultural development. Encouragement of private tubewell installation has been discussed in earlier sections, and the dependence of the program on private tubewell water has been noted. With adequate safeguards to ensure high quality performance, the private sector could also participate in the provision of material inputs of various kinds, including fertilizers, farm machinery, improved seeds, and plant protection. Government would continue to assume the major role in research and extension, and would maintain a supervisory role with respect to the quality of inputs offered to farmers and the advice on their use which accompanied sale by private agencies. While the Study Group thus takes the view that maximum encouragement and opportunity should be given to private sector participation, the timely provision of adequate inputs at incentive prices remains the primary objective at this time.

An effective credit system for the direct benefit of primary producers has yet to be developed. Credit tends to gravitate towards the more well-to-do elements in the community and to be virtually denied to the majority of farmers who operate the smallest scale farms. The cooperative credit movement has become largely ineffective at the level of the primary society which deals with the farmers. The growing commercialization of agriculture, implicit in the development program, requires better credit facilities and a change in the attitude of farmers towards credit itself. But better institutional credit arrangements alone may not provide a solution to the agricultural credit problem, and Government may have to actively promote a change in farmers' attitudes so that they see a clear distinction between agricultural credit for productive purposes and social credit for relief or domestic needs. The problem has been studied by the Credit Enquiry Commission, but it will take time to implement the recommendations.

A summary of conclusions in regard to institutions is offered below:

1. The Study Group feels that for some time to come major changes in institutions and patterns of organization should be avoided, and that greater efforts be made to improve the functioning of existing institutions.

2. There is need for much more effective coordination of planning, operations, and services to agriculture, and the Planning and Development Department appears the logical body to exercise much of this function.

3. A Provincial Irrigation Authority seems necessary to make basic policy decisions related to the evolving complex system of water supply.

4. The Study Group favors a closely integrated project management for public tubewell project areas.

5. Agricultural development requires effective research and extension services, and this involves both enhancement of career opportunities and better training and equipment for the tasks assigned.

6. Personnel shortages are likely to be most serious in the engineering field. These can be partially mitigated by expanded on-the-job training and by continued use of outside consultants.

7. There is scope for much greater participation by the private sector in the supply, distribution, and handling of agricultural inputs, and gradual inclusion of the private sector in these activities should help to accelerate the rate of use by farmers.

8. Lack of sufficient credit on reasonable terms could act as a curb on agricultural growth, but it would take considerable time to implement the recommendations for change and improvement which have already been advanced by the Credit Enquiry Commission.

Financial Requirements. Estimates have been made of the financial requirements of the Action Program, for both public and private sector expenditures, over the Third and Fourth Plan periods (1965–75). Excluding Tarbela, the requirements for the Third Plan period appear to fall within the original Plan allocation for the water sector, although some redistribution of the allocation of funds within the sector would be necessary. Similarly, the public sector expenditures on agriculture could be accommodated within the original Third Plan allocation to the agricultural sector. Government estimates of Fourth Plan allocations have not yet been drawn up, and the expenditure estimates used by the Study Group are extremely tentative because the actual Fourth Plan requirements would depend on progress made during the preceding Plan period. Nevertheless, the orders of magnitude of expenditures, again exclusive of Tarbela, are comparable to the amounts which have been allocated in the Third Plan, and therefore appear to be within reasonable expectations of the resources likely to be available.

Government allocated Rs. 2,662 million to the water sector for the Third Five Year Plan (1965–70).[1] The water resource portion of the Action Program outlined above, not including works associated with the Indus Basin Treaty or Tarbela Dam, would cost Rs. 2,441 million. The major redistribution of expenditures called for within the water sector includes a reduction in the ongoing public tubewell program relative to the earlier scheduling by WAPDA, and an increase in expenditures for surface drainage. The latter item would reflect a start on construction of the Indus Left Bank Outfall drain, which was not included in Third Plan projections. The Action Program also calls for pilot tile drainage projects, but this is a relatively small addition to the original Third Plan estimates.

The start of work on Tarbela Dam during the Third Plan period would add Rs. 1,414 million to the water sector total, bringing the full expenditure for the Action Program to Rs. 3,855 million. This is nearly 45 percent larger than the original Third Plan sectoral allocation, and is a reflection of the financial impact of Tarbela —more than one-third the total cost of the Action Program for the Third Plan period.

Estimated water sector expenditures for the Fourth Plan period (1970–75), excluding Tarbela, are Rs. 2,736 million. The comparison with the Third Plan costs for the same portion of the water sector shows that expenditures are expected to rise by only 3 percent. The completion of Tarbela by 1975 would again be the major single item. This has been estimated at Rs. 2,789 million for the Fourth Plan period. Together with the rest of the water sector, total expenditures would thus be Rs. 5,525 million. Of this total, Tarbela alone would cost approximately one-half. Five public tubewell schemes under the Action Program and some Tarbela expenditures would continue into the Fifth Plan period, bringing a commitment of about Rs. 130 million as a carryover from the Action Program period. Third Plan allocations and estimated expenditures for both Plan periods are shown in Table 9-3.

The foreign exchange component can be estimated in only an indicative way. Tubewells, surface irrigation, drainage and flood protection could involve a foreign exchange cost of about Rs. 4,150 million (equivalent to US$ 874 million) over the period 1965/66 to 1974/75. Investigations could require an additional Rs. 200–250 million (equivalent to US$ 42–53 million) in foreign exchange. Total foreign exchange requirements for the Action Program might thus be about Rs. 4,400 million (equivalent to US$ 927 million), from which would be deducted the foreign exchange component of the overrun of the Action Program into the Fifth Plan period, or about Rs. 75 million.

The estimates of private sector investment in water resource development include private tubewells and (in the Fourth Plan period) on-farm costs for drainage carried out by farmers in conjunction with the Sukh Beas Drainage Scheme. The estimates for private tubewell installation are based on the numbers of wells pro-

[1] Government of Pakistan, Third Five Year Plan, May 1965. A subsequent revision of December 1966 reduced this total to Rs. 2,180 million.

TABLE 9-3
COMPARISON OF PUBLIC INVESTMENT REQUIREMENTS FOR WATER DEVELOPMENT

	Third Plan Period		Fourth Plan Period	
	Plan Allocation[a]	Action Program	Plan Allocation	Action Program
	(Rs. million)			
Public Tubewells	1,389	1,044	n.a.	1,339
Surface Irrigation	793	705	n.a.	352
Surface Drainage	195	363	n.a.	516
Tile Drainage	—	39	n.a.	184
Flood Protection	73	74	n.a.	75
Investigations	187	191	n.a.	240
Miscellaneous	25	25	n.a.	30
Subtotal	2,662	2,441		2,736
Tarbela	1,414	1,414	n.a.	2,789
Total	4,076	3,855		5,525

[a] May 1965.

jected under the Action Program, which takes into account the deferment of some public tubewell projects. It also allows for some increase in the cost of private well construction. Expenditures on private wells have been projected at Rs. 428 million during the Third Plan period and Rs. 334 million in the Fourth Plan period. Expenditures for drainage have been estimated at Rs. 13 million in the Fourth Plan period. These are quite tentative, especially for the Fourth Plan period, because any shortfall in the public tubewell program would tend to raise the private sector estimates. Further, the rate of installation in noncommanded areas is unpredictable, and may well be substantially above the numbers which have been projected.

Plan allocations to the agricultural sector in the Third Five Year Plan place a heavy emphasis on promoting the use of agricultural inputs. About 40 percent of the allocation is for fertilizer subsidies, free plant protection service, and seed multiplication and distribution, of which fertilizer subsidies were the largest single item. An additional 20 percent was allocated for extension, research, mechanization and soil conservation. The balance covered activities such as animal husbandry, range management, colonization, forestry, fisheries, cooperatives, and the Agricultural Development Bank. The total allocation for the Third Plan period was originally Rs. 2,554 million. Third Plan allocations, and estimated expenditures for both Plan periods, are shown in Table 9-4.

The Study Group has assumed that the rate of subsidy on fertilizer use (approximately 30 percent) would be lower than the rate in effect at the time the Plan was drawn up. For the Fourth Plan period, the Study Group has raised the allocations for fertilizer subsidies and plant protection in accordance with its expectations relative to increasing use of inputs other than water. There should be increasing participation by the private sector in plant protection activities, but this would be a slow process and not likely to materially relieve the public sector of expenditures on this account during the Fourth Plan period.

TABLE 9-4
COMPARISON OF PUBLIC INVESTMENT REQUIREMENTS FOR AGRICULTURAL DEVELOPMENT

	Third Plan Period		Fourth Plan Period	
	Plan Allocation[a]	Action Program	Plan Allocation	Action Program
		(Rs. million)		
Fertilizer Subsidies	678 (395)	500	n.a.	700
Plant Protection Subsidies	300 (184)	300	n.a.	500
Extension and Research	182 (49)	180	n.a.	260
Mechanization	214 (123)	214	n.a.	2,835
Soil Conservation	105 (95)	105	n.a.	
Animal Husbandry	112 (90)	112	n.a.	
Colonization	117 (94)	117	n.a.	
Forestry and Fisheries	304 (171)	304	n.a.	
Others	364 (363)	364	n.a.	
Subtotal	2,376	2,196		4,295
Capital Liability[b]	178 (58)	178	n.a.	350
Total	2,554	2,374		4,645

[a] May 1965. Figures in parentheses are from the revision of Dec. 1966, but the revision, as made available, did not provide any provincial breakdown of Central Government allocations. The figures shown in parentheses thus represent the Provincial allocations only.
[b] On Government Account: Cooperatives, ADB, taccavi loans.

The Study Group program results in a reduction from the original Third Plan allocation to the agricultural sector of Rs. 2,554 million to Rs. 2,374 million, or about seven percent. Fourth Plan estimates tentatively total Rs. 4,645 million, or about 82 percent more than allocated by Government to the agricultural sector under the Third Plan. Foreign exchange requirements for the Third Plan period have been estimated at Rs. 378 million, or about 20 percent of the total. Despite rising use of inputs, the foreign exchange needs for fertilizer and mechanization should not increase substantially during the Fourth Plan period because there would be increasingly local capacity to produce these items. The Study Group has therefore assumed that foreign exchange requirements would remain at about the present level, or at approximately Rs. 400 million for the Plan period. For the Action Program period as a whole, the foreign exchange costs for agricultural development would be Rs. 778 million, or the equivalent of US$ 163 million.

The private sector would continue to make investments in land development, improvements of irrigation facilities (other than tubewells), additions to farm buildings and implements, and increases in livestock herds. Recurrent production expenditures, such as for fertilizers, would be excluded from this category. On the basis of the limited information available for such private expenditures, the projections show a total of Rs. 1,900 million during the Third Plan period and Rs. 3,800 million during the Fourth Plan period. The total for the period covered by the Action Program would thus be Rs. 5,700 million. Assuming that 90 percent of such private investment occurs in the irrigated areas of the Indus Basin, this would represent investments of Rs. 11 per acre and Rs. 23 per acre for the two Plan periods respectively. This would be less than 10 percent of the gross production value per acre of these lands, and therefore appears to lie within the realm of possibility. It should be emphasized, however, that these are extremely crude estimates of these kinds of private investment.

The total financial requirements for the Action Program, broken down by categories of water and agriculture, public and private, and the foreign exchange components are shown in Table 9-5. It indicates that expenditures on the whole during the Fourth Plan period would go up by about 68 percent over those during the Third Plan period, and that there would be increasing emphasis on agricultural development expenditures in both public and private sectors. It also indicates that even in the Fourth Plan the public sector would have to provide financial support to the extent of more than 70 percent of the total requirements. While this appears necessary, it also illustrates an anticipated lack of incentives to invest in agriculture which may be compounded by the limited access to institutional credit facilities. Tentative estimates show that at least Rs. 1,000 million may move from the rural to the urban sector each year in West Pakistan, which is a measure of the relative attractiveness of consumption of nonagricultural investment compared to investment in agriculture itself. To the extent that agriculture is likely to continue as the main contributor to GNP for some time, it would be highly desirable to redirect this flow of funds, and eventually reach a position where the private sector would make a substantially larger contribution to capital formation in agriculture. In this context, private tubewells offer an area of opportunity in which private investment and private initiative should be encouraged to make the maximum contribution.

TABLE 9-5
FINANCIAL REQUIREMENTS FOR THE ACTION PROGRAM IRRIGATION AND AGRICULTURAL EXPENDITURES 1965–75

	Third Plan		Fourth Plan		Total	
	Expenditures	Foreign Exchange	Expenditures	Foreign Exchange	Expenditures	Foreign Exchange
			(Rs. million)			
Public Sector:						
Water Development	3,855	1,700	5,525	2,450	9,380	4,150
Agricultural Development	2,374	380	4,645	400	7,019	780
Subtotal	6,229	2,080	10,170	2,850	16,399	4,930
Private Sector:						
Water Development	428	70	321	50	749	120
Agricultural Development	1,900	270	3,800	1,000	5,700	1,270
Subtotal	2,328	340	4,121	1,050	6,447	1,390
Total:						
Water Development	4,283	1,770	5,846	2,500	10,129	4,270
Agricultural Development	4,274	650	8,445	1,400	12,719	2,050
Total	8,557	2,420	14,291	3,900	22,848	6,320
US$ Equivalent (Mill.) @ Rs. 4.75 = US$ 1.00	1,801	510	3,023	824	4,825	1,334

A summary of conclusions in regard to financial requirements is offered below:

1. The financial requirements of the Action Program, excluding Tarbela, would appear to fall within the original allocations to the water and agricultural sectors for the Third Plan period. The subsequently revised allocations to the water sector are slightly below Action Program requirements, but revised allocations to the agricultural sector are considerably lower.

2. The water sector portion of the Action Program, again excluding Tarbela, would require about the same financing in the Fourth Plan as in the Third Plan period. Expenditures in the agricultural sector would rise sharply, however, as a result of the expected increase in the use of agricultural inputs.

3. The inclusion of Tarbela would increase the required allocation for the water sector by nearly 60 percent during the Third Plan, and would double the allocation for the Fourth Plan period.

4. Anticipated annual private investments (other than in tubewells) would be Rs. 11 per acre and Rs. 23 per acre in the Third and Fourth Plan periods respectively. These would be less than 10 percent of the gross production value per acre of the irrigated lands, and therefore the investments appear to be within the realm of possibility.

5. Total expenditures for water and agriculture during the Fourth Plan period should exceed those for the Third Plan by nearly 70 percent, and in the Fourth Plan public sector expenditures would still provide more than 70 percent of total requirements.

6. The foregoing expectation of continuing reliance on the public sector indicates a need for public policies which increase incentives to invest in agricultural development, and to reverse the apparent net flow of resources from agriculture to other sectors of the economy.

Agricultural Production

The Study Group has attempted to estimate 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. These Study Group estimates, differing somewhat from the IACA projections of production, reflect the major assumptions made by the Study Group, and in general anticipate large cropped acreages and greater use of non-water inputs in early years than IACA. This results in higher growth rates in the early years, but a smoother production path over the entire period of 35 years.

The Study Group projections envisage a growth in Gross Value Added (GVA) in the agricultural sector of 4.5 percent per annum between 1965 and 1975, and a growth rate of GVA for the entire period, 1965–2000, of 4.2 percent per annum. This compares to a growth rate of 3.8 percent for the Second Plan period. The growth rates measured in Gross Production Value (GPV) would be 5.2 percent per annum from 1965–75, and 4.5 percent per annum for the period 1965-2000. The GPV per cropped acre would rise three times or more in most parts of the Indus Basin, and in the canal commanded areas would reach an average of about Rs. 760 per cropped acre by the year 2000. In the early period of development, 1965–75, more than half the assumed increase in production would come from improved yields per acre. The relative importance of yields (compared with expansions in acreage) increases over time, until by 1985 improved yields become virtually the sole means by which further growth in production is achieved.

While the returns per cropped acre should rise on even the small holdings, the Action Program is not designed to cope with the problems of rural poverty which stem from the existence of numerous farmers with uneconomical small holdings and widespread underemployment. This type of rural poverty requires structural transformation, including the movement of population out of agriculture and into other occupations, as part of the long-term solution.

The Study Group projections show lower rates of growth after 1985 than before that date because of the declining contribution of acreage expansion, 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.

The Action Program was drawn up primarily on the basis of what is practically achievable and consistent with available resources. Production was projected independently of the assessment of likely future demands. Moreover, while prices of commodities were 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. Although this approach to production thus evolved somewhat in isolation from demand considerations, a comparison was made against projections of future demand to determine whether the Program might meet West Pakistan's requirements.

As would be expected, supply and demand projections did not show a balance for each commodity. Demand was based on the assumed income (expenditure) elasticities for different commodities over time, a "high" population growth rate, and a growth in income (expenditure) consistent with the growth projected for the agricultural sector. While there was a surprising closeness of the projected supply and demand of some commodities, there were also deficits and surpluses in the different reference years.

The Study Group concluded that the production and acreage which had been projected offer sufficient flexibility to adjust the surpluses and deficits. This adjustment could come about because acreage in surplus crops can, in many cases, be used for production of deficit crops within the same season and at about the same level of crop water requirements. The Study Group is confident that adequate flexibility exists in the proposed program to allay fears over major shortfalls in foodgrain production, but would emphasize that Government price and marketing policies would have to be fashioned in ways which encourage the shifts in cropping patterns needed to eliminate surpluses and deficits. Such policies should permit price incentives to play a constructive role in allocating agricultural resources.

The achievement of the rates of growth of agricultural production contained in the Study Group projections would represent a most commendable performance, although these rates are short of the targets contained in the Perspective Plan. Agriculture will continue to be the single most important sector in the West Pakistan economy for the foreseeable future, and the growth of the West Pakistan economy as a whole would therefore depend to a large extent on agriculture's performance. It is thus imperative that the agricultural sector receive the attention and support recommended throughout the Report. Although higher levels of production than projected by the Study Group appear technically feasible, it is the Study Group's opinion that within the given economic, social, and institutional environment, it would be unrealistic to expect growth of production considerably beyond that projected in the Report.

A summary of conclusions in regard to agricultural production is offered below:

1. The Study Group has projected an agricultural sectoral growth rate in Gross Value Added (GVA) of 4.5 percent per annum from 1965 to 1975, and an average 4.2 percent per annum for the period 1965–2000. This compares with a growth rate in GVA of 3.8 percent per annum over the Second Plan period.

2. The Study Group has projected a sectoral growth rate in Gross Production Value (GPV) of 5.2 percent per annum from 1965 to 1975, and 4.5 percent per annum for the period 1965–2000. The GPV per acre would increase by three times or more in most parts of the Indus Basin, and in canal commanded areas would reach Rs. 760 per acre by the year 2000.

3. More than half the assumed increase in production would come from improved yields, and improved yields would be virtually the sole means of production increase beyond 1985.

4. The Action Program is not designed to cope effectively with the problem of rural poverty, which requires a structural transformation in West Pakistan's economy accompanied by a movement of population out of agriculture and into other occupations as part of the long-run solution.

5. Although supply and demand projections did not show balance in the reference years, the Study Group believes that there is sufficient flexibility in the way the land and water resources can be used to meet future deficits, particularly in foodgrains. Adjusting to meet such possible deficits would require public policies which encourage the required shifts in resource use, including policies which permit price incentives to play a constructive role in allocating agricultural resources.

6. Higher levels of production than projected by the Study Group appear technically feasible, but it is the Study Group's opinion that within the given economic, social, and institutional environment, it would be unrealistic to expect growth of production considerably beyond that projected in the Report.

Annex 1

WATERCOURSE STUDIES

Background

At the time the Study Group was setting up the working arrangements for the study (June 1964), the LIP consultants were already at an advanced stage with a Regional Survey of the Sind; this survey was due to be completed in 1965. Included in the LIP survey were some 60 watercourse studies designed to obtain detailed basic data on farming conditions in the Sind. It was agreed with the Government[1] that the Study Group's consultants would set up a similar (but smaller and shorter duration) arrangement in the Punjab so that the combined results would provide a fairly good coverage of the irrigated plains and reasonably sound basic data. This annex contains in brief summary some of the findings of the two sets of watercourse studies.[2]

A watercourse is the basic unit of the irrigation system and in these studies is defined as the area of land served by a fixed outlet from a canal or distributary. Farmers may live within the watercourse, or in a nearby village, and often have land in more than one watercourse. It is the most suitable unit for studying on-farm irrigation practices. The objectives of the two studies were similar; namely, to determine at first-hand the present state of agricultural development, to provide basic and reliable data for the formulation of development plans, and to obtain a base from which the progress of development schemes could be assessed.

The main differences between the two sets of watercourse studies were in their size and duration. The LIP watercourse studies extended over some 18,170 acres in the Sind (representing 0.15 percent of the official CCA of the Region) and were conducted over four seasons. The IACA watercourse studies covered some 6,200 acres in the Punjab (0.03 percent of the CCA) with a partial coverage of a further 3,900 acres, and the period of study was less than two full seasons.

The study areas in the Sind were chosen to represent each of the main geographical areas as well as the major canal commands. Within the 12 categories established, a stratified sampling technique was employed to select 60 watercourses for detailed study with an average size of about 300 acres.

A different procedure was adopted by IACA in the Punjab. Ten representative sample areas, each covering 500 square miles, were delineated. In each of these sample areas two watercourses, sited wherever possible at the head and tail sections of a distributary, were selected for detailed study. This provided 20 watercourses for detailed study with an average size of about 300 acres.

Within the selected watercourses (60 in the Sind and 20 in the Punjab), detailed records were made of all farming activities. For the watercourses as a whole, these were made weekly or fortnightly, but within most watercourses one farm was

[1] Irrigation and Agriculture Section paper: IA/1 dated June 6, 1964.
[2] Lower Indus Report, Hunting Technical Services; Sir M. Macdonald & Partners.

selected on which daily records were made of all activities. These voluminous detailed records were analyzed to provide information on all aspects of farming practice including water management, frequency and methods of cultivation, physical inputs, yields, farm costs and some aspects of farm management. Some of the principal findings or observations emerging from these studies are set out below.

Land

In the irrigated areas of both regions, about 3 to 4 percent of the area is occupied by roads, canals, villages, etc., leaving available for agriculture about 96-97 percent of the gross area. In the Punjab more than 7 percent is also excluded, mainly because of salinity. The average culturable waste in the Sind was even higher, at 19 percent. There were marked differences in land tenure between the Punjab and the Sind. The former is characterized by small landowners predominantly farming their own land. By contrast, the Sind had larger landowners generally farming the land by sharecropping tenants.

Soils

Chemical and physical analyses of the soils of the Punjab suggested that quality varied widely. An attempt was made to assess the effects of soil quality on yield by grouping soil types into four major categories. Yields associated with these showed that only the poorest class of soils gave consistently lower yields. Since the distinguishing characteristics were heavy texture, marked salinity and alkalinity, it was concluded that these were important constraints. In the Punjab, some degree of salinity was present in 77 percent of all soil profiles examined and 28 percent of the samples showed some degree of alkalinity. For the Sind, where less precise measurements were made, it was evident that salinity in its extreme form was a very serious constraint on production. It was also concluded that these constraints could be reduced under conditions of better watering and controlled water tables.

Water

Cropping patterns in both regions were markedly influenced by the times during which canal supplies were available for irrigation, the major distinction being between perennial and nonperennial supplies. In the Punjab, some nonperennial canals supply water for short periods in winter. This, combined with the greater prevalence of fresh groundwater in the Punjab and its exploitation by tubewells and Persian wheels, tended to obscure the differences in the cropping on the perennial and nonperennial canals, which is very marked in the Sind. Comparisons between annual cropping intensities (though for different agricultural years) indicated an overall average of 123 percent for the Punjab and only 88 percent for the Sind. The studies showed that there was a considerable range of intensities in the Punjab, from 65 to 175 percent.

Both the Punjab and Sind investigations provided evidence of widespread underwatering. In the Punjab there was only limited evidence of higher yields resulting from higher applications of water alone. The Sind studies showed that increased water supply up to 20 inches in the case of wheat gave increased yield but, beyond this level, there was no further increase due to water alone, and yields actually declined. The general conclusion appeared to be that under prevailing conditions timing and regularity of supply is at least as important as the total amount of water.

Physical distribution of water on all watercourses is frequently complicated and inefficient. The LIP group estimated for the Sind that adoption of a rectangular field layout plus better watercourse maintenance would make 17.5 percent more water available. In addition, the studies indicated that there was considerable tampering with and blocking of outlets, together with other irregular practices. This was done mainly during the sowing season when there is a peak requirement for irrigation. The larger farmers frequently received additional supplies and, conversely, the more numerous smaller farmers received a reduced supply and suffered accordingly. The hazard of irregular supply is always present. Because of the uncertain and short supply, farmers deliberately plan to underirrigate, employing extensive rather than intensive practices.

Labor

In both regions, the studies report hidden unemployment as well as seasonal underemployment of labor. There is a considerable reserve of labor available to meet the increased demands of higher cropping intensities, especially if the underutilized family labor is included.

Livestock

Only a very small percentage of farmers had no working bullocks. In the Punjab the average cropped area per pair of bullocks was 12.5 acres. The comparable figure for the Sind was 16 acres. Between 20 and 50 percent of the annual cropped area was devoted to fodder crops in the Sind. The comparable area devoted to fodder in the Punjab was nearly 60 percent. Malnutrition amongst young and unproductive zebu cattle is prevalent in both regions. Stock density was higher in the Punjab at 505 animal units per thousand acres CCA compared with 379 in the Sind. The total annual amount of TDN fed to livestock averaged over 3,800 lb. for the Punjab compared with little more than 3,000 lb. for the Sind. While it appeared that the feeding of productive animals was adequate, at least from the Punjab studies, there was inadequate knowledge of TDN requirements for work animals. Even the higher figure of 3,800 lb. TDN above obscures the fact that the protein constituent fluctuates widely and is often low for extended periods, and it has been concluded that this is an important cause of delayed maturity in livestock. At present, no attempt is made to conserve such protein-rich fodder as berseem, and while working bullocks and cows in milk are presumed to be adequately fed, grazing stock or dry cows receive little supplementary rations and are forced to subsist on a low plane of nutrition based mainly on grazing and browsing. Very few farms were larger than the 80-acres holding deemed to be required in the Punjab to make tractor power in place of draft animals worthwhile. (The corresponding figure of 60 acres given from the Sind study is surprising in the light of current cropping intensities.) In their conclusions on the nutrition of work animals, IACA has pointed out that more extensive study is needed on the whole problem of work animals, their work output and feed requirements.

Fertilizer

The LIP group carried out numerous fertilizer trials on the main crops of the Sind. In most cases the trials were superimposed on actual farmers' fields. These were selected for uniformity of crop cover and therefore tended to reflect better-than-average farmers on better-than-average land and with favorable water conditions. Nevertheless, widespread underwatering was recorded. Average response of wheat, based on more than one hundred experiments conducted on lighter textured soils, showed that nitrogen at 40 lb. per acre without phosphate gave a 27 percent increase over the control yield of 16.9 maunds per acre. The increase with 200 lb. of single superphosphate added was 34 percent, a result similar to the long-term average obtained by the West Pakistan Department of Agriculture. Results on the heavier textured soils were less conclusive and yields without fertilizer were considerably lower at 5.5 maunds per acre. There were indications that higher dressings than 40 lb. of N would be optimal.

Evidence for yield response of rice to fertilizers indicated that the best results were obtained when this was applied at transplanting. Unfortunately, getting the best results from this top-dressing demands complete water control and fields to be drained prior to application. This condition could not generally be fulfilled in the Sind.

The failure of cotton, as grown under present conditions, to respond to fertilizer was ascribed mainly to low plant populations. These in turn were said to be a reflection of the farmer's reaction to the hazardous water supply situation and to inadequate plant protection measures.

Information from the Punjab study was less direct since no formal experiments other than those of the Rapid Soil Fertility Testing Scheme were available. These indicated that 40 lb. nitrogen and 200 lb. single superphosphate led to a yield increase of about 40 percent. Fertilizer usage was reported to be common throughout the Punjab watercourses. Unfortunately, IACA was unable to relate yields directly to fertilizer applications. They pointed out that from field observation, farmers appeared to be aware of the benefits of fertilizers especially when the amount of water was adequate with regularity of supply.

Improved Seed

The Punjab study indicated that farmers on all but one of the 20 watercourses purchased seed of the desirable American-type cotton, thus indicating that, provided the quality of seed was good and supplies were available, there should be no difficulty in introducing better varieties. In the case of rice also, the advantages of pure seed of recommended varieties has long been recognized. The supply is inadequate. Efforts to overcome the shortage of good seed have led to adulteration and abuses with consequent disrepute of the seed.

The studies also showed that a number of recommended wheat varieties bred in Pakistan are being grown in the Punjab watercourses. The best yielding of these require abundant water and rich soils or artificial fertilizer to achieve potential yields of the order of 56 maunds per acre. In practice, farmers have made wider use of a lower yield potential variety which is described as being suited to average fertility and irrigation conditions and this variety accounts for 36 percent of the total wheat acreage on the watercourses.

In its conclusions, IACA noted that while new varieties are readily accepted by the larger farmers, the majority of farmers are content to wait until seed becomes freely available as a result of local multiplication during which time they will have been able to assess its merits.

Cultivation Methods

Seedbed preparation was found to be one of the most important factors affecting germination and subsequent early development of grain. Because the soils of West Pakistan generally have poor structure, this aspect of cultivation is of great importance. Unfortunately, no generalized description of requirements to secure good seedbed conditions could be given. Consistently high yields of wheat were obtained only by those farmers who devoted considerable attention to seedbed preparation.

Other cultivation practices were shown to be of great importance in the Sind. Higher yield for both wheat and cotton were obtained with increased numbers of ploughings, smoothing, and good standards of levelling. The magnitude of the differences due to cultivation practices was impressive. For wheat, yield differences varied from 9 to 15 maunds per acre and cotton from 6 to 12 maunds according to the number of ploughings from one to seven. Even allowing for some interaction effects which could be attributed to other factors, these results indicate that agronomic practices reflecting management rather than physical inputs have great effects on yields.

Plant Population

Farmers on the Punjab watercourses were well aware of the relationship between plant population and yield of certain crops. But because of their expectation of shortage of irrigation water, they were generally cautious about increasing plant density. Even the highest plant populations recorded both for wheat and cotton were low by standards in other parts of the world. Averages for cotton in the Sind of 11,300 plants per acre and for the Punjab of 10,000 set a low limit to yield under existing conditions. The Sind study also showed for cotton that economic returns from the use of fertilizer and pesticide inputs were not likely to be obtained unless plant populations exceeded 16,000 plants per acre.

Credit

The situation regarding credit requirements was compiled from a sample of farmers from each of the 20 watercourses in the Punjab. Nearly 64 percent of the 460 farmers in the sample were found to be in debt. Of the indebtedness, which averaged Rs. 30 per acre, about 60 percent was estimated to be incurred in the interests of farming. No direct relationship between debt and farm-size class was evident; it was observed, however, that in the tenant group the debt per farmer was highest in the 0-5 acre class and lowest in the size class of 25 acres or more. Owners and owner/tenants generally had lower indebtedness than tenants. Furthermore, owner farmers with holdings of 15 or more acres in the Punjab were found to be capable of generating savings. The general conclusion was that, while there appeared to be an adequate supply of short-term credit available for working capital or purchase of small implements under present conditions, there was a shortage of medium-term and long-term credit for effecting major improvements such as land reclamation, drainage, installation of tubewells, etc. Short-term credit was generally obtained from noninstitutional sources. Better facilities for obtaining medium- and long-term credit should be made more readily available to farmers.

The official sources of credit were reported to be too difficult for the smaller farmers and more particularly sharecropping tenants to use. The difficulties to be overcome and the procedure involved before a loan could be obtained were too great. Where the Cooperative Bank was well established, it proved to be a popular source of credit. It was concluded that the establishment of more Cooperative Banks should be encouraged to provide medium- and long-term credit.

Yields

Both the Sind and Punjab studies indicated that given present agricultural practices the attainment of high yields is a relatively slow process even when good management is employed. Earlier discussion indicates the complexity of constraints which operate both in the Punjab and in the Sind. In general terms there was no identifiable situation on the watercourses which was unequivocally associated with high yields. Clearly, water is a generally limiting factor, and the farmers' response has been to adopt what seems to be a limited and rational system of underwatering. There were enough tubewells in the Punjab watercourses to provide a considerable range of water availability but, except in the case of wheat, IACA was unable to show that the watercourses with better water availability had better yields. These findings go some way towards explaining the reasons for the widespread practice of underwatering. It is evident that within limits spreading a limited amount of water over a wider area gives a higher production than concentrating that amount of water on a small area. Where farming intensities are high and sufficient water to include a leaching element is applied to the kharif crop, this practice is justified. But if farming intensities are low and insufficient water is applied in kharif to remove salt accumulated in rabi, continued underwatering would lead to a progressive decline in crop yields.

IACA has summarized the situation as one in which multiple limitations are acting together. Amongst them are general underwatering, deficiency of nitrogen, widespread salinity, for some crops damaging pests, a difficulty in obtaining good seedbeds, broadcasting rather than line sowing of crops and groundwater levels too high. All of these factors have been investigated by the research stations, usually as single variables, sometimes in restricted combinations, and often under conditions better than those found on the watercourses.

There is no doubt that additional water supplies lead quickly to increased production, but on the evidence of the watercourse studies IACA believes that the increase comes very largely from increased cropped area and only very secondarily from increased yields. In a situation where underwatering is a general practice it would be surprising if other limitations were not also effective, particularly since one limitation, salinity, should be rapidly improved by improved watering.

While the use of fertilizer was fairly common on the watercourses IACA was unable to show any uniform or striking response. Nevertheless, it is stated there is in West Pakistan, in general, much stronger evidence for the response to nitrogen than for the response to water. It seems possible that yield increases should be associated with fertilizer combined with water—in that order—and limited by other constraints. If this analysis is correct, there is no single input which should be expected to give dramatic increases in yields, and it is not by any means clear which inputs should receive priority. The weight of the evidence seems to favor fertilizers followed by water. There is a strong case for multiple factor experiments covering fertilizers, water delta, seedbed preparation, plant population, pest and disease control and variety. The current thinking that additional water followed by fertilizer and other inputs is a fully confirmed order of priorities may have to be reexamined.

Management and Extension Services

Management at farm level as illustrated by the farmers' skillful allocation of limited resources appears to be adequate at the present time and with present inputs. Overcoming the constraints on the factors involved in production would eventually need a complex series of new inputs. As this is attempted, there would be a need for more sophisticated management. The extension service should recognize this need in advance and begin to strengthen its farm management advice in conjunction with other specialists. This role of the extension services should be recognized as of paramount importance. The complexity and variability of the farming problems call for exceptional skill on the part of extension officers. IACA considers that identification of constraints under different situations calls for skills which are rare in the present services and, since these only develop slowly, their absence may act as a constraint on development.

The surveys indicated that farmers are receptive to advice. From the rapidity of the response to tubewell water, the readiness to change cropping patterns, the awareness that new varieties may be better than old ones, the acceptance of fertilizers and the general skill in using resources, IACA has concluded that conservatism and resistance to change should not be considered to be crippling constraints.

Annex 2

ANALYSIS OF IACA'S PRODUCTION PROJECTIONS BY AGRICULTURAL ZONES IN THE CANAL COMMANDED AREAS

Analysis of Growth of Agricultural Output by Zones

For purposes of assessing agricultural conditions and making projections, IACA grouped the canal irrigated lands having similar crop distribution into nine agricultural zones (see Map 2). Except for Zone I, Peshawar Vale, all are in the Indus Plains. The nine zones and the canal commands they included are given in Table A2–1.

TABLE A2–1

DIVISIONS OF CCA

Agricultural Zone	Canal Commands Included
Zone I —*Peshawar Vale*	Upper Swat, Lower Swat, Kabul River and Warsak High Level.
Zone II —*Punjab Rice Area*	Upper Chenab, Marala Ravi, Upper Jhelum, Ravi Dipalpur, Dipalpur above BS, northern tips of Lower Chenab, Bari Doab, Dipalpur below BS.
Zone III —*Punjab Cotton Area*	Lower Jhelum, Lower Chenab, Lower Bari Doab, Dipalpur below B.S., Pakpattan, Sidhnai, Haveli, Mailsi, Bahawal, Fordwah Sadiqia, Qaim, Panjnad Abbasia.
Zone IV —*Punjab Development Area*	Paharpur, Thal, D.G. Khan, Rangpur, Muzzafargarh.
Zone V —*Sind Cotton Area*	Ghotki, Khairpur, Rohri, Nara.
Zone VI —*Gudu and Sukkur Perennial Rice Area*	Northwest and Dadu.
Zone VII —*Gudu and Sukkur Nonperennial Rice Area*	Begari Sind, Desert, Pat, Khirtar, Rice.
Zone VIII—*Ghulam Mohammed Nonperennial Rice Area*	Pinyari, Fuleli, Kalri Baghar Feeder.
Zone IX —*Ghulam Mohammed Perennial Area*	Tando Bago, Gaja, Ochito, Kalri Pumps.

IACA based its estimation of 1965 cropping patterns and cropping intensities for all canal commands on data supplied by the Irrigation Department, the Bureau of Statistics, the 1960 Census and a paper by Ghulam Mohammed.[1] For the Sind, data compiled by the LIP consultants were used.

These data are not intended to represent the agricultural situation on any one farm, but to provide an average picture of a specific region. Within such a region, variations in cropping patterns, intensities and prevailing level of production reflect differences due to climate, soils, water supply, tenancy, farm size, use of inputs and husbandry practices, markets and processing facilities. Differences in cropping patterns and intensities are, however, generally more pronounced between rather than within agricultural zones because of the greater influence of some of the above factors as well as the respective stage of development.

The more important crops grown during the kharif and rabi seasons in the respective zones are given in Table A2–2 below, together with the percentages of land they occupied in each of the seasons. Throughout this annex, both the kharif and the rabi seasonal cropped acreages take into account the perennial crops, i.e., perennials are counted twice.

The zonal cropping characteristics are distinctive. Thus in Zone I, the Peshawar Vale, the main emphasis is on food crops rather than cash crops. Nearly 50 percent of the cropped acreage in kharif is under maize and more than 50 percent of the rabi acreage is under wheat. The greater part of the sugarcane is grown in Zones I and IX. Rice occupies 55 percent of the kharif cropped area in Zone II, the Punjab Rice Area, and even more in the Sind Rice Areas of Zones VI to VIII. Cotton, similarly, dominates the Punjab Cotton Area, Zone III, and the Sind Cotton Area, Zone V, but in these, as in other zones, the important position occupied by wheat is clearly shown. It is noteworthy that the areas under oil seeds, gram and pulses begin to increase at the expense of wheat from the Punjab southwards reflecting the increasing uncertainties of rabi water supplies. The high proportion of millet grown during kharif in the Punjab Development Area (Zone IV), is an indication of the farmers' preoccupation with subsistence rather than cash crops at a comparatively early stage of development.

Seasonal and annual cropping intensities and cropped acreages of the agricultural zones for 1965, and those projected by IACA for reference years, are given in Table A2–3. Real cropping intensity in each season will be the sum of the area under annual crops plus the area under perennials. Thus for Zone I, the actual kharif intensity for 1965 was 67.2 percent and that for rabi was 67.7 percent, giving the annual cropping intensity of 135 percent. This high intensity results from both large acreages under sugarcane and fruit, as well as to favorable water supplies. Low rabi intensities for Zones IV, V and VIII reflect the unreliability of rabi supplies mentioned earlier. Even with the large sugarcane acreage in Zone IX, the low rabi acreage suggests that perennial water supplies are not uniformly distributed throughout the zone.

IACA considers that the ultimate attainment of 150 percent cropping intensity would result from additional water supplies associated with other inputs in all zones except VIII for which rabi supplies would continue to be unreliable. The present and ultimate patterns shown in Table A2–3 reflect the proposals to use water

[1] Private Tubewell Development and Cropping Patterns in West Pakistan, "Research Report No. 28," Pakistan Institute of Development Economics, March 1965.

TABLE A2–2

PROPORTION OF CROPPED AREA UNDER MAJOR CROPS DURING KHARIF AND RABI SEASONS FOR THE NINE AGRICULTURAL ZONES

(percent)

	Kharif						Rabi			
Zone	Rice	Cotton	Maize	Millet	Fodder	Sugar	Wheat	Oilseeds[a] Gram Pulses	Fodder	Sugar
I. Peshawar Vale			47		5	26	53		11	26
II. Punjab Rice Area	49	11			14	9	63	7	20	8
III. Punjab Cotton Area		38			20	13	55	11	20	10
IV. Punjab Development Area		19		32	23	6	66	19	10	4
V. Sind Cotton Area		49			20	5	47	30	12	5
VI. Gudu and Sukkur Rice Area (perennial)	76				6	2	41	29	26	2
VII. Gudu and Sukkur Rice Area (non-perennial)	86				7		31	40	29	
VIII. Ghulam Mohammed Rice Area (non-perennial)	94				2		22	54	19	
IX. Ghulam Mohammed Rice Area[b] (perennial)	32	31			5	24	42	13	18	27

[a] Oilseeds in northern zones, gram and pulses increase southwards.

[b] Although in the rice area, the zone influenced by sugar mill at Tandojam.

TABLE A2-3

CCA, CROPPED ACRES AND CROPPING INTENSITIES FOR THE NINE AGRICULTURAL ZONES

(acres in million: intensity percent)

	Zones											
	I	II	III	IV	Total Punjab	V	VI	VII	VIII	IX	Total Sind	Basin Total
CCA	0.7	3.1	13.0	3.6	19.7	5.2	1.0	1.4	1.0	0.3	8.9	29.3
Reference Years												
1965												
Kharif Annuals	44.5	43.4	38.2	22.7	36.2	38.8	46.0	79.0	80.8	21.0	50.0	40.6
Rabi Annuals	45.0	53.0	49.0	37.2	47.5	39.5	55.1	57.8	21.2	18.8	41.4	45.6
Perennials	22.7	5.5	7.2	2.0	6.0	4.6	2.3	0.4	1.0	7.1	3.4	5.6
Total Intensity (%)	135	107	102	64	96	87	106	138	104	54	98	97
Cropped Acreage	0.9	3.3	13.2	2.3	18.8	4.5	1.1	1.9	1.1	0.2	8.7	28.4
1975												
Kharif Annuals	43.3	54.1	43.2	30.2	42.5	39.6	44.9	83.3	81.6	18.2	51.1	45.1
Rabi Annuals	40.9	62.8	58.9	49.1	57.7	51.4	61.1	58.4	23.1	21.6	49.4	54.8
Perennials	23.6	8.2	7.1	3.7	6.6	5.8	2.5	—	—	14.1	4.1	6.3
Total Intensity (%)	131[a]	133	116	87	113	103	111	142	105	68	109	112
Cropped Acreage	0.9	4.1	15.1	3.1	22.3	5.3	1.1	2.0	1.1	0.2	9.6	32.9
1985												
Kharif Annuals	51.3	62.1	49.6	46.4	51.0	45.4	55.9	73.0	63.4	19.8	52.1	51.3
Rabi Annuals	51.7	67.4	58.6	71.6	62.4	65.5	67.1	53.7	33.5	34.1	59.2	61.1
Perennials	25.2	10.0	8.8	5.8	8.4	8.9	4.7	—	—	18.9	6.4	8.2
Total Intensity (%)	153	150	126	130	130	129	132	127	97	92	124	129
Cropped Acreage	1.1	4.6	16.3	4.6	25.5	6.7	1.3	1.8[a]	1.0[a]	0.3	11.1	37.7
2000												
Kharif Annuals	59.1	66.6	67.3	60.7	66.0	62.3	64.2	91.0	95.0	37.3	69.8	67.0
Rabi Annuals	59.0	63.8	61.9	73.9	64.4	62.7	70.8	60.0	35.0	39.5	59.3	62.7
Perennials	27.3	9.8	10.4	7.7	9.8	12.5	7.5	—	—	41.6[b]	9.5	10.1
Total Intensity (%)	173	150	150	150	150	150	150	151	130	160	148	150
Cropped Acreage	1.2	4.6	19.5	5.4	29.5	7.8	1.5	2.1	1.3	0.5	13.2	43.9

[a] Reduction reflects conversion to full delta equivalent.

[b] Mainly sugarcane.

mainly for the cash crops, cotton and rice, as well as on fodder crops. Thus in Zone I, by 1975 IACA projects a reduced acreage consistent with the delivery capacity for full delta irrigation. This would reduce both the maize and wheat acreages. After 1975, however, there is a rapid increase in intensity, ultimately reaching over 170 percent.

IACA also expects a rapid increase in cropping intensity in the Punjab Rice Area (II) which should achieve 133 percent by 1975 and 150 percent by 1985. The expansion for other zones, between 1975 and 1985, is the result of raising the irrigation application to full delta by 1985 for the quite considerable proportion of cropped land which would continue to be underirrigated up to 1975. Rates at which desired intensities are achieved would vary between zones, especially where underlying groundwater is highly saline. Proportions of area with perennial surface water supply, effective precipitation and percent of area with good underlying groundwater for the nine zones are given in Table A2–4.

The magnitude of some of the agricultural problems is illustrated by Zone VIII. Besides having no perennial water supplies, this zone is also underlain with groundwater having TDS of the order of 2,000 or more ppm. The table also illustrates the advantage which the Punjab Zones II and III enjoy over the Sind. Not only are they nearer the source of water, but both perennial surface water availability and the quality of underlying groundwater are generally better. Moreover, effective precipitation is appreciably higher for the Punjab than for the more arid Sind region.

To examine IACA's growth of agricultural production, its projections for reference years based on its canal command analysis and its assumptions for prices and TDN value for production animals, were apportioned between the nine zones. From these, values of GPV per cropped acre were also derived. These data are given in Table A2-5. Striking zonal differences in GPV per cropped acre are shown in this table. The low GPV for Zone VIII in 1965 can be attributed in part to the absence of rabi water supplies and to a considerable dubari/bosi acreage (residual moisture cropping) from which extremely low yields are obtained.

TABLE A2–4
EFFECTIVE PRECIPITATION, PERENNIAL SUPPLY, AND USABLE GROUNDWATER FOR NINE ZONES

	Zone and Canal Commands	CCA '000 acres	Average Effec. Prec. ft.	Percent of Area With Perennial Water Supply	Percent of Area With Fresh Groundwater
I.	Vale of Peshawar	687	0.84	100	85
II.	Punjab Rice Area	3,113	1.08	51	82
III.	Punjab Cotton Area	13,020	0.44	68	55
IV.	Punjab Development Area	3,617	0.37	45	56
V.	Sind Cotton Area	5,218	0.13	87	25
VI.	Gudu and Sukkur Rice Area (perennial)	1,027	0.08	95	15
VII.	Gudu and Sukkur Rice Area (Nonperennial)	1,412[a]	0.08	—	25
VIII.	Ghulam Mohammed Rice Area (Nonperennial)	1,056[b]	0.17	—	—
IX.	Ghulam Mohammed Rice Area (perennial)	267[b]	0.17	100	—

[a] 75 percent of CCA underlain by groundwater 2,000 ppm TDS or greater.
[b] Entire area underlain by groundwater 2,000 ppm TDS or greater.

TABLE A2-5
CROPPED ACREAGE, GPV PER CROPPED ACRE[a] AND GROSS PRODUCTION FOR NINE AGRICULTURAL ZONES
(acres in millions; GPV per cropped acre in Rs.; total GPV in Rs. billions)

	Zones		1965			1975			1985			2000		
		Acres CCA	Cropped Acres	GPV Per Acre	Total GPV	Cropped Acres	GPV Per Acre	Total GPV	Cropped Acres	GPV Per Acre	Total GPV	Cropped Acres	GPV Per Acre	Total GPV
I	Peshawar Vale	0.7	0.9	337	303.5	0.9	406	365.3	1.1	614	675.0	1.2	869	1,043.1
II	Punjab Rice Area	3.1	3.3	256	863.8	4.1	361	1,481.1	4.6	562	2,589.4	4.6	780	3,598.3
III	Punjab Cotton Area	13.0	13.2	287	3,785.1	15.1	377	5,694.1	16.3	572	9,320.0	19.5	786	15,335.3
IV	Punjab Development Area	3.6	2.3	166	381.5	3.1	252	780.8	4.6	430	1,980.6	5.4	639	3,450.1
V	Sind Cotton Area	5.2	4.5	214	961.2	5.3	279	1,481.4	6.7	462	3,098.3	7.8	739	5,763.7
VI	Gudu and Sukkur Rice Area (Perennial)	1.0	1.1	163	179.7	1.1	249	274.5	1.3	423	550.6	1.5	668	1,001.6
VII	Gudu and Sukkur Rice Area (Nonperennial)	1.4	1.9	116	220.8	2.0	149	297.3	1.8	234	421.7	2.1	376	790.4
VIII	Ghulam Mohammed Rice (Nonperennial)	1.0	1.1	62	68.1	1.1	80	89.2	1.0	159	162.8	1.4	342	470.1
IX	Ghulam Mohammed Rice (Perennial)	0.3	0.2	167	24.1	0.2	310	56.1	0.2	640	157.4	0.4	1,020	435.4
	Total Commanded in Basin	29.3	28.5	238	6,766	32.9	320	10,520	37.7	503	18,956	43.9	726	31,888

[a] Seasonally cropped acres, i.e., perennials counted twice.

Steps were proposed by IACA for the removal of constraints. Improvements are reflected in the projected GPV per cropped acre at reference years in Table A2-5. As might be expected, growth would be less spectacular for zones of relatively high initial productivity. The improvements expected for the less favored zones are more readily seen by comparisons of compound growth for the three variables, cropped acreage, GPV per cropped acre, and total GPV, which are given in Table A2-6. The high overall growth of total GPV for Zone IX is due largely to the continuing expansion of sugarcane from about 18,000 acres in 1965 to over 80,000 by 2000.

For zones with unreliable rabi supplies, but without the further constraint of poor quality groundwater, the growth of acreage resulting from additional water is almost axiomatic. For zones with poor quality of groundwater and some waterlogging, additional supply cannot be effective until such constraints have been removed (Zones VI to VIII).

GPV per cropped acre as a measure of the contribution of all inputs, including the elimination of underwatering, is more difficult to interpret. Table A2-6 shows that highest yield growth is generally achieved during the decade 1975–85.

Analysis of Growth Factors

In order to assess the contribution of the separate effects of water and other inputs, an analysis was made by the Study Group of the increments in GPV attributable to (a) water alone, i.e., increased acreage at constant yield of GPV per cropped acre, and (b) due to other inputs, i.e., no increase in cropped acreage but employing IACA's full delta yields for the various reference years.[1] To do this, first acreage was derived from IACA's cropping intensities at reference years. Then the GPV was estimated employing IACA's cropping patterns, yield projections, and price assumptions. From these it was possible roughly to apportion the incremental contribution of either water alone or nonwater inputs to total GPV for each of the nine zones for the reference years. The difference between the sum of the acreage effect and the inputs effect from the total increment would be a rough measure of the interaction between these separate effects. Results of this analysis for the nine zones are summarized in Table A2-7.

The relative importance of water and inputs is illustrated by their percentage contribution to increments between reference years. Thus, where perennial supplies are limited as in Zones II and IV, a larger proportion of the expected increment would be expected from additional water. By contrast, in all zones except IV the effects of nonwater inputs on yield would be substantially greater. Even in Zone IV, the sums of input effects plus residual or interaction would be very large once the initial water shortage was overcome.

The observation that the residual (or interaction) proportion increases over the successive reference years is an axiomatic reflection of the importance of employing higher input levels after enlarging the cropped acreage in order to achieve best results.

The overall picture of development is one of higher growth of rabi acreages up to 1985 and thereafter a further rise in kharif acreage which by 2000 just exceeds the former. During this period, the increased area under perennial crops is a modest one, being from about three to six million acres at a rate of growth of 1.6 percent per annum.

[1] The analysis was based on Rupee values at constant prices as used by IACA.

TABLE A2–6

Growth Rates for Acreage, GPV per Cropped Acre, and Total GPV for Agricultural Zones

(percent per annum)

Zone	1965–75			1975–85			1985–2000			1965–2000		
	Cropped Area	GPV per Acre	Total GPV	Cropped Area	GPV per Acre	Total GPV	Cropped Area	GPV per Acre	Total GPV	Cropped Area	GPV per Acre	Total GPV
I	0	1.9	1.9	1.5	4.2	6.3	0.7	2.3	2.9	0.7	2.7	3.5
II	2.2	3.5	5.7	1.2	4.5	5.7	0	2.2	2.2	0.9	3.2	4.2
III	1.3	2.8	4.1	0.7	4.3	5.0	1.2	2.2	3.4	1.1	2.9	4.1
IV	3.0	4.2	7.4	4.0	5.5	9.9	1.1	2.5	3.7	2.4	3.9	6.5
V	1.6	2.7	4.4	2.4	5.2	7.7	1.0	3.2	4.2	1.6	3.6	5.2
VI	0	4.3	4.3	1.7	5.5	7.1	1.0	3.1	4.1	0.9	4.1	5.1
VII[a]	0.5	2.5	3.0	−1.0	4.6	3.6	1.0	3.2	4.2	0.3	3.4	3.7
VIII[a]	0	2.6	2.8	−0.9	7.1	6.2	2.0	5.2	9.0	0.7	5.0	5.7
IX	2.3	6.4	8.8	3.1	7.5	10.9	3.8	3.1	7.0	3.1	5.3	8.6

[a] See footnote to Table A2–7 regarding reduction in cropped acreage.

TABLE A2–7

ESTIMATED CONTRIBUTION OF WATER ALONE AND OTHER INPUTS TO INCREMENTAL GPV FOR NINE AGRICULTURAL ZONES
(effects measured in GPV in Rs. millions)

Zone	Total GPV 1965	Relative Contributions: Acreage	GPV/acre	Residual	Total GPV 1975	Relative Contributions: Acreage	GPV/acre	Residual	Total GPV 1985	Relative Contributions: Acreage	GPV/acre	Residual	Total GPV 2000
I. Peshawar Vale	303.5	11.0	40.0	10.8	365.3	62.5	219.0	25.2	275.0	58.1	220.2	89.8	1,043.1
Percent of Total Increment		18	65	17		20	71	9		16	60	24	
II. Punjab Rice Area	843.8	254.2	298.2	84.9	1,481.1	208.4	607.8	292.1	2,589.4	63.5	636.6	308.8	3,598.3
Percent of Total Increment		40	47	13		19	55	26		6	63	31	
III. Punjab Cotton Area	3,785.1	534.8	1,186.0	188.2	5,694.1	616.5	2,267.8	741.6	9,320.0	1,239.5	2,540.7	2,235.1	15,335.3
Percent of Total Increment		28	62	10		17	63	20		21	42	37	
IV. Punjab Development Area	381.5	205.2	123.8	70.3	780.8	360.9	307.9	531.0	1,980.6	298.9	373.1	797.5	3,450.1
Percent of Total Increment		51	31	18		30	26	44		20	25	55	
V. Sind Cotton Area	961.2	160.2	287.1	72.9	1,481.4	314.2	777.2	525.4	3,098.3	356.4	1,029.6	1,279.4	5,763.7
Percent of Total Increment		31	55	14		19	48	38		13	39	48	
VI. Gudu-Sukkur Rice Area (perennial)	179.7	6.9	81.8	6.1	274.5	31.3	188.2	56.6	550.6	36.6	237.9	176.5	1,001.6
Percent of Total Increment		7	86	7		11	68	21		8	53	39	
VII. Gudu-Sukkur Rice Area[a] (nonperennial)	220.8	10.9	58.5	7.1	297.3	−18.5	153.0	−10.1	421.7	56.0	216.3	96.4	790.4
Percent of Total Increment		14	76	10		−15	123	−8		15	59	26	
VIII. Ghulam Mohammed Rice Area[a] (nonperennial)	68.1	−2.8	29.1	−5.5	89.2	−5.5	82.7	−3.6	162.8	16.3	194.6	96.4	470.1
Percent of Total Increment		−13	139	−26		−9	118	−9		2	76	22	
IX. Ghulam Mohammed Rice Area (perennial)	24.1	16.3	11.1	4.6	56.1	26.3	29.0	46.0	157.4	73.0	30.2	174.8	435.4
Percent of Total Increment		51	35	14		26	29	45		26	11	63	
Total for West Pakistan	6,766	1,197	2,116	439	10,520	1,596	4,633	2,207	18,956	2,198	5,479	5,255	31,888
Percent of Total Increment		32	56	12		19	55	26		17	42	41	

[a] In Zones VII and VIII the negative contribution from acreage (water) shown arises as a result of IACA's procedure, where underwatering occurs, of reducing the actual cropped acreage to the full delta equivalent. This procedure results in a corresponding inflation of the GPV per cropped acre without however materially affecting the total GPV.

TABLE A2-8
RELATIVE CONTRIBUTIONS OF GROWTH FACTORS TO INCREMENTAL GPV
(as implicit in the IACA projections)

	1965 to 1975		1975 to 1985		1985 to 2000	
	Rs. billion	Percent	Rs. billion	Percent	Rs. billion	Percent
Total Increment	3.753	100	8.437	100	12.932	100
Thereof:						
Inputs	2.116	56	4.633	55	5.479	42
Water	1.197	32	1.596	19	2.198	17
Residual	.439	12	2.207	26	5.255	41

Analysis of IACA's projections clearly implies that nonwater inputs would make a substantially greater contribution to the increase in agricultural production than water alone. Even if the total residual effect were attributed to increases in irrigation supplies, the response to water would be less than that to inputs throughout the period up to 1985. To the extent that it can be traced in this analysis the relative contributions to the incremental GPV for the periods between reference years are demonstrated in Table A2-8, on the basis of the total CCA. This analysis would tend to overstate the input effects to the extent that the IACA yield projections beyond 1975 are generally based on full delta irrigation. The elimination of underwatering of an average of about 20 percent between 1965 and 1975 would thus be attributed to nonwater inputs. However, even if allowance is made for this, the analysis forcefully demonstrates the importance of nonwater inputs for rapid growth of agricultural production in the irrigated areas of West Pakistan.

TABLE A2-9
CONTRIBUTION OF CROPS AND LIVESTOCK TO TOTAL GPV
(Rs. billions)

	1965 Total GPV	1975 Total GPV	Growth 1965–75 (%)	1985 Total GPV	Growth 1975–85 (%)	2000 Total GPV	Growth 1985–2000 (%)
A. *Canal Commanded Areas*							
Crops	4.41	6.34	3.7	11.95	6.5	18.70	3.0
Livestock	2.35	4.18	5.9	7.00	5.3	13.19	4.3
Total	6.76	10.52	4.5	18.95	6.0	31.89	3.5
B. *Outside (Uncommanded) Areas*							
Crops	0.96	1.21	2.3	1.49	2.1	1.88	1.5
Livestock	0.97	1.58	5.0	2.71	5.5	5.27	4.6
Total	1.93	2.79	3.8	4.20	4.2	7.15	3.6
C. *Total for West Pakistan*							
Crops	5.37	7.55	3.5	13.44	5.9	20.57	2.9
Livestock	3.32	5.77	5.7	9.71	5.3	18.46	4.3
Total	8.69	13.32	4.3	23.15	5.7	39.03	3.5

Analysis of IACA's Aggregate Production Projections

IACA's totals of GPV for West Pakistan were obtained by adding GPV for the uncommanded outside areas to those of the nine zones and are shown in Table A2-9. The separate contributions of agriculture and livestock are also included as are growths between reference years.

The contribution of livestock production based on IACA's projections is extremely high. However, as discussed in Chapter II, the maintenance of a growth rate in livestock production in excess of 5 percent per annum for some 20 years (1965–85) would demand a level of herd management and breed improvement far in excess of current standards and difficult to attain. The growth of crop production for the period 1965–85 at 5.1 percent also represents a challenge of immense proportion and would only be made possible by the best use of the interdependent factors.

Annex 3

FACTORS AFFECTING CROPPING INTENSITIES

A cropping intensity of 200 percent would be the theoretical maximum. As discussed in the text, IACA has concluded that an overall intensity of 150 percent is a reasonable indicative target for the Indus Basin. This Annex illustrates how different factors impinge on cropping intensity and why 150 percent may be regarded as a reasonable overall average.

The example used here is based on IACA's Region III (Punjab Cotton Area). The first table, Table A3-1, shows the present distribution of crops between the two major seasons at a cropping intensity of 102 percent. The table also gives basic data on monthly rainfall, crop water requirements, and temperatures. The greatest occupancy of land by kharif crops occurs during July (36 percent), and by rabi crops in December (48.5 percent). The area under perennial crops must be added to each of these to determine the full occupancy of the land at any given month. Thus it is in November, rather than December, that the largest percentage of the land is utilized (58.5 percent), for some cotton and maize are still unharvested from the kharif season. If 10 percent of the land is reserved in all months for livestock use, then only 90 percent is the maximum available for cropping. An additional 31.5 percent of the land (90 percent minus 58.5 percent) thus represents what could be cropped in November if water were available. Actually, as the table shows, intensity could be increased by adding acreage in both kharif and rabi seasons if adequate water were available.

Table A3-2 illustrates IACA's conception of a feasible intensity of 150 percent under full delta irrigation. The same area is involved, and the same basic rainfall and temperature data apply. The peak month of land occupancy in the kharif season would still be July, but by September the fodder crop would have been harvested and some rabi crops would be sown. The acreage under crops would begin to build up again following further harvesting of rice and pulses in October, plus some sowing of rabi crops on land which was not occupied during the kharif season. Such sowing could take place, for example, because the cropping pattern shows a peak land occupancy in July of 73 percent, or 17 percent below the 90 percent maximum which reserves 10 percent for livestock use.

During October and November, the total land occupancy hovers around the 90 percent maximum, even exceeding this slightly in November. This is because some cotton would not be harvested until this time, and the full rabi crop could not be planted until the cotton-occupied land has been cleared. Some wheat sowing must therefore be delayed until December, a practice which is technically possible but results in reduced yields. Referring to the temperature data, the mean monthly temperature minimum drops eight degrees between November and December. One alternative is to grow less cotton and more fodder and pulses in order to advance the wheat planting date, but the economic returns from this pattern are likely to be lower than if cotton is retained at the expense of some reduction in wheat yields.

TABLE A3-1
Region III (Punjab Cotton Area)
Monthly Land Occupation
for a Cropping Intensity of 102 Percent

				Kharif						Rabi					
				Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Rainfall Average—inches				0.3	0.3	0.6	2.0	1.8	0.5	0.1	0.1	0.2	0.4	0.4	0.4
Crop Irrigation Requirement—inches				5.6	6.9	6.8	6.4	5.8	5.1	4.2	2.7	1.8	1.7	2.3	3.9
Mean Maximum Temp. (degrees F)				95	105	107	102	99	99	94	83	72	68	73	84
Mean Minimum Temp. (degrees F)				68	77	85	86	83	78	64	51	43	42	47	57
Mean Diurnal Temp. Difference (degrees F)				27	28	22	16	16	21	30	32	29	26	26	27
	Number Sowing	Crop Period	Gross Area												
		(months)	(%)	percent											
Kharif															
Rice	1	3½	2	—	—	—	2	2	2	1	—	—	—	—	—
Cotton	1	6	17	—	3	16	17	17	17	17	15	—	—	—	—
Maize	1	3½	3	—	—	—	1	2	3	3	1½	—	—	—	—
Fodder	2	2½	9	—	—	4½	9	6¾	2¼	—	—	—	—	—	—
Jowar	1	4	5	—	—	—	5	5	5	5	—	—	—	—	—
Others	1	4	2	—	—	2	2	2	2	—	—	—	—	—	—
Total (excluding perennials)			38%	—	3	22½	36	34¾	31¼	26	16½	—	—	—	—

Rabi															
Wheat	1	5½	31	20	—	—	—	—	—	7½	19	31	31	31	31
Fodder	1	5½	11	—	—	—	—	—	1½	6	9	11	11	11	11
Oilseeds	1	3½	2½	—	—	—	—	—	1¼	2½	2½	2½	—	—	—
Others	1	4	4	—	—	—	—	—	4	4	4	4	—	—	—
Total (excluding perennials)			48½%	20	—	—	—	—	6¾	20	34½	48½	42	42	42
Perennials															
Sugarcane	1	12	6	6	6	6	6	6	6	6	6	6	6	6	6
Fruit	1	12	1	1	1	1	1	1	1	1	1	1	1	1	1
Vegetables	1	12	½	½	½	½	½	½	½	½	½	½	½	½	½
Total			7½	7½	7½	7½	7½	7½	7½	7½	7½	7½	7½	7½	7½
Total Monthly Land Occupation				27½	10½	30	43½	42¼	45½	53½	58½	56	49½	49½	49½

Cropping Intensity (perennials twice)

Kharif 38 + 7½ = 45½%
Rabi 48½ + 7½ = 56%

101½%

TABLE A3–2
Region III (Punjab Cotton Area) Ultimate Cropping Intensity of 150 Percent

	Number Sowing	Crop Period (months)	Gross Area (%)	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
									percent						
Kharif															
Rice	1	3½	4	—	—	—	4	4	4	2	—	—	—	—	—
Cotton	1	6	35	—	3	35	35	35	35	35	32	—	—	—	—
Maize	1	3½	5	—	—	—	1	4	5	5	2½	—	—	—	—
Fodder	2	2½	18	—	4½	13½	18	9	—	—	—	—	—	—	—
Pulses	1	4	5	—	—	2½	5	5	5	2½	—	—	—	—	—
Kharif—Monthly Land Use			67	—	7½	51	63	57	49	44½	34½	—	—	—	—
Rabi															
Wheat	1	5½	29	17½	—	—	—	—	—	12	14	29	29	29	29
Fodder	1	5½	15	—	—	—	—	—	3	12	15	15	15	15	—
Oilseeds	1	3½	3	—	—	—	—	—	1½	3	3	3	—	—	—
Grams/Pulses	1	4	2	—	—	—	—	—	2	2	2	2	—	—	—
Maize	1	4	4	—	—	—	—	—	4	4	4	4	—	—	—
Green Manure	1	4	10	—	—	—	—	—	—	—	10	10	10	10	—
Rabi—Monthly Land Use			63	17½	—	—	—	—	10½	33	48	63	54	54	29
Perennials															
Sugar	1	12	5	5	5	5	5	5	5	5	5	5	5	5	5
Fruit	1	12	3	3	3	3	3	3	3	3	3	3	3	3	3
Vegetables	1	12	2	2	2	2	2	2	2	2	2	2	2	2	2
Perennials—Monthly Land Use			10	10	10	10	10	10	10	10	10	10	10	10	10
Real Total Monthly Land Use				27½	17½	61	73	67	69½	87½	92½	73	64	64	39

Cropping Intensity (perennials twice)

Kharif	67 + 10 =	77%
Rabi	63 + 10 =	73%
		150%

Another is to increase rice production at the expense of cotton in the kharif season, but the feasibility of this would depend on soil and water conditions to a great extent. In the area selected for the example, these factors preclude rice as a major alternative to cotton. The result of considerations such as these is that kharif crops would be held to 67 percent of the CCA and rabi crops to 63 percent of the CCA because of difficulties of fitting any succession of crops which is more economical. A constant 10 percent of the CCA is under perennial crops in all months. Adding in the perennials, the combined intensity of 77 percent in kharif and 73 percent in rabi equals the 150 percent which IACA has used as a design objective. In arriving at this end result, the maximum land occupancy by all crops in any month, not the maximum occupancy by the seasonal crops of kharif or rabi, has set the limits to the ultimate feasible cropping intensity, because this measure reflects the extent of overlapping in the succession of different crops grown.

Annex 4

IACA'S ESTIMATES OF COST OF GROUNDWATER MINING

The need to maintain the water table sufficiently below the surface to avoid salinity and waterlogging is agreed by all who have examined the problem, but expert opinions have diverged widely on the question of whether fresh groundwater should be continuously pumped to greater depths. The White House Panel Report, often referred to as the Revelle Report, recommended overpumping and so lowering the water table down to about 100 feet below ground level in order to meet the rapidly increasing water demand. SCARP IV is designed to permit lowering the water table to an equilibrium level calculated to reach a depth of 80 feet near the center of the well field. On the other hand, in the LIP Report, it is proposed that balanced recharge should be abstracted at relatively shallow levels of the water table. Harza plan to pump balanced recharge over the long term but with considerable periodic fluctuations of the water-table level in order to take full advantage of aquifer storage.

Continuous pumping of a groundwater resource beyond the recharge level is called mining. In the Indus Plains, it would theoretically always be possible to replace groundwater "mined" in this way at some future date by pumping less than the recharge over a long period. Nonetheless, there is a clear distinction between temporary overpumping to alleviate short-term shortages and continuous overpumping for a long period. Temporary overpumping is a valuable expedient as a means of maintaining supplies at times of lower than average river flows or before the introduction of surface storage projects; and in these cases, the replacement of the groundwater would form a part of the general plan. On the other hand, continuous overpumping implies no such replacement but rather the exploitation of water in the natural subsurface reservoir, as in the Revelle Report recommendation that the water table in areas of fresh groundwater should be lowered to a depth of about 100 feet below ground level over a period of 30 years. Continuous overpumping in this way is effectively mining, which involves substantial additional costs both for capital installation of the tubewells and for power to pump from the greater depths.

The increased capital costs consist of two elements. Firstly, the cost of all tubewells would be raised as deeper installations would be required to operate with the lowered water table. Secondly, extra installed tubewell capacity would be required to pump the mined water.

If the wells were to be designed for a final depth of water table at the 100-foot level, IACA estimates that capital costs would be increased by about 50 percent for each tubewell as compared to those for balanced recharge at 10 feet. The main items in this increased cost would be the pump housing and motor and controls; smaller amounts would be added for drilling and the gravel pack. However, it is unlikely that the wells would be designed initially for a condition which would not be applicable for 30 years, particularly as IACA has projected a life of only

20 years for the motors. IACA has therefore taken a lower increase of 30 percent in the capital cost of the wells. The maximum output, and hence capacity, of individual tubewells would be limited by the hydrological conditions of the aquifer regardless of whether the groundwater is mined. A typical four cusec well, without mining, commands about 600 acres and thus the extra capital cost for deeper installations would be:

$$30\% \text{ of } \frac{\text{Rs. } 90{,}000}{600} = \text{Rs. } 45 \text{ per acre}$$

If the water table is lowered from a depth of 10 feet to 100 feet below ground level, in an aquifer with a specific yield of 0.15, the amount of water mined would be 13.5 acre-feet per acre, which is equal to 0.45 acre-feet per acre per year for 30 years. Irrigation requirements would follow the same projected pattern as without mining and the increase in groundwater pumping would be provided partly from a higher utilization of the wells and partly from additional installed tubewell capacity. The increase in the designed quantity of groundwater to be pumped would be between 20 and 25 percent for which an increase of about 15 percent would be required in the installed capacity. The cost of this additional installed capacity would therefore be:

$$15\% \text{ of } 130\% \text{ of } \frac{\text{Rs. } 90{,}000}{600} = \text{Rs. } 29 \text{ per acre}$$

The additional capital costs are therefore:

45 + 29 = Rs. 74 per acre

Amortized over 20 years, the capital charges attributable to mining are then:

Depreciation	= Rs. 3.7 per acre per year
Interest at 8 percent	= Rs. 3.0 per acre per year
Capital Charge	= Rs. 6.7 per acre per year
Or: $\frac{6.7}{0.45}$	= Rs. 14.9 per acre-foot mined.

This capital charge of Rs. 14.9 per acre-foot mined compares with a capital cost of Rs. 6.9 per acre-foot pumped with balanced recharge, as derived by IACA. Turning now to the power costs of mining, IACA finds that the economic cost is substantially more than that of the immediate pumping involved, since allowance must be included for the considerable extra cost in perpetuity of pumping normal recharge from a lowered water table. IACA has projected a typical unit power cost of Rs. 7.4 per acre-foot for a four cusec public tubewell pumping against a total head of 40 feet.[1] If one acre-foot is then mined from an acre of the aquifer, the water table would be lowered by about 6⅔ feet and the power cost would be raised to Rs. 8.6 per acre-foot, in proportion to the pumping head. The incremental power cost in perpetuity caused by mining the acre-foot of water—to pump the annual recharge from a lower depth—would therefore be:

(8.6 − 7.4) = Rs. 1.2 per acre-foot pumped

[1] In other words, the tubewells would draw from some 30 feet below water level.

TABLE A4-1
EFFECTIVE COST OF MINING GROUNDWATER

Item	Cost
	(Rs. per acre-foot mined)
Capital	14.9
Power	45.6
Operation and Maintenance	2.6
Total Mining Cost, say	Rs. 63 per acre-foot

With a future recharge of two acre-feet per acre and future costs discounted at 8 percent (i.e., a discount factor of 12.5), the incremental power cost in terms of perpetuity to mine an acre-foot of water from an acre of the aquifer would be:

$2 \times 1.2 \times 12.5 =$ Rs. 30 per acre-foot mined.

Adding the initial cost of extracting the acre-foot of water, the approximate effective power cost of mining the acre-foot would be:

$7.4 + 30 =$ Rs. 37.4

A similar figure was calculated in IACA's Report[1] with different assumptions for the pumping head, economic electricity cost and wire to water efficiency. Depending also on the assumptions for specific yield of the aquifer and the amount of annual recharge, the power cost for mining an acre-foot of water from an acre of the aquifer may be taken as between Rs. 30 and 40.

Clearly the most significant item in this power cost, and indeed in the total cost of mining, is the additional cost in perpetuity of pumping recharge from the lower levels. This additional cost in perpetuity is related to the specific yield of the aquifer but is independent of the depth of water table. On the other hand, the actual power cost for each acre-foot mined would increase as the water table is lowered, and would be about Rs. 23.8 per acre-foot pumped with the water table at 100 feet below ground level. (The variation in power costs for actual pumping of the mined water would make the last acre-foot mined more expensive than the first.) The effective power cost to mine an acre-foot of water from an acre of the aquifer would then be:

$23.8 + (2 \times 1.2 \times 12.5) =$ Rs. 53.8 per acre-foot mined

The mean power cost between 10 and 100 feet would therefore be:

$$\frac{37.4 + 53.8}{2} = \text{Rs. } 45.6 \text{ per acre-foot mined}$$

For operation and maintenance, the same unit rates may be allowed as for balanced recharge pumping. These can now be added to the capital and power costs derived above to give the effective cost of Rs. 63 per acre-foot mined, if the water table is lowered from 10 feet to 100 feet below ground level over a period of 30 years.

[1] Volume 3, Annexure 4, "Climate and Hydrology."

The effective cost of Rs. 63 per acre-foot mined is the mean of Rs. 55 per acre-foot mined with a 10-foot water table and Rs. 71 per acre-foot mined with a 100-foot water table. This effective cost of about Rs. 63 per acre-foot makes mining appear to be about the same as surface storage when comparing the cost per acre-foot at watercourse. It is also evident that the effective cost of mining is several times that of pumping with balanced recharge.

However, apart from these economic considerations, there are several technical factors which would require detailed analysis before mining could be accepted. The most important of these is the possible intrusion of saline groundwater down the steep gradient into the fresh groundwater zones. The extent of this hazard would vary at different sites but additional buffer drainage wells might be necessary in order to safeguard the quality of usable groundwater. Other problems which could be caused by mining: increased losses from rivers and canals and diminished yields from existing wells. Finally, the construction of tubewells for mining could introduce additional constraints on the implementation capacity and so retard the general rate of development in the next decade.

For these reasons, IACA does not at this stage foresee a case for widespread mining of groundwater, although special cases could arise in particular areas. IACA made recommendations in regard to a policy of temporarily lowering the water table, as opposed to mining, and also discussed the possibility of inducing additional recharge in fresh groundwater zones.[1]

[1] IACA Report, Volume 5, Annexure 7.

Annex 5

SEQUENTIAL ANALYSIS OF A PROGRAM FOR IRRIGATION AND POWER DEVELOPMENT IN WEST PAKISTAN[1]

Introduction

Background

This report is an account of a series of sequential operation studies of the water and power system of West Pakistan performed in accordance with specific Terms of Reference. The objective of the studies was to carry out a behavior trial of IACA's assumed plan for distributing surface water and for the pumping of groundwater, simulating the 20-year period 1965 to 1985, using the computer program developed by Harza Engineering Co. International. The scope of the studies was also intended to test the Study Group's Consultants' power program against the system electrical demand.

Gibb, in association with the other Study Group Consultants, made system analyses for certain reference years, including 1975 and 1985, as part of the Special Study. Various potential forms of development of water and power resources were tested in the reference years under different conditions of river flows. These system analyses were used by IACA in conjunction with other studies in order to formulate the proposed program for development of irrigation supplies. The IACA projections for growth of storage demand were used by Chas. T. Main in their study of dam sites and the projections for tubewell pumping and hydro-energy generation were used by Stone and Webster in their study of power resources.

The sequential method of analysis evolved by Harza, as general consultants to WAPDA, enables a development program to be tested for any desired period of consecutive years. The methods of analysis and basic data used by Gibb and Harza were compared in some detail at meetings in London and Arnhem in February 1966; it was found that the exchange of data between the consultants since the inception of the Special Study had resulted in agreement on many of the basic parameters relating to system analysis. Subsequent to these meetings, the Study Group and WAPDA agreed on the desirability of initiating a series of studies combining the development program of the Study Group's consultants and the techniques of system analysis developed by WAPDA's general consultants.

The studies reported herein are the result of a cooperative effort between Gibb and Harza. Gibb held primary responsibility for preparing input data consistent with the Study Group's consultants' development program and the associated technical criteria and assumptions, for selecting the sequences of river flows adopted, and for evaluating the results. Harza provided advice and assistance in arranging and processing the input data in the form required for the analysis, and in the use of computer facilities.

[1] Excerpt from a report prepared by Sir Alexander Gibb and Partners, London, 1966. Minor editorial changes have been made.

Input data were prepared over the period July to August 1966. The studies were then carried out in Chicago in August, 1966, using the IBM 7094 computer at the Illinois Institute of Technology Research Institute.

Conditions of Sequential River Flows

Three main analyses and one supplementary analysis were made under different sequences of flow in the Indus, Jhelum and Chenab Rivers. Water years, assumed to begin in October, were used rather than calendar years. Thus a water year begins in October of the previous calendar year and continues until September of its own calendar year. In each case the analysis was applied to projections for the 20-year sequence of water years from 1966 to 1985. Four conditions of sequential river flows were used.

Mean Year Sequence. A mean water year was used in each of the 20 years for this analysis. The mean was taken from monthly flows over the same 41-year period of water years, 1923 to 1963, as were adopted in the IACA studies. This sequence provided a direct comparison with many of the IACA projections.

First Historic Sequence. For this sequence actual recorded river flows were used. The historic period of water years 1926 to 1945 was applied in the same sequence to the period of the study 1966 to 1985. In this way the program was tested under a sequence of river flows which were known to have actually occurred.

Second Historic Sequence. This analysis provided a second test of the program under actual river flows. The same period of water years was used as in the previous analysis but the order of the sequence was transposed by 10 years. The historic flows of the water years 1926 to 1935 were applied to the period 1976 to 1985 and the years 1936 to 1945 were applied to 1966 to 1975.

Supplementary Sequence. The river flows in this analysis were the same as in the first historic sequence except that certain flows were replaced by those of a critically low water year. This analysis served as a further test on the power program and as a check on the possible scale of irrigation shortages. The critical water year selected was 1955, which was also used in the IACA studies. In this water year, the lowest October to May flow of record occurred on the Indus, Jhelum and Chenab Rivers combined. This critical year was applied to 1976 and 1985. It was not used for the water year 1974, which is likely to be difficult for power, as both the historic sequences happened to produce low rabi flows for that year.

The conditions of sequential river flows are discussed in more detail with the assumptions for other tributary river flows in Section D below. The other input data were the same in each of the sequential analyses.

The Development Program

IACA considered potential development of water resources in the Indus Basin from the combined aspects of agriculture, water supply and economics. These considerations led to a proposed groundwater and canal development program. The installed tubewell capacities, canal sizes and irrigation requirements used as input data for the sequential analyses were based on this program for development.

The dominant feature during the first decade of the IACA program 1965–75 is the continued installation of tubewells to provide new irrigation supplies and simultaneously to control the water table. The following decade, from 1975–85, would witness the extension of public tubewells fields over the outstanding usable groundwater areas and hence the achievement of fully integrated tubewell and canal supplies. IACA's estimate of public and private tubewells which would be operating in reference years from 1965 to 1985 under their proposed program is shown in Table A5-1.

The scheduled completion of Mangla Dam (4.5 MAF) on the Jhelum River in 1967 had a predetermined place in the IACA program as also did the proposed Tarbela Dam (8.6 MAF) which, under the IACA terms of reference, was assumed to begin operation on the Indus River in the autumn of 1974. Surface storage development was also expected at Chasma in 1971, but the reservoir size there would be relatively small (0.5 MAF). Further storage proposed by IACA at Sehwan/Manchar (2.2 MAF capacity), equivalent to 1.8 MAF of useful storage, in 1982 would be particularly related to the enlargement and remodelling of Rohri Canal. Other storage projects would be implemented after 1985, the last reference year for the sequential analysis.

The improved irrigation supplies and the control over the watertable in usable groundwater zones form the background to canal enlargement in the IACA program. Canal enlargement is applied to a limited number of canal commands in the first decade but the program for enlargement gains momentum and takes the leading rule in further development. IACA's projections for the areas which would be developed by canal enlargement and by tubewells and horizontal drains are shown in Table A5-2 for 1965, 1975 and 1985.

From their projections for development, IACA calculated the tubewell pumping requirements. Stone and Webster took these IACA estimates for tubewell pumping and added their own projections for other power demands in order to derive a program for the installation of power generating equipment. The power installation program and the basic load forecasts form part of the input for the sequential analyses and are described in Section D below.

Method of Analysis

General

The method of analysis consists of a numerical model of the Indus Basin Power and Irrigation System which simulates system operation using time intervals of one month for any desired period of years. The system corresponds geographically to the Indus Plains and the Peshawar Vale and the storage reservoirs on the Indus and its principal tributaries. The basic model includes all existing irrigation and

TABLE A5-1
PROJECTED NUMBER OF WELLS IN OPERATION

Plan Year	1965	1970	1975	1980	1985
Public Wells (2 to 5 cusec capacity)					
Usable groundwater	2,200	9,500	19,800	32,200	34,300
Saline groundwater	—	—	200	4,500	9,800
Private Wells (Approx. 1 cusec capacity)					
Canal commanded and noncommanded areas					
Electric	9,000	17,000	24,000	18,000	23,000
Diesel	23,000	35,000	24,000	5,000	2,000

TABLE A5–2
AREAS DEVELOPED UNDER PROPOSED PROGRAM
(millions of acres CCA)

	1965	By 1975	By 1985
Saline groundwater area under subsurface drainage development:			
Vertical drainage by tubewells	—	0.5	4.3
Horizontal drainage by tile drains	—	0.3	1.1
Total saline groundwater area with subsurface drainage	—	0.8	5.4
Usable groundwater area under public tubewell development	1.3	10.8	18.7
Total area under groundwater development	1.3	11.6	24.1
Area under development by canal enlargement	—	0.9	5.9

power facilities, projects under construction, and all major potential projects. Individual components of the system may be included, excluded, or modified by suitable selections of input data. The water and power demands of the system are also defined by input data chosen to correspond to projected future demands. An IBM 7094 electronic computer is used to perform the computations.

The account of the method of analysis contained in this section is largely confined to a discussion of those areas where the procedures followed in the Harza method differ from the procedures and assumptions adopted in the system analyses made by IACA in the course of the Special Study. A more detailed account of the Harza method of analysis is given in 'A Guide to the Computer Program' published by Harza in March 1966 and revised in September 1966.

Integrated Use of Surface and Groundwater

The IACA and Harza system studies differ in regard to the use of groundwater. In the IACA analysis, the pattern of groundwater pumping is predetermined by discrete canal command studies in which allowance is made for groundwater mixing and the state of development of public and private tubewells. The remainder of the watercourse requirement is made up by surface water deliveries. The elements of surface water are then aggregated to build the demand throughout the system. The Harza computer program works in the reverse manner, by first distributing surface water throughout the system and then pumping in the canal commands to meet the watercourse requirements. Both studies aim to balance the volume of recharge in a command by an equal amount of groundwater pumping, thus maintaining the groundwater at a fairly constant level. In the Harza system system. The Harza computer program works in the reverse manner, by first dislimited by canal capacity or by a general shortage of water in the system; IACA assumed the same principle in their development plan.

In practice, the two approaches would produce much the same results. Consequently it was decided to retain the Harza logic in the analysis without any change to the computer program.

The Harza and IACA methods of analysis both assume a high degree of coordination between surface water distribution and groundwater use. Both consultants recognize the difficulty of including privately owned tubewells in an integrated system. Current indications are that utilization factors for private wells are much lower than for public wells. Preliminary system analyses made by Harza indicated that the lower utilization factors associated with private tubewells could be recognized in the analysis by means of input data rather than by a change in the computer program. The effective pumping capacity for private wells was taken as 30 percent of installed capacity and for public wells as 87 percent of the installed capacity, which represents the maximum monthly utilisation rate adopted as a criterion by IACA.

Power and Energy Generation

Although the S&W basic load projections and plant installation schedule were adopted as input data for the sequential study, complete compatibility cannot be achieved due to differences that exist between the S&W method of computing the peaking capability at the hydro plants and that of Harza. Stone and Webster impose a limitation on peaking capability in months when reservoir outflow is less than the flow required for continuous full-gate operation of the turbines. Harza do not impose any restriction on peaking capability other than that resulting from the head on the turbines; and it is assumed that full-gate output can be developed whenever required. However, in the months of minimum reserve generating capacity the reservoir outflows are in most cases sufficiently large to allow full-gate opertion; therefore at such times the Stone and Webster method does not result in any significant reduction in peaking capability. Furthermore, the S&W analysis of generating capability is based on calculations at 10-day intervals and the hydro capability for any month is governed by the lowest 10-day period. In the Harza analysis, hydro peaking capability is determined by the head corresponding to the mean reservoir level for the month. In effect, the comparison would be between a minimum capability and an average value.

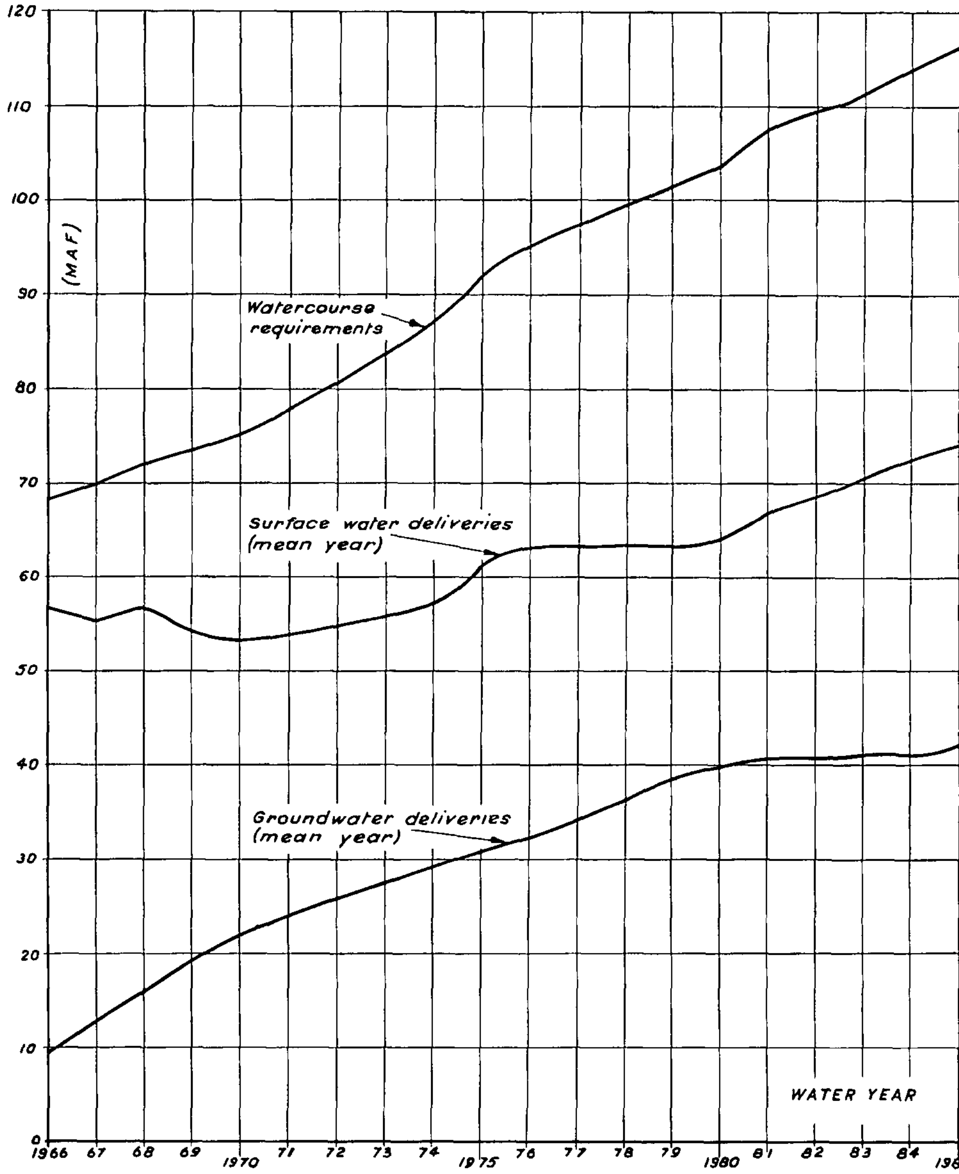
It was decided to retain the Harza logic in the analysis, although it was recognized that the peak reserve indicated might be higher than obtained in the S&W analysis.

Load Dispatching and Interzone Transfers

The basic power and energy demands for the North and South Zones are defined by input data and groundwater pumping loads are computed in the analysis. Total power and energy demands are therefore obtained for each month of each year of the analysis and for each zone. Two important elements of the load duration curve are then derived, the maximum ordinate, which is the peak demand, and the total area under the curve, which is the total energy. By assuming the curve to be parabolic and to be a function of the system load factor, it is possible to define the complete shape of the monthly load duration curve, and to match the requirements with the hydro and thermal components.

A load-dispatching process is used in the analysis to determine peak reserves or deficiencies in each zone, and to compute interzone transfers of power and energy. For the purposes of the analysis the South Zone includes Karachi. Transfers between the North and South Zone can only take place after interconnection, the date of which is determined by input data (1973 in the analyses described herein). Transfers from South to North take place only when there is a capacity deficiency in the North and reserve capacity in the South. Transfers from the North to South will always take place when there is surplus hydro capacity after the demands of the North Zone have been met, to reduce the consumption of thermal power in the South Zone.

VOLUME II
ANNEX 5
FIGURE 1



GROWTH OF WATERCOURSE REQUIREMENTS
AND MEAN YEAR DELIVERIES.

Input Data

General

The input data used in the sequential analysis fall into six main categories.

1. Data descriptive of the existing and future physical components of the irrigation system, such as canal commands, main canals, link canals, barrages and reservoirs, and tubewells for irrigation and drainage.

2. Data relating to groundwater hydrology including seepage loss factors, areal variations in groundwater quality, aquifer storage coefficients, and estimates of recharge from rivers, link canals and rainfall.

3. The surface water supply to the system expressed as monthly river flows by years at the rim stations.

4. The demand for irrigation water expressed as monthly watercourse requirements by years for each canal command, based on the development program selected for analysis.

5. Projected demands for basic power and energy for each month of the study period, the factors used to express groundwater pumping in terms of electric power and energy. and the capacities and characteristics of existing and future thermal and hydroelectric generating plants.

6. System operating criteria such as groundwater mixing ratios, reservoir release patterns, and minimum releases below reservoirs and barrages.

For the analyses described in this report, the input data are consistent with the IACA and S&W development programs and the associated assumptions and criteria. Different conditions of surface water supply to the system were considered in each of the sequential analyses but other input data remained the same in each analysis.

The Irrigation System

Comparison of Canal Commands. In their basin studies, IACA used 61 divided canal command units, whereas the Harza analysis allows for 45 units covering the same geographical area. It was therefore necessary to combine certain IACA units, and in some cases to split units in order to make them compatible with the computer program. The configuration of commands that was finally adopted corresponds closely to that used in Harza studies except that Abbasia was combined with Panjnad, Desert with Pat, and Pinyari with Fuleli. Thus 42 canal commands emerge which are shown in Table A5-3 with the corresponding IACA commands indicated where the nomenclature differs.

Link Canals. The system includes all existing link canals, the link canals of the Indus Basin Project, the canals required for diversion of Indus waters to offstream storage reservoirs, and the canals associated with the Sehwan Development.

The head and tail capacities of the link canals are defined by input data for each year of the study; capacities are set at zero in the years prior to commissioning. None of the canals required for offstream storage set in the Harza program are included in the IACA program and hence their capacities are zero throughout the study. The links of the Indus Basin Project are introduced in the analysis in accordance with the current construction program.

There are three canals in the South Zone considered as link canals: the Nara Feeder, which is the existing canal supplying the Nara Command from Sukkur;

the Sehwan Feeder, which serve Sehwan Command (Rohri South) from Sehwan; the Sehwan-Nara Link which will serve the Nara Command from Sehwan.

In the IACA program, the Sehwan Feeder is assumed to commence operation in 1982, and Nara Command continues to be served from Sukkur through 1985.

TABLE A5-3
CANAL COMMANDS

Canal Command in Sequential Analysis	Culturable Commanded Area	Corresponding IACA Command
	(million acres)	
Upper Dipalpur	.372	Dipalpur above BS Link
Central Bari Doab	.595	Ravi Syphon Dipalpur Link Int.
Raya Branch	.427	Existing nonperennial area commanded by Raya Branch in Upper Chenab.
Upper Chenab Internal	1.018	Existing perennial area and the remainder of the existing nonperennial area of Upper Chenab.
Marala Ravi Internal	.105	Marala Ravi Link Int.
Sadiqia	.975	Existing perennial area of Fordwah and E. Sadiqia.
Fordwah	.387	Existing nonperennial area of Fordwah and E. Sadiqia.
Pakpattan	1.047	Pakpattan above SM Link, Mailsi above SM Link, Qaim, and Bahawal above MB Link.
Lower Dipalpur	.611	Dipalpur below BS Link.
Lower Bari Doab	1.575	Lower Bari Doab including Ravi offtakes.
Jhang and Rakh Branches	1.278	Area of Lower Chenab commanded by Khanki headworks and the Lower Chenab Canal Feeder.
Gugera Branch	1.703	Area of Lower Chenab commanded by Khanki headworks.
Upper Jhelum Internal	.543	Upper Jhelum.
Lower Jhelum	1.500	Lower Jhelum.
Bahawal	.596	Bahawal below MB Link.
Mailsi	.996	Mailsi below SM Link and Pakpattan below SM Link.
Sidhnai	.754	Sidhnai.
Haveli Internal	.143	Haveli.
Rangpur	.344	Rangpur.
Panjnad and Abbasia	1.455	Panjnad and Abbasia.
Upper Swat	.276	Upper Swat.
Lower Swat	.169	Lower Swat, Doaba and Sholgara.
Warsak	.119	Warsak High Level Right and Left Bank.
Kabul	.123	Kabul River, Jui Sheikh and Inundation.
Thal	1.641	Thal.
Paharpur	.104	Paharpur.
Muzaffargarh	.656	Muzaffargarh.
D. G. Khan	.872	D. G. Khan.
Desert and Pat	.382	Desert and Pat.
Begari Feeder	.693	Begari Sind.
Ghotki Feeder	.513	Ghotki.
North West	.633	North West.
Rice	.337	Rice.
Dadu	.394	Dadu.
Khairpur West	.252	Khairpur West.
Khairpur East	.330	Khairpur East.
Rohri	1.075	Rohri North and Rohri South until 1983; thereafter Rohri North only.
Sehwan	1.405	Rohri South from 1983.
Eastern Nara	1.559	Eastern Nara.
Kalri	.274	Kalri Baghar.
Lined Channel	.152	Lined Channel (Gaja and Tando Bago).
Pinyari and Fuleli	.897	Pinyari and Fuleli.

Canal Capacities. The IACA figures for canal capacity were adopted throughout. At various points in time, canal capacities were enlarged in accordance with the IACA program.

Reservoirs. The study assumes that three major reservoir schemes are introduced into the system.

Low Mangla has an initial live capacity of 4.94 MAF between El.1202 and El.1040. The useful storage at a drawndown level of 1075, that was used in the IACA studies, is 4.5 MAF. For practical reasons the volume of water trapped in the Jari arm was neglected but the effect of this extra water is considered in the evaluation of results. Impounding commences at Mangla in April 1967.

Tarbela has an initial live storage content of 9.3 MAF between El.1550 and El.1300. However the IACA assumption is that drawndown will only be to El.1332, which allows a live capacity of 8.6 MAF. Impounding is assumed to start in August 1974 and it was considered for the purpose of the analysis that this would permit only 5.0 MAF to be stored in the first year of operation. Full impounding begins in June 1975.

The Sehwan project is assumed to come into operation in September 1982 with a storage capacity of 2.2 MAF, taken from the LIP Report, which after evaporation allows a useful storage of about 1.8 MAF.

All three reservoirs are subject to evaporation losses and sedimentation. In the case of Mangla and Tarbela, evaporation losses are small in relation to storage capacity and only amount to an annual value of 0.05 and 0.1 MAF, respectively, during the release period. At Sehwan, however, they are significant and account for about 20 percent of the storage capacity. On the other hand, Mangla and Tarbela, particularly the latter, suffer from quite severe sedimentation. The sediment is treated as a function of river flow and at both these reservoirs 50 percent of the sediment is considered as depleting live storage. The figures used for sedimentation are such that in a mean water year Mangla depletes at a rate of 0.02 MAF a year and Tarbela at 0.12 MAF a year.

No allowance is made in the study for the Chasma reservoir, which would store up to 0.5 MAF, since it was considered that it would be best operated on a variable release pattern; and the computer program allows variable operation only at the main reservoirs. However, allowance can be made for this in considering the results.

Tubewell Installation. The pattern of tubewell installation is based on the IACA projections for public and private tubewell development. Tubewell capacity is in two parts: tubewells used for irrigation and in some cases also for drainage in the areas of usable groundwater, and tubewells used for drainage alone in the areas of saline groundwater.

In the areas of usable groundwater, the tubewell capacity was calculated for every command for each of the 20 years of the study. For public tubewell areas the effective capacities used are 87 percent of the existing, or planned, installed capacities, since 87 percent represents the peak monthly utilisation factor projected by IACA. In the case of private tubewells, a different approach was used. The IACA projections have assumed an annual utilization factor for private wells of 27.4 percent. The difficulty that arises is that the logic of the computer program will try to maintain the groundwater table at a fixed level, in this case 10 feet. This has the effect that in an area of low installed tubewell capacity, the pumps will be used to 100 percent of their capacity, which will give unrealistic quantities of groundwater pumping. To offset this tendency the value of effective capacity for private tubewells was taken as 30 percent of the installed capacity. This will correct the annual pumping total, though at the same time it leaves no flexibility in the monthly figure. In areas of mixed development (i.e., private and public wells in the same command), the capacities of public and private tubewells were added. Some allowance was also made for Persian wheels in the early years of the study. The use of groundwater in a command is physically limited by the capacities as computed above, but mixing criteria also impose limitations which are discussed later in this Annex.

Drainage capacity in the saline areas was installed in accordance with the IACA plan. Three options exist for the disposal of drainage water: (i) to discharge it into the river; (ii) to evaporate it in salt-pans; (iii) to pass it by drains into the sea. Also, in some commands drainage pumping and release of drainage to the rivers is restricted to months of high river flow in order to ensure dilution of drainage effluent.

Groundwater Hydrology

Quality of Groundwater. In order that water table depths and drainage requirements can be estimated, each canal command is divided into 'area good' and 'area bad.' 'Area good' is the area wherein mixing criteria allow all recharge to be pumped for irrigation use and are defined as the part of the gross commanded area lying outside the 3000 ppm isogram, or the 2000 ppm isogram in the case of the Lower Indus canal commands. 'Area bad' is the area wherein none of the recharge can be used for irrigation use and is the part of the gross commanded area lying within the 3000 ppm isogram (or 2000 ppm for Lower Indus). The use of groundwater quality data in the determination of mixing ratios will be explained in due course.

Aquifer Storage Coefficient. The aquifer storage coefficients used in the study are 0.15 for the North Zone and 0.13 for the South Zone. This means, for example in the South Zone, that one cubic foot of aquifer below the water table contains 0.3 cubic feet of recoverable groundwater. The change in depth to groundwater (an average value for each canal command) is a simple computation based on aquifer storage coefficient, 'area good' or 'area bad,' and the difference between pumping and recharge. Estimates of depth to groundwater are therefore directly related to the aquifer storage coefficient.

Canal Loss Factors. Loss factors used to compute seepage and evapotranspiration losses from the main canal systems and the link canals are those used by IACA in their system analysis. The annual computed losses as a percentage of annual canal head diversions are about 28 percent in the North Zone, and 23 percent in the South Zone. Annual link canal losses range from 5.2 MAF to 6.1 MAF.

The proportion of main canal losses going to groundwater recharge is defined by input data; in this analysis a value of 0.80 was used.

Watercourse Field Losses. The losses assumed in the analysis are for watercourse loss, 10 percent of watercourse delivery, and for field losses, 30 percent of field delivery. IACA assume that one half of the watercourse loss and one third of the field loss are nonrecoverable. Therefore the recoverable loss, or recharge, is 23 percent of the watercourse delivery and this value is used for all canal commands in the system.

River Losses and Gains. The factors and equations used to compute river losses and gains were derived by Harza from flow records for the period 1937–46 and were also used in the IACA studies.

Groundwater Recharge. The three main components of groundwater recharge are: (i) seepage from main canal systems (all channels in a canal command between the head of the main canal and the head of the watercourse); (ii) seepage from watercourses and deep percolation from the fields; and (iii) other losses to groundwater which include seepage from link canals and rivers, and rain throughput.

Components (i) and (ii) are directly computed in the analysis. The factors required for the computation are introduced as input data.

Component (iii) is input data and values of this component for each month and for each canal command are computed by hand. Previous studies are used to obtain total link canal and river losses. River losses in each river reach were divided into the seepage and evapotranspiration components and the recharge from each reach computed and a similar calculation was made for link canals. The annual contribution of links and rivers to recharge within the canal commands is of the order of 9 MAF. This is less than total seepage losses since some losses occur outside the canal commands. The distribution of the link and river recharge between the commands is based on map studies, and rain throughput is added to obtain monthly values of component (iii) for each canal command.

The computer program is so written that the computed values for components (i) and (ii) for each month in each command are added to input values for component (iii) to obtain total recharge. The total recharge is then multiplied by a factor (defined in the input data) to obtain the distribution of recharge between 'area good' and 'area bad'; values for this factor are obtained by map studies and hand computations based on previous system analyses.

Surface Water Supplies

Indus, Jhelum and Chenab Supplies. The conditions of sequential river flows used in the analysis have already been described. In the historic sequence, the actual river flows have a considerable bearing on the results of the analysis. Months of high river flow can produce plentiful surface water supplies and a reduction of groundwater use, whereas low flows can increase the tubewell pumping requirements and cause shortages. The mean water year used by IACA may be regarded as a bench mark; from this mean an examination of variations in the historic sequence provides a valuable guiding light in which to view the results.

Table A5-4 shows how the rabi flows from October to March for the historic sequences vary from the 41-year mean flows used by IACA. The most striking feature is that on total balance for the 20-year period, the rabi flows between October and March in the Jhelum and Chenab Rivers combined are 17 MAF less than mean. The Chenab has a particularly large number of low-flow years with a total of 12 MAF less than mean in rabi over the 20-year period. The Indus rabi flows are slightly higher than mean on balance over the 20 years.

The overall effect of the variations in the historic sequences from the mean water years would be to produce rather critical conditions of surface water availability in the areas served by the Jhelum and Chenab Rivers alone. These critical conditions would in turn be reflected in the remainder of the system in spite of the fact that Indus flows in total are reasonably close to the mean. One factor which in-

TABLE A5-4
VARIATIONS OF HISTORIC RABI FLOWS FROM MEAN FLOWS

Water Year	Equivalent Water Year In First Historic Sequence	Equivalent Water Year In Second Historic Sequence	Variation of Historic Rabi Flow October to March From 41-Year Mean Flow (MAF) Indus	Jhelum	Chenab
1926	1966	1976	− .1	−1.0	−1.1
27	67	77	− .7	−1.4	−1.2
28	68	78	+1.0	− .2	−1.0
29	69	79	−1.2	+ .7	− .3
30	70	80	+4.6	+3.0	+ .7
1931	1971	1981	0	− .3	−1.3
32	72	82	+2.2	− .3	−1.2
33	73	83	− .1	−1.2	−1.1
34	74	84	− .5	−1.1	− .7
35	75	85	+ .5	−1.0	− .8
1936	1976	1966	+1.3	+ .8	− .3
37	77	67	−1.6	− .3	− .9
38	78	68	−1.7	+ .1	+ .3
39	79	69	+2.8	+ .2	− .5
40	80	70	− .8	−1.6	−1.6
1941	1981	1971	−3.4	−1.7	−1.9
42	82	72	+1.6	+1.1	+ .5
43	83	73	+1.2	+ .9	+ .8
44	84	74	− .9	−1.1	0
45	85	75	− .6	− .7	− .5
		Total	+3.6	−5.1	−12.0

fluenced the choice of years was that Harza had already processed figures for river flows in a 13-year sequence and considerable extra work was avoided by incorporating this 13-year Harza period into the 20-year period for the sequential analysis. It was also considered that a more trenchant test of the IACA program would be provided by low rabi flows than by high flows.

Apart from these overall considerations of the 20-year period, there are significant variations in individual years and months. The lowest combined rabi flow was in 1941, equivalent to 1981 in the first historic sequence and to 1971 in the second historic sequence, when the total flow was 7.0 MAF less than the mean. On the other hand in 1930, equivalent to 1970 and 1980 in the first and second sequences respectively, the total flow was 8.3 MAF higher than the mean.

For input into the computer program, flows of the Indus River at Attock are divided into the component flows of the Kabul River at Warsak, the Swat River at Amandara and the Indus at Tarbela. The Indus at Tarbela is itself composed of the Indus at Darband plus the Siran River, a small tributary between Darband and Tarbela. Indus flows at Darband were based on Attock records and were derived from the method agreed in 1964 by Gibb, Harza and TAMS.[1] Studies were made by Harza in 1964 to derive data for the Swat and Kabul Rivers which, when combined with the Tarbela flows, would be consistent with the Attock record. The

[1] IACA's Comprehensive Report, Annexure 4.

study revealed an annual discrepancy of about 4 MAF, which was removed by the introduction of a tributary inflow to the Kabul below Warsak. Tributary inflow on the Swat River below Amandara represents supplies from the Panjkora River, a major tributary of the Swat.

A further tributary inflow was introduced on the Jhelum River in order to take account of the recorded gains in the river between Mangla and Rasul.

Ravi and Sutlej Supplies. Surface water supplies from the Ravi and Sutlej Rivers were treated differently from those of the Indus, Jhelum and Chenab. Under the terms of the Indus Waters Treaty, the flows of the Ravi and Sutlej will be available for use wholly by India after March 31, 1970, unless Pakistan applies for a deferment of up to three years. The procedures for sharing supplies in the Ravi and Sutlej during the transition period before March 31, 1970, are set out in Annexure H of the Indus Waters Treaty. In January 1966, Harza made a study (unpublished) in order to determine how much water could actually be expected by Pakistan from these rivers during the transition period. Harza based their calculations on discharges in the water year 1945, which they considered to correspond approximately to average year runoff conditions for the Ravi and Sutlej. They then computed the minimum supplies which would have to be released by India to fulfill her obligations under the Treaty. Supplies were considered in two periods; the first period extended to September 30, 1968, after which it was assumed that Mangla releases would be fully available for use in Pakistan; and the second period was from October 1, 1968, to the end of the transition on March 31, 1970. It was calculated that in the second period, starting on October 1, 1968, there would be no rabi water supplies available from India. During the first period, up to the September 30, 1968, there would be supplies from the Sutlej River at Ferozepore and from the Ravi River at Madhopur through the Upper Bari Doab Canal. The total rabi flows entering Pakistan between October and March in the water years 1967 and 1968 would be:

Ravi River to Central Bari Doab Canal	0.48 MAF
Sutlej River at Ferozepore	1.80 MAF
Total	2.28 MAF

The supplies computed by Harza for the Ravi and Sutlej Rivers were used in each of the sequential analyses. The rabi supplies computed by Harza are substantially less than either the assumed replacement storage at Mangla of 4.75 MAF or the historic deliveries from the Ravi and Sutlej. The effect on the analysis of these low rabi supplies is to produce theoretical shortages (which may or may not have occurred in practice during a period well before the IACA projections become effective).

Watercourse Requirements

Irrigation water requirements at the watercourse are functions of the development program and are the primary determinants of the scope and timing of other physical works such as storage reservoirs, enlargement of main canals and link canals, tubewell capacities and the generating facilities needed to serve the pumping loads. Monthly watercourse requirements for each canal command for each year of study constitute the most important block of input data. The watercourse requirements account for 10,000 separate values out of about 60,000 separate values for all kinds of input data in each sequential analysis.

As part of their planning studies, IACA computed watercourse requirements for the reference years 1970, 1975 and 1985; estimates were also made for present conditions of development. For the years 1975 and 1985, the requirements were based on full crop watering for the projected cropping patterns and intensities. In the period prior to 1975, the transition from present-day watercourse deliveries with its associated underwatering and unregulated deliveries to optimal deliveries was accomplished in three ways.

First, in commands where public tubewells are installed, full delta watercourse requirements coincide with the implementation of the project.

Second, in the remaining commands, supplied by the Jhelum and Chenab Rivers, Mangla Reservoir is assumed to be capable of regulating rabi flows. In these areas historic seasonal totals were maintained but redistributed by months in accordance with the computed requirements.

Third, in commands served by the Indus main stem in which no public tubewell development was scheduled before 1975 mean historic monthly deliveries were maintained without regulation.

In the second and third cases, an extra allowance was made for the contribution of private pumping.

These figures were derived for the 61 development units of the IACA study and therefore had to be rearranged to suit the 42 canal commands used in the analysis. Finally, it was necessary to interpolate between the reference years to obtain watercourse requirements for the remaining years of the study period. Interpolation factors were used which were keyed to the IACA projections for growth of intensities. A program was developed for an IBM 1620 computer and used to compute the monthly values and punch the cards in the format required for the IBM 7094. Such an approach necessarily involves a certain degree of approximation and the validity of the figures should only be viewed on an overall basis.

Power Demands and Installation

The forecasts of basic power and energy demands prepared by Stone and Webster were used as input data in the sequential analysis. The basic load includes all classes of load other than pumping loads for irrigation and drainage. Pumping loads are computed in the analysis by applying factors to the monthly volumes of groundwater pumping and then added to the basic loads to obtain energy and power demands for the system.

The thermal plants and hydroelectric generating units were introduced during the study period in accordance with the S&W schedule. The boundary of the North Zone is south of the Multan thermal plant. The South Zone includes Karachi for the purpose of this analysis. The capacity of the North-South intertie is defined by input data, and a capacity in excess of potential transfers was used in the study in order to determine the maximum extent to which the output of the North Zone hydro plant could be used in the South.

Operating Criteria

Mixing Ratios. In the IACA studies, groundwater quality zones were treated as separate entities and mixing ratios as outlined in Table A5-5 were adopted.[1]

Reservoir Operation. The reservoirs were operated in the manner suggested in the IACA Report with the following fixed release patterns, as shown in Table A5-6.

The releases at Tarbela were slightly modified in 1975 since only 5 MAF was impounded in the previous year. The release patterns were developed to make allowance for an average condition of low rabi, but they would clearly be modified in operation to match the variation in river flows. It was, however, considered too complicated to vary the release patterns in the study, and hence they remained constant.

After an examination of preliminary results, it was concluded that there was no justification in maintaining the drawdown level at Mangla as high as 1075 ft. Consequently, the reservoir was drawn down to 1040 in all years except 1975, when there appeared to be a slight shortage of power capability.

The following outlet facilities were assumed to be effective:

Mangla below spillway crest (1086):	4 tunnels
Tarbela below spillway crest (1492):	4 tunnels
Sehwan	No restriction

Outlet capacities below the spillway level at Mangla and Tarbela are governed by the installation of turbines and valves. Above the spillway crest the capacity is virtually unrestricted.

Link Canals. The computer program provides for several alternative modes of operation for the Chasma-Jhelum and Taunsa-Panjnad Links. In this analysis, the Chasma-Jhelum Link is operated to meet requirements at Trimmu, and the Taunsa-Panjnad Link is operated to meet requirements at Panjnad, when Jhelum and Chenab flows are not sufficient to meet the demands at these diversion points.

[1] Although the computer study does not deal with groundwater zones, explicitly the mixing ratio is controlled in the program by a factor which only permits a proportion of the watercourse delivery to be met by groundwater. This factor will vary from 1.0 in a fresh groundwater zone to zero in a saline zone, and for a command with different zones a weighted average factor was calculated. These calculations were made separately for each command over the 20 years and account for the apparent monthly variation of pumping capacity. This factor was also used to control the internal distribution of groundwater within a canal command and prevent pumps from supplying the watercourse requirements of an area not served by tubewells. This is particularly important in the case of private tubewells, which are concentrated in portions of the canal command and cannot supply the remainder of that command.

TABLE A5-5
MIXING RATIOS

Deep Groundwater Quality Zone	Average Mixing Ratio Surface Water to Groundwater
(ppm TDS)	
0–1000	No restriction
1000–2000	1 :1
2000–3000	$2\frac{1}{2}$:1
Over 3000[a]	No groundwater use

[a] Over 2000 ppm in Lower Indus commands.

TABLE A5-6
FIXED RELEASE PATTERNS

	(monthly percentage of live storage)							
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Mangla[a]	23	15	10	10	24	18	—	—
Tarbela	—	8	11	21	26	19	10	5
Sehwan	—	10	30	27	33	—	—	—

[a] Due to an input error, a small amount of impounding takes place at Mangla in April. In fact this makes no significant difference to the analysis as in a mean year 0.3 MAF is in any case involuntarily impounded due to the restriction of the outlet capacity.

Principal Results of Analysis

General

The results of the sequential analysis for 1966–85 generally confirm the earlier studies made by IACA for certain reference years, including 1975 and 1985. The water and power demands of the system, as projected by IACA and S&W, are adequately served by the physical works embodied in their development programs.

It is also true that the sequential analysis revealed some irrigation shortages in the early years of development, and also in some months of critically low water years prior to the commissioning of Tarbela. But the former shortages occur before the IACA projections become effective, and the latter shortages are reflections of the underwatering assumed by IACA in the pre-Tarbela period.

The minimum reserve generating capacity of the system is higher in most years than indicated in the S&W report due to the lower pumping loads derived in the study.[1] A study to determine whether these findings would justify modifications in the power development would be beyond the scope of this report.

The method of sequential analysis is a valuable technique for examining alternative development plans and for providing a basis for planning decisions. It would, however, be unwise to attach too much emphasis to the figures derived in this study. It should be recognized that any particular topic will in most cases require more detailed analysis than is possible in this form of study. Studies using a time base shorter than one month would be required when considering the design or operation of individual projects. This comment applies to features such as reservoir release patterns, outlet capacity requirements, and integrated operation of the thermal and hydro plants, where the results of a sequential analysis should be supplemented by daily or weekly operation studies.

Four copies of the complete series of computer output for this study were produced. One copy was submitted to the Study Group, one sent to WAPDA, and one each retained by Gibb in London and Harza in Chicago. The breakdown summaries for the North and South Zones, mean year sequence, are shown in facsimile at the end of this Annex.

Irrigation Supplies

Surface and Groundwater Deliveries. Table A5-7 presents a summary of the watercourse requirements for the next two decades and shows the breakdown of

[1] The pumping loads derived are in line with later projections made by IACA in July 1966.

TABLE A5-7
WATERCOURSE REQUIREMENTS AND MEAN YEAR DELIVERIES
(MAF)

Year	Watercourse reqt.	Surface water	Ground-water	Shortage
1966	68.7	56.8	9.6	2.3
1967	70.3	55.4	12.9	2.0
1968	72.4	56.7	15.6	0.1
1969	73.8	54.2	19.2	0.4
1970	75.3	53.3	21.7	0.3
1971	78.2	54.1	23.8	0.3
1972	80.6	54.4	25.6	0.6
1973	83.8	55.7	27.1	1.0
1974	87.3	57.0	29.1	1.2
1975	92.1	61.1	31.0	0.0
1976	95.3	63.2	32.1	0.0
1977	97.4	63.2	34.2	0.0
1978	99.6	63.3	36.3	0.0
1979	101.8	63.2	38.6	0.0
1980	103.9	64.2	39.7	0.0
1981	107.8	67.1	40.7	0.0
1982	109.6	68.9	40.7	0.0
1983	111.7	70.6	41.1	0.0
1984	114.3	73.1	41.2	0.0
1985	116.5	74.4	42.1	0.0

deliveries in terms of surface and groundwater, under mean year conditions. The volume of groundwater pumped is slightly higher than projected in the IACA report for the reference years. Groundwater pumping is considered in a later section below.

Shortages and Surplus. The crucial test of the IACA program as analyzed in this study is the extent to which the planned installation of groundwater and surface water facilities can meet the demands of the projected agricultural growth. Any deficiency would appear as a shortage at the watercourse. The pattern of shortages that arise under mean year conditions is shown in Table A5-8.

TABLE A5-8
WATERCOURSE SHORTAGES (OCTOBER–MAY) MEAN YEAR SEQUENCE
(MAF)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
1966	.58	.65	.40	.26	.41	—	—	—	2.30
1967	.42	.51	.31	.22	.51	—	—	—	1.97
1968	—	—	.03	—	.05	—	—	—	.08
1969	—	—	.08	.13	.19	—	—	—	.40
1970	—	—	.07	—	.22	—	—	—	.29
1971	—	—	—	—	.27	—	—	—	.27
1972	.01	—	.08	.09	.44	—	—	—	.62
1973	—	—	.11	.27	.55	.10	—	—	1.03
1974	—	—	.06	.33	.64	.20	—	—	1.23
1975	—	—	—	—	.04	—	—	—	.04

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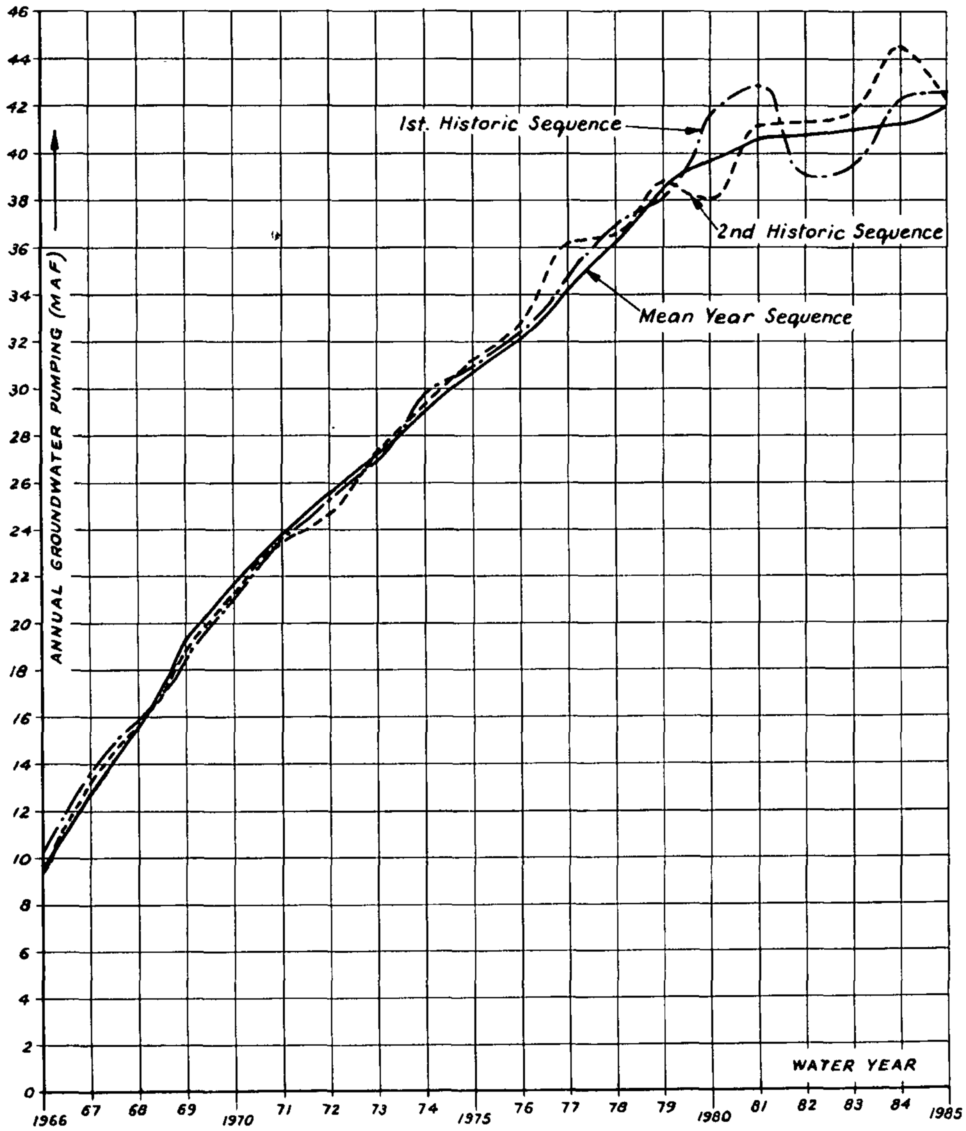
ANNEX 5
FIGURE 2



GROUNDWATER PUMPING BY YEARS

No shortages were revealed in the analysis beyond 1975, at which point there is ample surface storage available and the tubewell program is well advanced. This result in itself is not very significant, since the program is geared to meet water requirements in conditions lower than mean. Any deficiencies would have been surprising and an indication of incorrect projections; there are occasional small shortages in kharif, but these are the result of approximations in the method of calculation and can be ignored. The total shortage prior to 1975 is 8.2 MAF and occurs primarily in two periods, the first two years of the study, and the period from 1972 to 1974, just before Tarbela comes into operation. The combined shortage of 4.3 MAF in 1966 and 1967 arises from the restricted allowance that has been made for the flows of the Ravi and Sutlej Rivers in the transition period before the advent of Mangla storage. The early years of the study are based on present deliveries, and do not form part of the IACA plan. Hence such shortages are not very meaningful; in practice they would depend entirely on the actual flows passed down the Sutlej and Ravi. The impact of Mangla reservoir in the water year 1968 is evident, and this factor, in conjunction with increasing tubewell capacity, reduces shortages to a low level until 1973. At this point, the demand is rising in anticipation of Tarbela storage. The shortages are equivalent to about 3 percent of deliveries from October to April in 1973, rising to 3¼ percent in 1974. These small shortages are the result of interpolation in the input data and would be reflected in the underwatering projected by IACA before Tarbela.

A measure of the efficiency of the use of water is the extent to which surface water is passed to the sea during the period of reservoir release. The surplus at Ghulam Mohammed is shown in Table A5-9. A certain quantity of water is passed to the sea in October, a month during which substantial releases are made at Mangla. All the Mangla releases however are effectively used upstream of Trimmu

TABLE A5-9
SURPLUS AT GHULAM MOHAMMED (OCTOBER-MAY)
MEAN YEAR SEQUENCE
(MAF)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
1966	2.2	.5	0	.2	0	.3	1.5	3.3
1967	2.8	.6	.1	.2	0	.3	1.6	3.1
1968	2.8	.8	.1	.2	.1	.4	1.7	3.6
1969	2.8	.7	.1	.3	0	.3	1.7	3.5
1970	2.7	.7	.1	.2	0	.1	1.6	3.7
1971	2.8	.8	.1	.1	0	.1	1.5	3.3
1972	2.4	.5	.1	0	0	0	1.2	3.0
1973	2.4	.4	0	0	0	0	1.0	2.7
1974	2.3	.4	0	0	0	0	.8	2.2
1975	1.7	.2	0	0	0	0	.9	2.0
1976	2.0	.4	0	0	0	0	1.4	2.4
1977	1.9	.4	0	0	0	0	1.3	2.4
1978	2.0	.4	0	0	0	0	1.3	2.4
1979	2.1	.4	0	0	0	0	1.3	2.4
1980	2.2	.3	0	0	0	0	1.0	2.0
1981	2.0	.2	0	0	0	0	.5	1.5
1982	1.7	.1	0	0	0	0	.3	1.2
1983	0.4	0	0	0	0	0	.1	1.1
1984	1.1	0	0	0	0	0	0	.9
1985	0.9	0	0	0	0	0	0	.7

and the surplus at Ghulam Mohammed is entirely due to flows from the Indus. In 1976 some water is surplus during the release period, but by 1982 this has shrunk to inconsiderable proportions.

A study of the shortages that occur under the historic sequences of river flow is a more revealing test of the program than under the mean year sequence. These figures are shown in Table A5-10 and A5-12 with the corresponding surpluses in Tables A5-11 and A5-13. As would be expected, the shortages are somewhat larger than under mean year flows. Again neglecting the first two years of the study, the first historic sequence reveals October to May shortages during 1968–74, totalling 7.3 MAF. This is an average shortage of about 3¼ percent of the rabi watercourse requirement during the period, with the highest shortage of 6½ percent occurring in 1974. For 1975–85, the total shortage is 2.8 MAF. Of this Figure, however, 2.2 MAF occurs in the month of October, which is a special case. These shortages occur in those areas which are only commanded by Mangla. The watercourse requirements in these commands are at a high peak in October and there is little spare capacity in the tubewells to supplement shortfalls in the river flows. The problem is accentuated by the selection of a historic sequence of flows that contains rather low rabi flows for the Chenab and Jhelum. The October to March mean for the 20 years is about 0.85 MAF below the 41-year mean. Thus the system has been tested under somewhat severe circumstances. The shortages in low water years could be alleviated to some extent by modifying the releases at Mangla for October, as suggested by the IACA report.

Apart from the October shortage, there is a total of 0.6 MAF occurring at random during the rabi months over the entire 10-year period from 1975 to 1985. This represents less than 0.5 percent of the watercourse requirement and may be

TABLE A5–10
WATERCOURSE SHORTAGES (OCTOBER–MAY)
FIRST HISTORIC SEQUENCE
(MAF)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
1966	.90	.64	.40	.45	.94	.20	.16	—	3.69
1967	.41	.62	.43	.42	1.01	.78	.26	.20	4.13
1968	.51	.09	.20	.16	—	.16	—	—	1.12
1969	—	—	—	.03	.42	—	—	—	0.45
1970	—	—	—	—	—	—	—	—	—
1971	.41	—	.07	—	.43	.05	—	—	0.96
1972	.01	—	—	.06	.51	—	—	—	0.58
1973	.11	—	.08	.35	.88	.28	—	—	1.70
1974	—	—	.10	.43	1.02	.72	—	.21	2.48
1975	.44	.04	—	—	—	—	—	—	0.48
1976	.17	—	—	.05	—	—	—	—	0.22
1977	.15	—	—	—	—	—	—	—	0.15
1978	.39	—	—	—	.03	—	—	—	0.42
1979	.23	—	.01	.09	—	—	—	—	0.33
1980	.01	—	—	.06	.02	.04	—	—	0.13
1981	.57	—	—	—	.15	—	—	—	0.72
1982	—	—	—	—	—	—	—	—	—
1983	—	—	—	—	—	—	—	—	—
1984	—	—	—	—	—	.01	—	—	.01
1985	.30	—	—	—	—	.07	—	—	.37

TABLE A5-11
SURPLUS AT GHULAM MOHAMMED (OCTOBER–MAY)
FIRST HISTORIC SEQUENCE
(MAF)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
1966	2.2	0.6	.1	.2	0	0	1.2	2.5
1967	4.4	1.1	.1	.1	0	0	.6	1.0
1968	2.0	0.4	0	.2	.2	.9	2.7	5.2
1969	2.4	.6	.1	.2	0	.2	1.1	1.4
1970	3.8	1.4	.5	.6	.2	1.3	4.1	6.1
1971	2.2	.7	.2	.1	0	0	1.2	2.6
1972	3.3	1.1	.2	0	0	0	.9	1.2
1973	2.1	.3	0	0	0	0	.1	1.4
1974	3.5	.7	.1	0	0	0	0	0
1975	1.3	.2	0	0	0	0	.8	2.0
1976	2.0	.4	0	0	0	.5	1.9	4.8
1977	1.7	.2	0	0	0	0	1.1	3.1
1978	.7	0	0	0	0	0	1.9	6.3
1979	.9	0	0	0	0	1.1	2.7	5.1
1980	2.1	.4	0	0	0	0	.4	.9
1981	.5	0	0	0	0	0	.1	2.0
1982	.7	0	0	0	0	0	1.4	1.8
1983	.7	.1	.3	.1	.1	0	.5	.5
1984	1.9	.1	0	0	0	0	0	.1
1985	.7	0	.1	0	0	0	0	0

regarded as negligible. In any case, the capacity of the Chasma reservoir would be more than adequate to overcome these shortages.

The pattern of shortages in the second historic sequence bears a marked resemblance to that of the first historic sequence. From 1968 to 1974, there is a total October to May shortage of 9 MAF; the worst annual total reaches 2.5 MAF in 1971. From 1975 onwards the shortage is 2.9 MAF, of which the largest proportion, 1.7 MAF, occurs in the month of October for similar reasons as before. Of the remaining shortages, part arises in 1975, when the full benefit of Tarbela is not available, and part is due to an exceptionally low May in 1984.

In both historic sequences, occasional shortages are apparent in June, and there are also September shortages in the Jhelum and Chenab commands in the early years of the second historic sequence before the completion of the T-P Link. The effect of a low June would be offset by a reduction in the reservoir impounding for that month.

Finally, an examination of the critical years in 1976 and 1985 reveals no significantly large shortages. The conclusion that can be drawn from these results is that, subject to the limitations of the accuracy of the basic assumptions, the IACA program contains adequate facilities to meet the irrigation demands. The IACA program was not intended to meet requirements under all conditions that might arise, and thus small shortages were expected in some months of the historic sequences. Such shortages as exist are confined almost entirely to the period prior to 1975, or more pertinently prior to the commissioning of Tarbela, and even these shortages are put in perspective when compared to the total projected watercourse deliveries over the 20 years of 1840 MAF.

TABLE A5-12
WATERCOURSE SHORTAGES (OCTOBER–MAY)
SECOND HISTORIC SEQUENCE
(MAF)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
1966	.91	.74	.43	.47	.63	0	0	0	3.18
1967	.85	.60	.36	.31	.58	.29	0	0	2.99
1968	.48	.08	.04	0	.11	0	0	0	.71
1969	.75	.16	.39	.35	.09	0	0	0	1.74
1970	.23	.01	.22	.19	.65	.57	0	0	1.87
1971	.68	.06	.27	.19	.90	.40	0	0	2.50
1972	.01	.04	.18	0	.02	0	0	0	0.25
1973	0	0	0	0	.41	0	0	0	0.41
1974	0	0	.08	.33	.74	.41	0	0	1.56
1975	.17	0	0	0	.20	.18	0	0	0.55
1976	.15	0	0	.06	.17	0	0	0	.38
1977	0	0	0	.09	.14	0	0	0	.23
1978	.39	0	0	.06	0	0	0	0	0.45
1979	0	0	0	0	.01	0	0	0	0.01
1980	0	0	0	0	0	0	0	0	0.0
1981	.08	0	0	0	0	0	0	0	0.08
1982	0	0	0	0	0	0	0	0	0.0
1983	.34	0	0	0	0	0	0	0	.34
1984	0	0	0	0	.01	.11	0	.24	0.36
1985	.53	0	0	0	0	0	0	0	0.53

Control of the Water Table. The IACA program emphasizes the intensive installation of tubewells in areas underlain by usable groundwater. Both public and private development are important to this program in the early years, but by 1980 most of the usable groundwater in the canal commanded areas would be covered by the public tubewell projects. These projects would then be extended during the decade after 1980 at a declining rate, into the few remaining canal commanded areas with usable groundwater. Also by about 1980 the early public tubewells would be operating at about their maximum average utilisations. The general pattern of pumping to be expected from the IACA program is therefore a steadily increasing quantity of water pumped up to about 1980 with a decreasing rate of pumping thereafter, approaching the peak level by 1985. This pattern is confirmed in the sequential analyses as can be seen from the groundwater pumping by years shown in Annex Figure 2. The slightly higher groundwater delivery than in the IACA study is caused in 1975 by dewatering and in 1985 by overpumping; also there is slightly more pumping due to an assumption of higher recharge from rivers and link canals than in the IACA study. The effect of these factors on the tubewell pumping is very small.

Other aspects of Annex Figure 2 which call for comment are the effects of surface water storage and the relation of pumping in the historic river flow sequences to pumping under mean year conditions. The advent of Tarbela storage which would be effective in the water year 1975 might be expected to cause a reduction in tubewell pumping. Nonetheless, the rate of increase in groundwater use is apparently unaffected by the additional surface water made available from Tarbela. There are five reasons set out below for this apparent anomaly.

1. The most important reason is that tubewells are used up to the limits of their effective capacity to prevent the further rise of a water table which has risen to within 10 feet of ground level. Very little overpumping takes place before the ad-

TABLE A5–13
SURPLUS AT GHULAM MOHAMMED (OCTOBER–MAY)
SECOND HISTORIC SEQUENCE
(MAF)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
1966	2.3	.6	.1	.2	.1	1.0	2.2	5.6
1967	2.7	.5	.0	.2	0	0	1.5	4.0
1968	1.4	.2	.1	.2	0	.4	2.6	7.5
1969	1.9	.4	0	.2	.1	1.5	3.0	6.3
1970	2.7	.8	.1	.1	0	0	1.0	2.5
1971	.8	.1	0	0	0	0	.9	3.8
1972	1.3	.2	0	0	0	.2	2.3	3.7
1973	3.6	1.7	.1	0	0	0	1.4	2.1
1974	3.2	.6	0	0	0	0	.6	1.5
1975	1.8	.2	0	0	0	0	.9	1.2
1976	2.1	.5	.1	0	0	0	.8	1.2
1977	3.6	.9	.1	0	0	0	.1	0
1978	1.0	0	0	0	0	.5	2.1	4.1
1979	1.8	.4	0	0	0	0	.7	.2
1980	3.4	1.1	.3	0	0	.9	3.6	4.7
1981	1.3	.1	0	0	0	0	.2	.6
1982	2.6	.5	0	0	0	0	.5	0
1983	.4	0	0	.1	.1	0	0	.1
1984	2.1	.1	0	0	0	0	0	0
1985	.8	0	0	0	0	0	0	.8

vent of Tarbela in the sequential analyses, as pumping is limited both by the installed tubewell capacity and by the amount of the irrigation requirements in the project areas. Effectively, therefore, because there has been but little overpumping before Tarbela, there is also no reduction in the groundwater pumping after Tarbela; instead there is an increase due to the larger number of tubewells installed.

2. Many of the tubewell projects are still in a phase of dewatering which would continue regardless of additional storage water.

3. The crop water requirements used as input for the analyses are related in part to a rise in intensities due to the use of Tarbela water outside tubewell project areas.

4. It is assumed in the analyses that impounding at Tarbela would not be possible until August 1974, with the result that only 5 MAF would be released in the water year 1975.

5. The Tarbela release patterns are based on low rabi rather than mean year river flow conditions and so some surpluses would be passed to the sea in months such as April and May. However, this point is largely outweighed by the requirements of balanced recharge.

Between 1975 and 1980, extensive control of the water table should be provided by the tubewell projects. By this time it should be possible under the IACA projections for the public tubewells to make use of the aquifer as a balancing reservoir with the amount of groundwater pumping related to the availability of surface water. This potential use of aquifer storage is shown by the greater variations of the historic series from the mean year conditions in the later years of the study. The variations from mean conditions in the individual years are caused solely by the differences in river flows. It can be seen from Annex Figure 2 that, although these variations are significant, they do not differ by more than about 5 percent from the mean when considered on a yearly basis.

A further aspect of the control of the water table is the amount of overpumping beyond the balanced recharge level. IACA concluded that a satisfactory average level for the water table would be about 10 to 15 feet below ground level but that temporary overpumping beyond the balanced recharge level would be desirable at times of low surface water availability or prior to the introduction of new surface storage water. In the computer program for the sequential analyses, the recharge is balanced by withdrawals from the aquifer at an average level of 10 feet below the ground when sufficient surface water is available. Pumping beyond the 10-foot level may be regarded as an overdraft on the aquifer. The cumulative totals for these overdrafts in the sequential studies are shown in Annex Figure 3. The overdraft is small before 1975 as it is restricted to those areas in which public tubewells would already have controlled the water table. A reduction of the overdraft in 1976 is evident in the mean year study due to the use of Tarbela water. In the historic sequences, the overdraft actually increases at this time—due to low Chenab flows and consequent overpumping in the Punjab SCARPs in the case of the first historic series, and due to low rabi flows in both the Jhelum and the Chenab in the case of the second historic series.

The amount of overpumping is not large, but it increases steadily after 1976 until the total overdraft on the aquifer is approaching 8 MAF in 1985 in the mean year sequence. Some alleviation of this overdraft is provided by reservoir releases at Sehwan/Manchar from 1982 onwards. The overdrafts in the historic sequences vary from year to year according to the monthly river flows, and these variations, shown in Annex Figure 3, emphasize how sensitive the overdraft is to the river flow conditions at any stage of development. By 1985, the total overdraft reaches about 16 MAF in the first sequence and about 18 MAF in the second sequence, or about double the overdraft in the mean year sequence. There are two reasons for this higher level of overpumping found in the historic sequences. Firstly, as explained in an earlier section, the total rabi flows on the Jhelum and Chenab in the historic period 1926–46 are about 17 MAF lower than under the 41-year mean conditions. This factor alone is sufficient to account for the differences in overpumping between the historic and mean year sequences and provides an indication of the way in which the system would be capable of overpumping if faced with a series of low rabi years. The second reason for the higher rate of overpumping in the historic sequence is the constraint imposed by canal capacities in certain commands. The effect of this constraint is that the overdraft on the aquifer cannot always be replaced by additional surface water at times of high river flows.

The total overdraft of 8 MAF in 1985 with the mean year sequence would be equivalent to a drawdown of less than three feet over the entire fresh groundwater area in the canal commands. In practice, the drawdown would be concentrated in certain canal commands, but this general figure for the drawdown does indicate that the overpumping would not be at all excessive. Between 1976 and 1979, in the mean year sequence, the total overdraft is increasing at a rate of only about ½ MAF a year, which is very small in relation to the total irrigation deliveries of about 100 MAF a year. The more rapid increase in overpumping at a rate of about 1 MAF a year after 1979 is indicative of the rising demand for storage projected in the IACA program.

Resulting depth of water table in the fresh groundwater areas can be illustrated by Rohri Canal command, which is representative of the Lower Indus Region and

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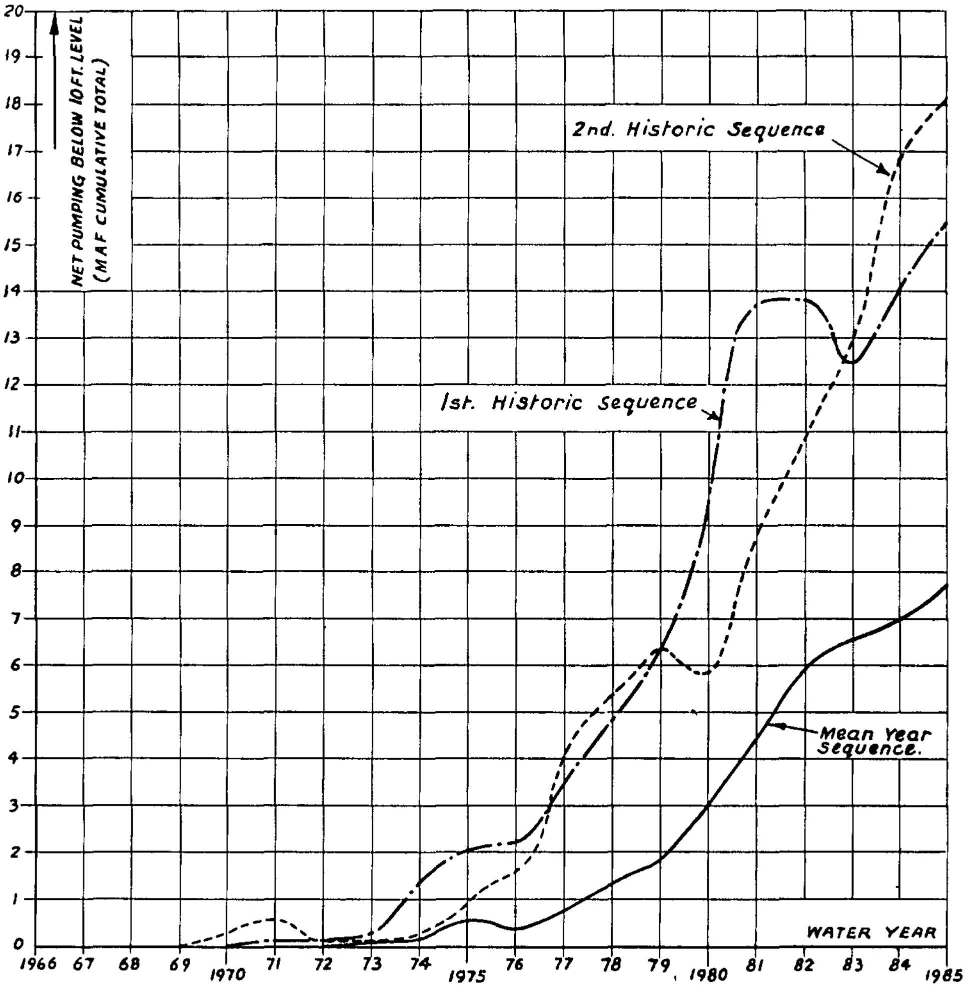
ANNEX 5
FIGURE 3



OVERDRAFT ON THE AQUIFER BELOW 10 FT. LEVEL.

also has the greatest drawdown of any of the commands in the basin under the method of analysis. By 1982, the water table is at a depth of over 40 feet in the mean year sequence or over 70 feet after a series of low river flows in the first historic sequence. After 1982, the overdraft on the aquifer is reduced by the introduction of storage water from Sehwan/Manchar and the enlargement of Rohri Canal. In practice, a water table depth of 70 feet in this area may be unacceptable for technical reasons and is certainly greater than envisaged by IACA. Some overpumping to raise intensities before 1982 was foreseen by IACA but not on this scale. However, the logic of the computer program in its present form is not designed to eliminate drawdown by changes in surface water distribution. In practice, the drawdown in Rohri could be alleviated by increasing pumping in upstream commands and thereby releasing additional surface water for use at Rohri in the rabi season.

In contrast to Rohri, for instance, the depth of the water table in Panjnad and Abbasia Canal commands remains stable through the period of analysis. However, it should not be concluded that all the overdraft at Rohri could be transferred to Panjnad and Abbasia. Part of the reason for the stable level of the water table in Panjnad and Abbasia is that the canal capacities are adequate to replenish the aquifer at times of high river flow. In any case, the pumping could not be increased above the level of requirements in this command. Nonetheless, it would be feasible to increase slightly the amount of pumping here and in the Trimmu commands in order to alleviate the overdraft in Rohri.

Another illustration is Lower Jhelum Canal, which depends for its supplies on the Jhelum River with Mangla reservoir and cannot be served by the Indus. In this command, there would be some overpumping prior to canal enlargement but the overdraft would be entirely made good before 1985 by use of the enlarged canal combined with the projected additional link canal capacity in the Punjab. There are variations in the depth of the water table which can be attributed to the availability of surface water in the conditions of river flow used for the analyses. The water table is generally deeper under the historic sequences due to the constraint of the canal system, which prevents the same degree of aquifer replenishment as would be possible under mean conditions.

The water table in commands served by the Chenab River alone remains generally within the 10- to 15-foot range, in spite of the low rabi flows in the historic sequences.

Link Canal System. IACA expected the existing and IBP link canal system to be adequate until about 1980, when a rising demand is predicted for additional link capacity in the Punjab. An allowance was made in the input data for an additional 0.3 MAF/month capacity in the RQ and QB Links from the water year 1981 onwards. This additional capacity in the sequential analyses is utilized in many months in the QB Link and in a few months in the RQ Link.

Allowance was also made in the input data for 10 percent excess over the design capacity in the TSMB Link in all years. The excess capacity seemed reasonable from the reports of early operation of the Link. Without the additional capacity there would have been some shortages in the canals served by the TSMB Link. In practice, the shortages could alternatively have been largely removed by using supplies passed downstream from the RQBS Link.

No capacity constraints were apparent in the other link canals.

Use of Surface Storage. The IACA analysis projected a firm demand for storage on the Indus of about 5 MAF in 1975 rising to 9 MAF in 1985 under mean conditions of river flow. Projections for the period between 1975 and 1985 were made by interpolation between the reference years.

The sequential analyses are operational rather than analytical in nature; therefore they are not suited to an evaluation of the IACA projections for growth of stored water demand. While a general assessment can be made of the use of surface storage water, it is not possible to quantify the results.

The results of the sequential analyses are illustrated in Table A5-14 which shows the breakdown of irrigation deliveries in the mean year sequence for the period November to April, before and after the commissioning of Tarbela Reservoir. The fact that river outflow during November–April increases by only 0.6 MAF between 1974 and 1976 would seem to indicate that nearly all the storage water is absorbed immediately. It cannot, however, be deduced that this represents a firm demand for storage because the computer program will tend to utilize surface water in preference to groundwater. The analysis is further complicated by the fact that neither the capacity of tubewells nor the operation of reservoirs are based on mean year conditions; they are geared to low rabi conditions.

A general examination of the results of the sequential analysis confirms that a steadily rising storage requirement exists from 1972 onwards under the IACA program. In Annex Figure 3, the pattern of overdraft on the aquifer shows the drawdown increasing from 1977. Up to 1979, the relatively small drawdown is in fact the result of the constraints in individual canal commands, but beyond then the rate of drawdown is more rapid; this is an indication that Tarbela storage water is being fully absorbed and that the system is becoming short of water again, as projected by IACA.

Between 1975 and 1985, the watercourse requirements during the release period are increasing at a rate that is approximately linear. The same is true of the pumping capacity, and it is reasonable to conclude that this will be also true of the storage demand.

Power

General. The sequential analysis provided an opportunity to compare the Stone and Webster program for power development with the system demands. The demands of the system are the S&W basic load forecasts, included as input data, and

TABLE A5-14
WATER BUDGETS BEFORE AND AFTER TARBELA
PERIOD NOVEMBER TO APRIL—MEAN YEAR SEQUENCE
(MAF)

	1974	1976	Increase
Watercourse Requirement	30.3	33.5	3.2
Comprising:			
Surface Water Deliveries	16.5	20.7	4.2
Groundwater Pumping	12.6	12.8	0.2
Shortages	1.2	0	−1.2
Canal Head Diversions	24.3	29.9	5.6
River Outflow	1.2	1.8	0.6

the groundwater pumping loads computed in the analysis. The five principal conclusions to be drawn from the results of the sequential studies are set out below.

1. There are deficiences in peaking capability in the North Zone prior to commissioning of the first Mangla units;

2. Minor and infrequent deficiencies occurring in the North Zone after completion of the intertie in 1973 are met by transfers from the South Zone;

3. There are no deficiences of peaking capability in the South Zone after 1971; prior to 1971 there may be deficiencies in certain areas within the South Zone which would not be revealed by the analysis;

4. System peaking capability exceeds system demand for the entire period following completion of the North-South intertie;

5. There are substantial power transfers from North to South in the months of July through January after the first Tarbela units are commissioned.

The principal results of the analysis with regard to power and energy generation appear in the summary sheets of the computer printout (sample at end of Annex). The headings are generally self-explanatory. A 'Peak Reserve'—the difference between peaking capability and total peak load—is listed for each zone, and for the system. When 'Peak Reserve' is negative, as in the period 1973–85, there is a 'Firm Capacity Transfer' having the same value.

In the North Zone, after Mangla is in operation, the hydro plants will serve most of the power and energy demand, and the load-dispatching process adopted in the analysis has the effect of maximizing the use of the hydro plants and minimizing the use of the thermal plants. It is believed that this method yields realistic values for the 'Thermal Capacity to Load,' but the 'Thermal Energy to Load' would in practice be somewhat greater than computed and the 'Hydro Energy to Load' correspondingly less. This is because the thermal plants, in order to be available at the time of peak demand, would be operating at part load during off-peak hours, although the hydro plants could meet the off-peak load.

Pumping Loads. The power and energy required for groundwater pumping are computed in the sequential analysis in contrast to the basic loads which are input. Pumping loads are a significant part of the system demands. The annual energy demands for groundwater pumping within the canal commands are tabulated in Table A5-15.

TABLE A5–15
ANNUAL PUMPING ENERGY LOAD
MEAN YEAR SEQUENCE
(million kwh)

Year	Pumping Energy	Percent of Total Load	Year	Pumping Energy	Percent of Total Load
1966	494	14	1976	2,877	23
1967	726	18	1977	3,153	23
1968	897	19	1978	3,462	22
1969	1,205	22	1979	3,747	22
1970	1,466	22	1980	3,932	21
1971	1,776	23	1981	4,283	21
1972	1,982	24	1982	4,393	20
1973	2,191	23	1983	4,608	20
1974	2,448	23	1984	4,626	19
1975	2,738	23	1985	4,731	18

TABLE A5-16
PEAK PUMPING LOAD (MW)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1975												
Mean	517	398	353	381	525	503	194	249	447	477	546	534
1st Historic	518	428	380	405	540	549	193	222	415	473	556	546
2nd Historic	533	418	366	357	554	531	167	212	426	478	545	539
1985												
Mean	865	684	554	653	853	809	413	505	726	791	941	932
1st Historic	919	759	589	671	943	900	403	533	751	808	999	990
2nd Historic	952	754	619	705	911	903	413	500	757	783	1,003	1,013
Critical	899	759	640	735	959	969	834	722	694	686	985	968

Monthly peak power loads for the years 1975 and 1985, given in Table A5-16, indicate the magnitude and annual distribution of peak pumping loads. No interruption of service to tubewells was assumed in deriving these values.

In general, the power and energy demands for pumping obtained in the sequential analysis are lower than the values adopted as a basis for the Stone and Webster development program.

Peak Reserves. The minimum reserve capacities of the system after the North-South intertie becomes effective are shown in Table A5-17. The peak reserves obtained in the sequential analysis are somewhat greater than those given in the S&W report. The principal reasons for the difference are firstly the lower pumping loads and, secondly, the higher hydro peaking capability obtained due to the method of calculation in the sequential analysis. Table A5-18 presents a comparison of results for the critical water years 1976 and 1985, in which adjustments have been made to place the figures on a similar basis.

TABLE A5-17
MINIMUM PEAK RESERVE
INTERCONNECTED SYSTEM 1973-1985

	Mean Water Year		1st Historic Sequence		2nd Historic Sequence		Critical Years	
Year	Month	MW	Month	MW	Month	MW	Month	MW
1973	March	421	March	400	March	505		
1974	March	364	March	288	March	334		
1975	March	345	March	304	March	314		
1976	May	555	May	635	March	523	March	453
1977	May	571	May	619	March	530		
1978	May	682	May	721	May	747		
1979	May	564	May	623	May	531		
1980	May	644	March	652	May	625		
1981	May	710	March	594	March	717		
1982	May	735	May	772	May	650		
1983	May	760	May	739	April	755		
1984	May	965	May	994	May	546		
1985	May	1,036	May	990	May	1,095	May	800

TABLE A5-18
RESERVE GENERATING CAPACITY
COMPARISONS FOR CRITICAL WATER YEARS IN 1976 AND 1985

	May 1976		May 1985	
	Sequential	S&W	Sequential	S&W
	MW	MW	MW	MW
Peak pumping load	384	709	722	1,211
Less interruptible	—	130	—	187
Peak basic load	1,850	1,850	4,162	4,162
Total peak load	2,234	2,429	4,884	5,186
Hydro capacity	1,070	1,043	1,937	1,717
Thermal capacity	1,662	1,662	3,747	3,796
Total capability	2,732	2,705	5,684	5,513
Reserves	498	276	800	327
Adjustments				
(a) Tubewells outside canal commands	−15		−55	
(b) Assume no load shedding		−130		−187
(c) Use common value for total capability				
Adjusted reserves	−27		−171	
	456	146	574	140

Transfers of power between zones obtained in the mean year analysis for 1976, 1980 and 1985 are given in Table A5-19. Transfers were not limited by intertie capacity, since a large capacity was adopted for the intertie in order to determine the potential for interzone power transfers.

Transfers are North to South, except for the negative value which is South to North. The maximum South to North transfer of 214 MW occurs in April 1985 (critical water year conditions).

Reservoir Operation

Since the reservoirs are influenced by both irrigation and power considerations, we have dealt with them under a separate heading. To draw any justifiable conclusions on reservoir operation, it is necessary to examine the subject on a time interval that is shorter than the monthly base used in the study. Nevertheless, it is possible to comment on three aspects of reservoir operation, namely drawdown levels, outlet capacities, and release patterns.

Drawdown Levels. The results of the analysis seem to confirm the view that the Mangla reservoir should be drawn down to the 1040 level when required. In the pre-Tarbela period, there would in general be a need for as much water as can be made available from the reservoir. Nothing arose in the analysis to suggest any alteration in the Tarbela drawdown level of 1332.

Outlet Capacities. The outlet capacity at Mangla of four tunnels has certain restrictive effects. It causes the involuntary impounding in a mean year of 0.3 MAF in April and it is not even possible to pass the full releases in March that were projected in the IACA plan. While no shortages were apparent in April, they did arise in March.

Release Patterns. The justification for the release patterns adopted is that relatively few shortages arose after 1975, and such shortages as arose before 1975 could not be much alleviated by altering the Mangla release pattern. Two points

TABLE A5-19
INTERZONE POWER TRANSFERS—MEAN YEAR SEQUENCE
(MW)

Month	1976	1980	1985
October	539	833	1,221
November	564	916	1,320
December	500	855	1,281
January	373	630	923
February	80	121	233
March	0	0	0
April	0	0	0
May	0	0	−30
June	0	0	0
July	400	584	1,262
August	413	641	1,251
September	424	645	1,265

regarding the release patterns, however, may need further consideration. Firstly, it may be necessary to increase Mangla releases in October during months of low flow. Secondly, releases from Tarbela in April and May tend to be wasted to the sea up to 1980 under conditions of mean flow. Such releases are, however, needed to counteract low flows in these months, and they serve the dual function of reducing groundwater pumping and at the same time increasing hydro capability in the months of lowest peak reserve. Fairly severe shortages can occur on the Indus in April and May, which is the critical period for the sowing of kharif crops, and a small retention in the reservoir up to the first 10 days of May will act as a safeguard. As a rough indication of the effect on peaking capability of storage in April, it can be calculated that every 0.1 MAF stored during this month is equivalent to increasing the peak reserve of the system by a value varying from 20 mw in 1977 to 30 mw in 1985. Thus the drawing down of the Tarbela reservoir by the end of March would require a compensating increase in peak reserve of the order of 200 mw, which may be a high price to pay for extra releases in the early part of the year.

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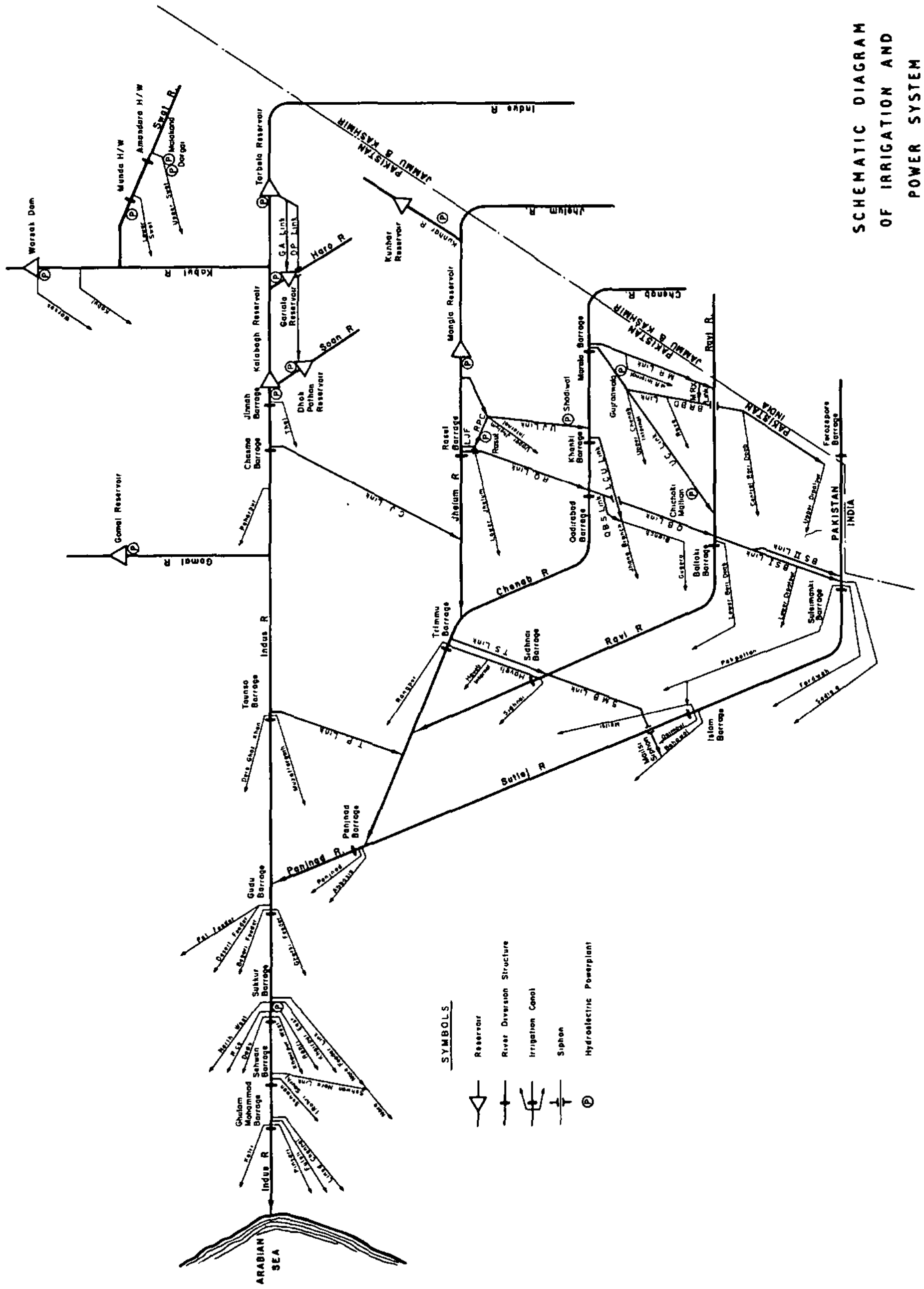
ANNEX 5-FIGURE I



SCHEMATIC DIAGRAM OF IRRIGATION AND POWER SYSTEM

Reproduced from diagram prepared by Harza for WAPDA

WEST PAKISTAN IRRIGATION AND POWER OPERATION STUDY-FEB 1965 REVISED VERSION

STUDY NUMBER 6685072110

YEAR 1972

NORTH ZONE SUMMARY

WATER (MAF)	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	TOTAL
FROM RIVER INFLOW	5.430	3.230	2.780	2.760	2.970	5.040	7.890	13.500	21.960	31.160	27.910	12.890	137.520
FROM STORAGE RELEASE	1.115	0.727	0.485	0.485	1.163	0.805	-0.320	-1.064	-1.594	-1.398	-0.384	0.001	0.019
FROM TRIBUTARIES	0.280	0.200	0.220	0.210	0.240	0.730	1.100	1.090	0.840	1.340	0.930	0.550	7.730
FROM DRAINS	0.025	0.023	0.023	0.023	0.024	0.025	0.014	0.014	0.014	0.026	0.028	0.021	0.259
TO RESERVOIR EVAPORATION	0.022	0.010	0.006	0.001	0.005	0.004	0.005	0.020	0.031	0.024	0.026	0.002	0.156
TO RIVER OUTFLOW	3.174	1.580	1.157	1.060	0.878	1.476	3.453	7.217	12.544	21.129	20.745	10.353	84.766
TO RIVER LOSS	-1.492	-0.109	0.098	0.219	0.273	0.606	1.552	2.664	3.765	6.409	2.666	-2.408	14.242
TO LINK LOSS	0.468	0.286	0.247	0.260	0.352	0.390	0.247	0.239	0.320	0.278	0.317	0.330	3.735
TO CANAL LOSS	1.203	0.820	0.745	0.751	0.976	1.129	1.082	1.062	1.247	1.091	1.238	1.286	12.630
TO WATERCOURSE	3.476	1.597	1.251	1.186	1.914	2.995	2.345	2.337	3.313	2.197	3.493	3.899	29.998
FROM GROUND WATER	2.333	1.262	1.061	1.195	2.400	2.048	1.141	1.408	1.997	2.545	2.797	2.730	22.916
SHORTAGE AT WATERCOURSE	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.004	0.009
WATERCOURSE REQT.	5.809	2.854	2.312	2.381	4.314	5.043	3.486	3.745	5.310	4.742	6.294	6.633	52.923
PUMP CAPACITY GOOD AREA	3.011	1.605	1.255	1.332	2.454	2.795	2.026	2.027	2.920	2.671	3.135	3.288	28.518
PUMPED FROM GOOD AREA	2.333	1.262	1.061	1.195	2.400	2.048	1.141	1.408	1.997	2.545	2.797	2.730	22.916
EVAPORATION GOOD AREA	0.428	0.307	0.284	0.243	0.299	0.392	0.351	0.428	0.493	0.886	0.959	0.614	5.685
RECHARGE TO GOOD AREA	2.382	1.488	1.182	1.228	1.890	2.366	1.894	2.005	2.581	3.843	4.165	3.098	28.122
NET CHANGE -- GOOD AREA	-0.379	-0.082	-0.163	-0.210	-0.809	-0.074	0.402	0.170	0.090	0.412	0.409	-0.246	-0.479
PUMP CAPACITY BAD AREA	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.360
PUMPED TO DRAINAGE	0.025	0.023	0.023	0.023	0.024	0.025	0.014	0.014	0.014	0.026	0.028	0.021	0.259
EVAPORATION BAD AREA	0.324	0.181	0.167	0.187	0.257	0.308	0.231	0.266	0.350	0.513	0.538	0.408	3.729
RECHARGE TO BAD AREA	0.342	0.193	0.170	0.190	0.277	0.330	0.253	0.281	0.366	0.541	0.571	0.430	3.945
NET CHANGE BAD AREA	-0.007	-0.011	-0.019	-0.020	-0.003	-0.003	0.009	0.002	0.002	0.002	0.004	0.001	-0.043
DRAIN STORAGE CONTENT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY (MILLION KWH)													
TOTAL PUMP LOAD	170.27	90.55	77.09	87.68	181.07	152.41	76.91	99.40	142.38	189.67	207.60	200.61	1675.63
TOTAL BASE LOAD	278.00	281.00	295.00	280.00	287.00	273.00	291.00	298.00	305.00	309.00	316.00	316.00	3529.00
TOTAL ENERGY LOAD	448.27	371.55	372.09	367.68	468.07	425.41	367.91	397.40	447.38	498.67	523.60	516.61	5204.63
HYDRO ENERGY TO LOAD	446.41	370.94	369.60	363.12	361.66	408.85	361.38	396.18	447.35	498.63	523.56	516.57	5064.25
THERMAL ENERGY TO LOAD	1.83	0.60	2.47	4.55	106.38	16.53	6.51	1.20	0.00	0.00	0.00	0.00	140.07
ENERGY DEFICIENCY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INTERZONE ENERGY TRANSFER	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HYDRO ENERGY SURPLUS	61.72	81.64	11.30	16.81	0.00	4.22	109.18	188.89	234.91	261.81	294.22	191.70	1456.40
POWER (MEGAWATTS)													
PEAK PUMP LOAD	321.42	220.96	207.35	223.91	331.53	302.04	177.11	223.31	289.90	338.56	357.55	346.34	3339.98
PEAK BASE LOAD	649.00	656.00	691.00	680.00	652.00	637.00	674.00	696.00	711.00	719.00	741.00	741.00	8247.00
TOTAL PEAK LOAD	970.42	876.96	898.35	903.91	983.53	939.04	851.11	919.31	1000.90	1057.56	1098.55	1087.34	11586.98
HYDRO CAPACITY TO LOAD	840.71	785.08	747.21	714.92	674.83	700.96	657.36	801.54	934.70	1041.81	1120.35	1129.36	10148.84
THERMAL CAPACITY TO LOAD	129.71	91.88	151.14	188.98	308.71	238.08	193.75	117.77	66.20	15.76	0.00	0.00	1501.97
FIRM CAPACITY TRANSFER	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PEAK RESERVE	323.29	361.12	301.86	248.02	128.29	198.92	243.25	319.23	370.80	421.24	458.80	479.03	3853.86

SOUTH ZONE SUMMARY

WATER (MAF)	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	TOTAL
FROM RIVER INFLOW	2.803	1.810	1.655	1.905	1.761	1.931	3.811	6.988	9.829	17.065	19.396	9.976	78.932
FROM STORAGE RELEASE	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000
FROM TRIBUTARIES	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FROM DRAINS	3.478	1.894	1.575	1.754	1.752	1.926	5.758	9.686	13.366	27.290	33.037	17.054	118.571
TO RESERVOIR EVAPORATION	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000
TO RIVER OUTFLOW	2.094	0.400	0.016	0.000	0.001	0.000	1.325	2.392	3.194	8.266	11.989	8.015	37.693
TO RIVER LOSS	-2.085	-0.285	-0.017	0.070	0.059	0.080	0.763	0.863	0.935	2.953	2.013	-1.803	3.544
TO LINK LOSS	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	1.089
TO CANAL LOSS	0.619	0.407	0.408	0.471	0.434	0.498	0.442	0.897	1.007	1.029	1.012	0.787	8.012
TO WATERCOURSE	2.084	1.197	1.157	1.274	1.177	1.262	1.190	2.745	4.602	4.727	4.292	2.888	28.594
FROM GROUND WATER	0.330	0.185	0.191	0.452	0.706	0.162	0.089	0.151	0.497	0.666	0.762	0.671	4.862
SHORTAGE AT WATERCOURSE	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.004	0.000	0.000	0.007
WATERCOURSE REQT.	2.414	1.382	1.348	1.726	1.883	1.424	1.279	2.896	5.103	5.396	5.054	3.559	33.464
PUMP CAPACITY GOOD AREA	0.743	0.560	0.576	0.674	0.712	0.551	0.487	0.670	0.806	0.828	0.828	0.828	8.263
PUMPED FROM GOOD AREA	0.330	0.185	0.191	0.452	0.706	0.162	0.089	0.151	0.497	0.666	0.762	0.671	4.862
EVAPORATION GOOD AREA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.034	0.034
RECHARGE TO GOOD AREA	0.326	0.193	0.192	0.255	0.247	0.236	0.180	0.348	0.536	0.771	0.793	0.611	4.688
NET CHANGE -- GOOD AREA	-0.004	0.008	0.002	-0.197	-0.459	0.074	0.091	0.197	0.039	0.105	0.030	-0.094	-0.209
PUMP CAPACITY BAD AREA	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	7.080
PUMPED TO DRAINAGE	0.442	0.322	0.302	0.314	0.323	0.276	0.254	0.303	0.390	0.480	0.490	0.475	4.370
EVAPORATION BAD AREA	0.457	0.257	0.245	0.300	0.320	0.267	0.229	0.766	1.106	1.360	1.278	0.756	7.341
RECHARGE TO BAD AREA	0.771	0.464	0.450	0.522	0.537	0.541	0.485	1.069	1.538	1.929	1.866	1.221	11.393
NET CHANGE BAD AREA	-0.128	-0.114	-0.096	-0.092	-0.106	-0.003	0.002	-0.000	0.042	0.089	0.098	-0.010	-0.318
DRAIN STORAGE CONTENT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY (MILLION KWH)													
TOTAL PUMP LOAD	53.88	35.69	36.65	63.93	90.87	34.56	24.67	32.86	69.88	91.78	101.53	92.93	728.74
TOTAL BASE LOAD	551.00	547.00	544.00	545.00	527.00	544.00	564.00	581.00	592.00	597.00	609.00	615.00	6816.00
TOTAL ENERGY LOAD	604.88	582.69	580.65	608.93	617.87	578.56	588.67	613.86	661.88	688.78	710.53	707.93	7544.74
HYDRO ENERGY TO LOAD	589.41	579.34	479.87	528.23	31.11	0.00	0.00	0.00	0.00	530.43	571.46	573.57	3883.42
THERMAL ENERGY TO LOAD	15.44	3.32	100.74	80.15	586.71	578.52	588.63	613.82	661.84	158.30	139.02	134.30	3660.76
ENERGY DEFICIENCY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INTERZONE ENERGY TRANSFER	-589.41	-579.34	-479.87	-528.23	-31.11	0.00	0.00	0.00	0.00	-530.43	-571.46	-573.57	-3883.42
HYDRO ENERGY SURPLUS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
POWER (MEGAWATTS)													
PEAK PUMP LOAD	100.53	57.96	62.58	112.77	138.69	65.15	37.81	54.42	122.90	145.17	153.62	143.41	1195.02
PEAK BASE LOAD	1164.00	1143.00	1141.00	1150.00	1116.00	1148.00	1197.00	1229.00	1249.00	1260.00	1281.00	1302.00	14380.00
TOTAL PEAK LOAD	1264.53	1200.96	1203.58	1262.77	1254.69	1213.15	1234.81	1283.42	1371.90	1405.17	1434.62	1445.41	15575.02
HYDRO CAPACITY TO LOAD	963.73	1028.72	958.11	747.67	282.55	0.00	0.00	0.00	0.00	726.89	785.37	790.35	6283.39
THERMAL CAPACITY TO LOAD	300.80	172.24	245.47	515.10	972.14	1213.15	1234.81	1283.42	1371.90	678.28	649.25	655.06	9291.63
FIRM CAPACITY TRANSFER	-963.73	-1028.72	-958.11	-747.67	-282.55	0.00	0.00	0.00	0.00	-726.89	-785.37	-790.35	-6283.39
PEAK RESERVE	285.47	349.04	346.42	437.23	445.31	486.85	465.19	416.58	328.10	294.83	265.38	254.59	4374.98

SYSTEM SUMMARY

WATER (MAF)	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	TOTAL
FROM RIVER INFLOW	5.430	3.230	2.780	2.760	2.970	5.040	7.890	13.500	21.960	31.160	27.910	12.890	137.520
FROM STORAGE RELEASE	1.084	1.323	1.351	2.143	3.243	2.388	0.459	-0.594	-5.150	-5.791	-0.331	0.007	0.132
FROM TRIBUTARIES	0.280	0.200	0.220	0.210	0.240	0.730	1.100	1.090	0.840	1.340	0.930	0.550	7.730
FROM DRAINS	3.538	1.905	1.584	1.765	1.768	1.944	5.773	9.743	13.466	27.401	33.151	17.162	119.200
TO RESERVOIR EVAPORATION	0.053	0.023	0.012	0.002	0.010	0.012	0.016	0.040	0.070	0.035	0.028	0.026	0.328
TO RIVER OUTFLOW	2.094	0.400	0.016	0.000	0.001	0.000	1.325	2.392	3.194	8.266	11.989	8.015	37.693
TO RIVER LOSS	-3.653	-0.139	0.267	0.580	0.447	0.804	1.936	3.378	3.517	8.460	5.654	-4.106	17.144
TO LINK LOSS	0.593	0.486	0.429	0.477	0.564	0.598	0.486	0.416	0.427	0.378	0.410	0.432	5.696
TO CANAL LOSS	1.976	1.298	1.234	1.398	1.654	1.806	1.582	2.081	2.301	2.211	2.328	2.129	21.998
TO WATERCOURSE	5.795	2.695	2.399	2.667	3.793	4.956	4.119	5.747	8.242	7.469	8.214	7.058	63.155
FROM GROUND WATER	4.382	2.238	1.700	2.171	3.889	3.154	1.808	2.098	3.537	3.901	4.840	4.907	38.625
SHORTAGE AT WATERCOURSE	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.004	0.000	0.000	0.007
WATERCOURSE REQT.	10.177	4.933	4.099	4.838	7.682	8.110	5.927	7.845	11.783	11.374	13.054	11.965	101.787
PUMP CAPACITY GOOD AREA	5.465	3.039	2.452	2.751	4.528	4.857	3.721	3.972	5.156	4.753	5.514	5.686	51.895
PUMPED FROM GOOD AREA	4.382	2.238	1.700	2.171	3.889	3.154	1.808	2.098	3.537	3.901	4.840	4.907	38.625
EVAPORATION GOOD AREA	0.000	0.000	0.025	0.025	0.002	0.000	0.012	0.009	0.027	0.133	0.082	0.048	0.363
RECHARGE TO GOOD AREA	3.207	1.849	1.491	1.728	2.604	3.043	2.338	2.676	3.417	4.919	5.352	4.102	36.728
NET CHANGE -- GOOD AREA	-1.175	-0.388	-0.234	-0.468	-1.288	-0.111	0.518	0.569	-0.147	0.885	0.431	-0.852	-2.260
PUMP CAPACITY BAD AREA	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	9.888
PUMPED TO DRAINAGE	0.622	0.372	0.350	0.381	0.406	0.355	0.331	0.426	0.583	0.693	0.689	0.678	5.887
EVAPORATION BAD AREA	0.735	0.430	0.401	0.471	0.567	0.555	0.441	0.984	1.377	1.750	1.711	1.078	10.500
RECHARGE TO BAD AREA	1.187	0.705	0.669	0.776	0.884	0.952	0.788	1.402	1.957	2.521	2.497	1.711	16.049
NET CHANGE BAD AREA	-0.170	-0.097	-0.082	-0.075	-0.089	0.043	0.015	-0.009	-0.004	0.079	0.097	-0.045	-0.338
DRAIN STORAGE CONTENT	3.720	3.758	3.798	3.854	3.921	3.982	4.045	4.111	4.204	4.306	4.392	4.488	48.581
ENERGY (MILLION KWH)													
TOTAL PUMP LOAD	413.08	216.01	170.10	216.04	374.22	301.20	177.56	207.99	347.30	385.60	465.80	472.49	3747.40
TOTAL BASE LOAD	1034.00	1036.00	1057.00	1062.00	1037.00	1041.00	1081.00	1130.00	1148.00	1153.00	1184.00	1190.00	13153.00
TOTAL ENERGY LOAD	1447.08	1252.01	1227.10	1278.04	1411.22	1342.20	1258.56	1337.99	1495.30	1538.60	1649.80	1662.49	16900.40
HYDRO ENERGY TO LOAD	1431.54	1248.62	1126.29	1197.82	824.40	762.89	666.22	718.11	833.37	1380.19	1510.66	1528.06	13228.18
THERMAL ENERGY TO LOAD	15.44	3.32	100.74	80.15	586.71	579.21	592.27	619.80	661.84	158.30	139.02	134.30	3671.08
ENERGY DEFICIENCY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INTERZONE ENERGY TRANSFER	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HYDRO ENERGY SURPLUS	284.10	15.96	0.00	121.50	461.31	249.64	293.34	273.11	452.15	493.03	477.79	355.91	3477.85
POWER (MEGAWATTS)													
PEAK PUMP LOAD	700.25	473.45	416.53	491.28	673.32	570.99	384.31	438.60	652.06	681.59	762.42	763.55	7008.34
PEAK BASE LOAD	2306.00	2297.00	2344.00	2360.00	2300.00	2305.00	2421.00	2492.00	2552.00	2563.00	2611.00	2632.00	29183.00
TOTAL PEAK LOAD	3006.25	2770.45	2760.53	2851.28	2973.32	2875.99	2805.31	2930.60	3204.06	3244.59	3373.42	3395.55	36191.34
HYDRO CAPACITY TO LOAD	2705.45	2598.20	2515.05	2336.18	2001.18	1521.52	1326.97	1357.98	1761.17	2566.31	2724.18	2740.49	26154.67
THERMAL CAPACITY TO LOAD	300.80	172.24	245.47	515.10	972.14	1354.46	1478.34	1572.62	1442.90	678.28	649.25	655.06	10036.67
FIRM CAPACITY TRANSFER	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PEAK RESERVE	1686.20	1814.76	1741.53	1621.90	1164.86	782.54	658.66	564.38	694.10	1458.72	1487.75	1481.94	15157.33

Annex 6

REVIEW OF IRRIGATION AND AGRICULTURAL ASPECTS OF TARBELA PROJECT

The only project for surface water storage to be implemented in the course of the Action Program (1965 to 1975) is the Tarbela Dam (see Chapter IV). This project was subjected to detailed studies in the first phase of the Indus Special Study. The results of the evaluation were presented in the Study Group's "Report on a Dam on the Indus at Tarbela," dated February 15, 1965. In the course of that study, various reservoir capacities were evaluated. It was found that a dam providing a live storage capacity of 8.6 MAF with a drawdown level commensurate with the electricity generation requirements (elevation 1332 feet) would form the most favorable alternative.

In accordance with the agreements reached with the Pakistan Authorities, a reservoir of this size, available for service by 1974, was then assumed as given. For the inclusion of this project in the Action Program, however, the earlier Tarbela evaluation had to be reviewed in the context of Basinwide water development.

For this purpose the coordinating consultant for the Indus Special Study, Sir Alexander Gibb and Partners, prepared a report[1] which contains an attempt by the consultant to evaluate the Tarbela project as an integral part of a comprehensive water development program extending beyond the period of the Action Program. The Study Group's review of the consultant's evaluation is set forth in this Annex. A summary of the review is given in Chapter IV.

The Project

Project Description[2]

Initially, the Tarbela reservoir would have a gross storage capacity of 11.1 MAF. Of this 8.6 MAF would be live storage available for irrigation releases.[3] Because of the high sediment load of the Indus, estimated at 440 million tons annually at Tarbela site, the reservoir is expected to silt up at a rate of 0.12 MAF per annum for the first 20 years. It would be fully depleted to a final volume of one MAF after about 50 years.

Taking into account the reservoir depletion, the quantities of water available for irrigation releases at reference years would be about as set forth in Table A6-1. In the context of the comprehensive development of West Pakistan's water resources, the reductions in the availability from Tarbela would at all stages be more than compensated by the successive exploitation of other water development opportunities (Chapter V).

[1] "The Tarbela Project. Evaluation of the Tarbela Project within the Development Programme of the Indus Basin," dated November 1966.
[2] For a description of the physical works, see Annex I to Volume I.
[3] Based on drawdown level of 1332 feet.

TABLE A6-1
QUANTITIES OF STORED WATER AVAILABLE FOR IRRIGATION RELEASES AT TARBELA

Storage Release Period	Available Storage (MAF)	Storage Release Period	Available Storage (MAF)
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

The releases of the above quantities from Tarbela would follow an operational pattern reflecting aggregate system requirements. The pattern used for planning purposes is based on slightly less than mean water flows in the Indus with priority for irrigation requirements during the winter months. Allowance for electricity generation has been made to the extent that such release requirements would not conflict with irrigation demands. An operational reserve would be maintained for releases during April and May because greater variations from the mean flow occur more frequently during these months. This would have the added advantage of reducing the need for groundwater pumping and increasing the hydro generation at a time of the year when power capability would be at its lowest under the proposed power program. On the basis of these considerations, the operational pattern established by IACA for the Tarbela reservoir is set forth in Table A6-2. The filling of the reservoir would thus take place over a period of two months, while the releases would extend over seven months with peak withdrawals during January, February and March.

Because of its location on the Upper Indus and the construction of trans-Punjab link canals under the Indus Basin Project, Tarbela releases could be served directly to any parts of the Indus Basin South and South West of the line formed by the Chasma-Jhelum link and the TS and SMB links. Indirectly, however, Tarbela would also serve the areas North and Northeast of this line, inasmuch as it would substitute for Mangla supplies in the areas under its direct command. Because of the interchangeability of surface water supplies during the rabi season throughout most of the canal system, Tarbela water would, over time, not be used in any one specified area; it would add to the overall availability in the system at times and in places of most stringent scarcities. Measured at Attock, the regulating effect of Tarbela would increase the mean Indus flows during the months of November to April initially by about 65 percent.

TABLE A6-2
TARBELA RELEASE PATTERN

Reservoir Filling		Storage Releases			
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

Tarbela Water Availability and Distribution

In conveying Tarbela water to the watercourses, considerable distribution losses would occur. Because Tarbela would serve the system as a whole, these losses have been assumed to be of the same proportion as the general average losses from basin storage releases as a whole. Applying this assumption, the consultant has determined the quantity of Tarbela water available at watercourse head in accordance with the following formula:[1]

$$T(WC) = \frac{Q(WC)}{Q(R)} \times T(R)$$

Because of the integrated nature of water development, and the improvement of water allocations and distribution anticipated in the IACA program, the quantity of Tarbela water available at watercourse head (T(WC)) in the formula would include substitution effects of groundwater pumping and net savings in surface water deliveries resulting from improved distribution and consequent reduction in losses. This may somewhat overstate the proportion of actual Tarbela deliveries to total availability at watercourse head. However, to the extent that distribution improvements during the rabi season would be dependent on river flow regulation provided by Tarbela, this would be representative of the project's indirect benefits in this respect.

The quantities of stored water delivered to watercourse heads at reference years determined in this way are summarized in Table A6-3 for groups of canal commands. As development proceeds, the net incremental water use during the storage release period would exceed the Tarbela capacity. Therefore, actual Tarbela use was assumed to be either the total net incremental use or the availability from Tarbela at watercourse heads, whenever the latter would be less.

[1] Q(WC)—Incremental stored water requirements above historic use.
Q(R) —Incremental stored water requirements above replacement requirements (Sutlej and Ravi replacements).
T(R) —Tarbela storage available during scarce water period.

TABLE A6–3
PROJECTED INCREMENTS OF STORAGE USE OF WATERCOURSE HEADS

River and Reservoir Commands	Development CCA	Incremental Water Use During Release Period		
	(mill. acres)	1975	1985 (MAF)	Ultimate
Kabul and Swat	0.7	−0.15	−0.44	−0.46
Indus (Tarbela) only	3.3	0.18	0.25	0.31
Indus (Tarbela), Jhelum and/or Chenab:				
(a) Northern Commands	4.3	0.76	1.44	2.26
(b) Lower Indus Commands	9.0	0.62	2.59	5.62
Jhelum	2.0	−0.19	−0.21	−0.13
Chenab and/or Jhelum	7.6	0.99	0.86	3.44
Chenab only	2.5	0.46	0.97	1.14
Total	29.4			
Net Incremental Water Use at Watercourse Heads During Storage Release Period:		2.67	5.46	12.18

TABLE A6-4
TARBELA RELEASES AND WATERCOURSE AVAILABILITIES DURING PERIOD OF RABI SCARCITIES

Storage Release Period	Releases	Watercourse Deliveries	Storage Release Period	Releases	Watercourse Deliveries
	(MAF)			(MAF)	(MAF)
1975/76	5.0[a]	2.67	1990/2000	5.46	3.02
1979/80	7.23	4.16	2004/2005	4.50	2.74
1984/85	7.06	4.27	2009/2010	3.65	2.23
1989/90	6.65	3.95	2014/2015	2.80	1.71

[a] Quantity assumed to be available for release because of partial impounding in preceding high flow period which would still have been affected by construction.

The resulting quantities available from Tarbela at watercourse heads were interpolated for each year over the lifetime of the project. In Table A6-4, a summary of the releases is given for the period of rabi water scarcities and of the Tarbela water availabilities at watercourse heads for reference years. These quantities would be made available during the periods of rabi water scarcity and would initially not include the operational reserve maintained for releases in April and May. The relationship of releases to watercourse deliveries in the table also includes the increasing distribution efficiency with conveyance losses gradually decreasing from about 47 percent to 39 percent.

Because most of these losses would percolate to the groundwater aquifer, IACA has in its water distribution analyses admitted Tarbela water only in those commands where either sufficient tubewell capacity would be in operation to recover the added recharge or where the water table is at a satisfactory depth and Tarbela losses would not immediately contribute to further waterlogging. Furthermore, IACA has scheduled Tarbela water deliveries strictly in accordance with its projections in each canal command of intensity growth, crop water requirements, and other sources of supply. In combination, these constraints impose an unrealistic limitation on the effective utilization of the reservoir. During the early period of operation, this results in an imputed surplus availability at Tarbela which would diminish over time and disappear by 1982.

A comparison of these imputed surpluses with the watercourse requirements under mean year flow conditions indicates initial surpluses of about 3 to 5 percent at watercourse heads (Table A6-5). While substantial increases in watercourse

TABLE A6-5
INITIAL STORAGE SURPLUS IN RELATION TO WATERCOURSE REQUIREMENTS DURING SCARCE PERIODS

Year	Watercourse Requirements[a]	Implied Surpluses: At Reservoir	Implied Surpluses: At Watercourse Heads[b]	Surpluses as Percent of Watercourse Requirements
		(MAF)		
1976	28.0	3.50	1.5	5.4
1977	28.5	3.25	1.5	5.3
1978	29.1	3.00	1.4	4.8
1979	29.6	2.50	1.2	4.1
1980	30.1	2.00	0.9	3.0

[a] Annex V, Sequential Analysis. [b] After losses (47%).

availability during a single season may be difficult to absorb, the Study Group believes that the surpluses of the order in the table would not materialize in reality. Since farmers generally overextend their cropped acreage relative to the available irrigation supplies in the rabi season, such marginal surpluses should be readily absorbed together with the total supplies available during the periods of rabi scarcity.

The losses incurred in the conveyance of Tarbela water from the reservoir site to the crops would be partially re-used. To the extent that they would occur in usable groundwater zones, they could be recovered through groundwater pumping. While these quantities cannot be assessed with any precision, the consultant has made an arbitrary estimate of the valuable recharge from Tarbela.[1] These quantities are shown in Table A6-6 for reference years. For purposes of project evaluation, the value of these recharge quantities would need to be reduced by the extra pumping costs required for their recovery. However, these losses would add to the total annual recharge and would thus contribute to higher utilization of the installed tubewell capacities. Within the principle of balanced recharge pumping, this would improve the efficiency of groundwater projects.

Cost Estimates and Expenditure Schedule

The costs used for purposes of the economic evaluation are summarized in Table A6-7. Excluding power facilities the capital costs of the dam would thus be $625 million or about Rs. 2,977 million equivalent.

Following the proposed program of construction, these costs would be incurred roughly in accordance with the schedule in Table A6-8. Because of the long construction period, maintenance and operational expenditures would occur during construction. Annual O&M expenditures have been estimated by the consultant at about Rs. 10.4 million continuing from 1972 onwards.

Project Evaluation

The evaluation of the Tarbela project as an integral part of a comprehensive water development program, covering the entire gravity irrigation system in the Indus Basin, poses a number of methodological problems. Tarbela would add not more than about 4 percent to the total water availability in the system. However, the project would be capable of delivering these quantities at a time of utmost scarcity. Because of this regulation effect on gravity flows, the water delivered by Tarbela would be of a greatly increased scarcity value. Nevertheless, these quan-

[1] Appendix 1, The Tarbela Project, page 4.7.

TABLE A6–6
USABLE TARBELA RECHARGE AT REFERENCE YEARS

Year	Usable Recharge	Year	Usable Recharge
	(MAF)		(MAF)
1975/76	0.3	1999/2000	1.1
1979/80	0.8	2004/2005	0.9
1984/85	1.4	2009/2010	0.7
1989/90	1.5	2014/2015	0.6

TABLE A6-7
ESTIMATED COST OF THE TARBELA PROJECT[a]
(US$ million equivalent)

Reservoir Works	Total		Foreign Exchange	
Precontract Costs[b]	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
Power Facilities (Units 1 to 8 Inclusive)				
Civil Engineering Works	55.1		35.7	
Contingencies (20%)	11.0		7.1	
Mechanical and Electrical Equipment	35.6		31.7	
Contingencies (10%)	3.6		3.2	
	105.3		77.7	
Engineering and Administration	8.4		7.0	
Total Units 1 to 8		113.7		84.7
Estimated Total Project Cost Including First 8 Units		739.0		474.1

[a] Excluding taxes, duties, levies and interest during construction.
[b] Excluding costs incurred prior to January 1964.

tities of water could alternatively be provided by groundwater pumping, if recharge could be induced during the summer months when surplus river flows occur. This in turn would require the increase in canal capacities to convey surface water for induced recharge. In addition, this would require power facilities sufficient to meet greatly increased pumping loads during the winter months.

Aside from other storage possibilities, which are discussed in Annex II of Volume I, the alternative to Tarbela would thus consist of a program of canal enlargement combined with tubewell fields to recover the recharge and supported by corresponding power facilities.[1] While theoretically conceivable this alternative contains a number of practical difficulties. It would require canal remodelling on a large scale; the consultant feels this is not within the scope of the existing implementation capacity. It would furthermore require the adoption of irrigation practices by farmers during the summer months under which inducement of substantial quantities of recharge could take place. This would not only be difficult to achieve but would also lead to recharge in saline groundwater areas as well as in groundwater areas requiring mixing with surface supplies. In the absence of Tarbela, the latter would be limited in the rabi season by the historical flows in the rivers without regulation (other than that provided by Mangla). This alternative would thus restrict rabi development mainly to fresh groundwater areas. In these areas, it would require groundwater pumping concentrated in a few months of the rabi season, thus creating accentuated peak power demands.

[1] Another alternative would include groundwater mining. This has been rejected by IACA for reasons of costs (see Chapter III).

TABLE A6-8
TARBELA COST STREAM FOR PURPOSES OF ECONOMIC ANALYSIS

Year	Capital Investment	Percent	Year	Capital Investment	Percent
	(Rs. mill)			(Rs. mill)	
1965	10.0	0.3	1970	428.4	14.4
1966	65.7	2.2	1971	482.7	16.2
1967	78.1	2.6	1972	433.2	14.6
1968	393.2	13.2	1973	368.4	12.4
1969	436.5	14.7	1974	223.7	7.5
			1975	56.6	1.9
			Total	2,976.5	100.0

The alternative described above would appear impractical in the near future and has been excluded from the evaluation of Tarbela. The consultant's evaluation has instead been based on the simulation of a completely integrated water supply system. In the development of this system, canal enlargement requirements have been minimized because of practical limitations. Groundwater 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 would stay within the generation, transmission, and distribution capacity of the power program. Under this supply schedule, Tarbela releases would take place between November and April, with nearly 70 percent of its availability released during January, February and March, the month of greatest surface water scarcity.

The Tarbela releases would thus meet demands in the integrated supply schedule not provided for by other sources. No other means of meeting this specific demand would exist under the comprehensive water development program since complete integration of all water resources is assumed. The consultant has therefore defined the period of Tarbela irrigation releases as the "Scarce Rabi Water Period." Quantitatively, this scarcity has been largely determined within existing canal capacities, except for the period after 1985 when canal enlargement would take place on a larger scale. Within any storage release season, the "scarce rabi water period" was thus taken to be generally that period of the rabi season during which irrigation demands (measured at rim stations) after groundwater supplies[1] would exceed the river inflow under mean year flow conditions.[2] As water requirements increase because of expansion of rabi intensities and, at a later stage, kharif intensities, the period of scarcity would change as in Table A6-9. The timely limitation of the period of scarcity and therefore Tarbela releases for irrigation does not extend to the operational reserve discussed earlier. For purposes of Tarbela evaluation, however, the consultant has used only the releases during the scarce rabi water period.

[1] The provision of groundwater would follow a predetermined pumping pattern based on a distribution of the pumping requirements in accordance with other crop needs, peak and average utilization rates of the tubewells, and power availability.

[2] Where surface supplies would be integrated with groundwater supplies in project areas, the use of mean year flows supplemented by pumping would provide adequate supplies in each month in four years out of five.

TABLE A6–9
PERIOD OF RABI SCARCITY

	Reservoir Capacity	Storage Availability during Scarce Period	Period of Scarcity
	(MAF)	(MAF)	
On completion	8.6	7.3	Nov. to March
1985	7.4	7.0	Nov. to April
2000	5.4	5.4	Nov. to May

The storage releases during the period of scarcity after conveyance losses and the recovery of such losses would give the total quantities of valuable water provided by Tarbela. These have been determined by the consultant as set forth in Table A6-10. Recharge would be recovered in accordance with the adopted groundwater pumping schedules and therefore not necessarily during the scarce rabi water period.

To determine the agricultural benefits attributable to the Tarbela project, the consultant has distinguished between Tarbela deliveries and recoverable recharge. The value per acre-foot of Tarbela deliveries has been determined by dividing total water availability during the period of scarcity into the total value of rabi production in the irrigated parts of the Indus Basin, based on the production projections made for individual canal commands. This approach implies that the irrigation supplies used on rabi crops, but not during the period of scarcities, i.e. before and after the period of scarcity, could be considered as a free good. In quantitative terms, this means that only about 85 percent of the water used during rabi has been related to 100 percent of the rabi production. On this basis, the consultant has determined the values per acre-foot and the net benefits attributable to Tarbela deliveries (Table A6-11). The values per acre-foot in the table represent the average value of water defined as scarce. The assessment of marginal values would have required the simulation of the irrigation system without Tarbela which would have had to be based on substantially different priorities for canal enlargement and especially groundwater development.[1] However, the consultant's evaluation of Tarbela is in accordance with the agreed terms of reference. These required IACA to prepare a cohesive water development program with the availability of main storage by 1974 as a given datum. Nevertheless, an attempt was made by the Study Group

[1] This is further substantiated in Supplemental Paper No. 4, Volume III.

TABLE A6–10
WATERCOURSE DELIVERIES FROM TARBELA

Year	Storage Releases Used at Watercourse Head	Recoverable Recharge	Total at Watercourse Heads
		(MAF)	
1975/76	2.67	0.3	2.97
1979/80	3.80	0.8	4.60
1984/85	4.27	1.4	5.67
1989/90	3.95	1.5	5.45
1999/2000	3.02	1.1	4.12
2004/2005	2.74	0.9	3.69
2009/2010	2.23	0.7	2.97
2014/2015	1.71	0.6	2.31

TABLE A6–11
NET BENEFITS ATTRIBUTABLE TO TARBELA BEFORE RECHARGE[a]

Rabi Year	Watercourse Deliveries	Value/Acre-Foot	Attributable Net Benefits
	(MAF)	(Rs.)	(Rs. mill)
1975/76	2.67	135	360.5
1984/85	4.27	149	631.5
1999/2000	3.02	169	510.4
2014/2015	1.71	174	297.5

[a] See Appendix Tables A6–1 and A6–2.

to determine the effects of postponement of Tarbela in an alternative sequence of development in the linear programming analysis. It was found that the proposed sequence of development would result in net savings in terms of present worth (1965—at 8 percent) of about Rs. 226 million including power benefits above the next best sequence.

The recoverable recharge has been valued by the consultant on the basis of the average value per acre-foot of water for both seasons. This assumes that recharge would be pumped at any time of the year according to requirements. For reference years, the recharge values determined by the consultant would be as set forth in Table A6-12. The recharge values are again based on averages for all canal commands in the Indus Basin.

For the comprehensive phase of the Special Study, the power consultant also regarded Tarbela as an integral part of the development program and no separate evaluation of Tarbela power benefits was made. In evaluating Tarbela the consultant has, therefore, used the power benefits given in the Study Group's report on Tarbela. Though the installations of turbines at Tarbela, and consequent increase in generating capacity, are now scheduled to proceed more rapidly, the load forecast remains much the same. The consultant has estimated that these changes may increase the power benefits over those assumed in the 1965 report by 5 to 10 percent. Because the irrigation benefits are considerable and dominate the evaluation, such an adjustment would have only marginal impact and the consultant has therefore adopted the unadjusted 1965 benefit values for power. These were defined as the net savings of the Tarbela hydro generation over alternative thermal generation. The present worth at 8 percent of the net benefits of power would be about Rs. 378 million; the flow of the benefits over the lifetime of the project is shown in Appendix Table A6-13.

TABLE A6–12
VALUE OF TARBELA RECHARGE

Year	Recoverable Recharge	Value/Acre-Foot	Attributable Recharge Benefits[a]
	(MAF)	(Rs.)	(Rs. mill)
1975/76	0.3	96	33.3
1984/85	1.4	114	162.8
1999/2000	1.1	152	167.1
2014/2015	0.6	159	91.4

[a] Before pumping costs.

In summary, the joint benefits of Tarbela according to the consultant would thus be about as set forth in Table A6-13. The present worth as of 1965 at 8 percent of the total costs to the economy, including operation and maintenance costs, have been estimated by the consultant at Rs. 1,959 million. In the consultant's assessment, the B/C ratio of the project would thus be 1.9 and the corresponding rate of return would be about 13.3 percent.[1]

Similar to the assessment of effects of postponement of Tarbela on agricultural benefits discussed above an exercise has been carried out by the Study Group to determine the affects on power of various timings and drawdown levels for Tarbela. This analysis confirms that a sequence of power development including postponement of Tarbela would involve higher costs to the economy than the sequence proposed. The analysis also indicates that the assumed drawdown level of 1332 feet for irrigation would be compatible with the envisaged power generation program though there may be some advantages in short-term variations around this level.

In testing the results of the consultant's evaluation, the Study Group has introduced a number of different assumptions. Methodologically, the Study Group proceeded from the point of view that the Tarbela releases would perform an assigned function within an integrated water supply schedule. The scarcity argument becomes irrelevant since the supply schedule is the very instrument through which all scarcities are being met by all available sources within the set of physical constraints operative in the system at any point in time. Furthermore, under a fully integrated supply schedule supporting a rapidly growing cropping intensity, the contributions of the individual sources of supply become increasingly indistinguishable. Though specific functions are assigned to each source of supply, this does not exclude the probability that a different function could be performed by the same source. However, in harmonizing agricultural, power, technical and operational needs, the supply schedule has been optimized to the extent that the integrated supplies support, over a 12-month period, the water requirements of an integrated cropping pattern. This consideration led the Study Group to conclude that Tarbela should be evaluated as a source of water within the total supply schedule rather than as a project satisfying specific scarcities.

It follows from the above that the value of Tarbela water would be equivalent to the average value of incremental water made available over a cropping cycle in the system as a whole. While the assessment of the latter would again have depended on an alternative water development program, the Study Group felt it could

[1] See Supplemental Paper No. 7, Volume III.

TABLE A6–13
PRESENT WORTH AS OF 1965 AT 8% OF TARBELA BENEFITS[a]

	Rs. Million
Net Present Value of Tarbela Deliveries	2,747
Net Present Value of Recoverable Recharge	645
Power Benefits	378
Total	3,770

[a] According to the original 1965 report. For comparison with modified benefits, see Table A6–15.

use, as representative of this value, the results of 11 evaluations of projects located in various parts of the Basin and covering more than five million acres CCA. Most of these projects would actually absorb increasing amounts of surface water, though not necessarily Tarbela water. These values represent the improvement of agricultural practices and the use of nonwater inputs generally assumed to take place in project areas more rapidly than elsewhere. Though inconsequential, inasmuch as not all incremental rabi surface supplies would be used in project areas, this would imply a slightly favorable bias. At watercourse heads, the weighted average value per acre-foot of incremental water used in these areas would increase from about Rs. 37 in 1975 to about Rs. 80 by 1985 and Rs. 118 by the end of the century.

Applying these values to the total Tarbela deliveries at watercourse heads, and extrapolating to full Tarbela availabilities by neglecting the theoretical surpluses assumed by the consultant, the Study Group derived the net benefits attributable to the Tarbela deliveries at reference years (Table A6-14). This assessment of benefits is based on the extrapolation of weighted average values of incremental water use within project areas to the full utilization of all water availabilities from Tarbela within the system at large. Over the lifetime of the project, this would be equivalent to a present worth at 8 percent of about Rs. 1,475 million.

To the above, the value of recoverable recharge of about Rs. 187 million net of pumping costs has been added. This value has been based on the recharge quantities determined by the consultant and the average value per unit of incremental water as assessed in the project evaluations. Allowance for costs of recovery were assumed to be Rs. 17 per acre-foot of recharge pumped. Associated charges for canal remodelling have been allowed for by deducting the costs as determined by IACA from the aggregate benefits.

Including power benefits of about Rs. 611 million, as assessed by the Study Group,[1] total attributable benefits of Tarbela, discounted at 8 percent to 1965, have thus been estimated by the Study Group at Rs. 2,241 million. This compares to a present worth of total costs at 8 percent including O&M expenditures of Rs. 1,885 million.[2] The benefit-cost ratio at 8 percent would thus be about 1.2. The corresponding rate of return of the project would be 9.2 percent.

The above results of the consultant's and the Study Group's analyses may be considered as the range within which the Tarbela benefits are likely to fall. Further tests carried out by the Study Group indicate this, as shown in Table A6-15. The Study Group's 1965 evaluation was based on incremental water use in specific "Priority Areas." The details are set out in the Study Group's report on Tarbela, dated February 15, 1965. The consultant's evaluation has been discussed above and the details are set forth in Appendix 1. In the modified evaluation, total rabi supplies (rather than "scarce" supplies) have been related to total rabi production.

In this evaluation, alternative sequences of storage development on the Indus have not been considered. Instead, this evaluation was to assess the beneficial

[1] For the purpose of this analysis, power benefits have been assessed as the cost differential between a power program based on Tarbela in 1975 and the next best program including Kunhar by 1981. See Supplemental Paper No. 7, Volume III.

[2] IACA's present worth of costs of Rs. 1,959 million is based on the discounting of the cost stream to a midyear point. The above analysis is based on discounting to the beginning of the year.

TABLE A6–14
STUDY GROUP'S ESTIMATE OF NET AGRICULTURAL BENEFITS ATTRIBUTABLE TO TARBELA BEFORE RECHARGE

Rabi Year	Storage Availability	Value/Acre-Foot at Storage Site[a]	Attributable Net Benefits
	(MAF)	(Rs.)	(Rs. mill)
1975	5.0	20.3	102
1985	7.1	43.6	310
2000	5.0	66.2	331
2015	2.7	89.2	241

[a] The conversion to storage site became necessary in order to evaluate total availability at assumed loss factors of 45 percent rather than partial releases.

effects of a given quantity of storage and regulation irrespective of its particular site as long as the latter would not impair the required command capabilities. The assessment of the best sequences of storage facilities is, however, discussed in Volume I.

An analysis of five alternative sequences of storage development, carried out by the consultant, consisted essentially of a comparison of total costs as well as costs per unit of water made available of feasible sequences of storage works—that is, of sequences which would provide roughly equivalent amounts of water at the same time points as the proposed program. While one of the alternatives would appear competitive with the program proposed, the analysis shows that there would be no definite cost advantage and that the most favorable alternative would be less well prepared and investigated and therefore less firm in its aggregate estimates. Since the timing of Tarbela around 1975 is vital to the water development program as a whole, the fact that it is ready for immediate implementation, while little is known of some of the component parts of the second best sequence, gives the project under consideration a decided advantage.

Conclusions

The results stated above can only be indicative of the range of benefits the Tarbela project is likely to produce. Because of the complex technical interdependencies of the various water development activities, of which this project forms part, and the resulting joint benefit and cost occurrences, it is difficult to establish more than a well-founded representative evaluation.

TABLE A6–15
RESULTS OF TARBELA EVALUATION UNDER VARYING ASSUMPTIONS

	1965 Study Group Evaluation	Consultant's Evaluation	Consultant's Evaluation Modified	Study Group[a] Evaluation	
				I	II
Net Present Worth of Benefits at 8% (Rs. million)	3,537	3,770	3,353	1,994	2,241
Power Benefits as % of Total	18.3%	10.0%	10.7%	18.3%	27.3%
Benefit/Cost Ratio (at 8%)	1.9	1.9	1.8	1.1	1.2
Rate of Return	13.3%	13.3%	12.5%	8.4%	9.2%

[a] In the Study 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 Study Group.

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. Storage of a given quantity of water, at a given time, as would be provided by Tarbela, forms a vital part of this process. In the course of this transformation, the value of surface water storage would be enhanced by the presence of tubewell fields and conversely the provision of main-stem storage greatly improves the efficiency of tubewell development. The simultaneous development of the two sources of irrigation supplies not only leads to a greater flexibility in the operation of the system but also to a mutually enhanced efficiency in reservoir and tubewell utilization.

In view of the need to develop a balanced supply of irrigation water, to meet the projected system needs and reduce the risks involved in the exclusive development of groundwater, the Study Group is satisfied that main-stem storage of around 8 MAF is required by about 1975. On the basis of its analyses, the Study Group concludes that the Tarbela project as planned would meet this requirement at reasonable costs and with greater certainty than other feasible alternatives. The project would make a substantial contribution to the growth of agricultural production in West Pakistan as well as towards meeting future power needs. To the extent that the functional contributions of this project are measurable, the Study Group is satisfied that a range of computed returns from 9.2 percent to 13.3 percent represents a fair assessment of the benefits and the economic justification of the project.

The value per unit of incremental water in tubewell project areas has been determined for each year as the total incremental net production value (NPV) over the total incremental water availability. The incremental NPV has been defined as the difference in NPV attainable "with" and "without" further water development. Within a given project area the average value per acre-foot of incremental water thus takes account of the acreage expansion as well as the yield raising effects of additional water supplies under the prevailing conditions and their projected development.

For purposes of the Tarbela evaluation the values determined in the above described manner were weighted by the amount of additional surface water absorbed in each tubewell project area and the weighted average value found for eleven project areas has thus been applied to the Tarbela quantities. While the Bank Group evaluated twelve tubewell projects (see Part II of this Annex) at the time of this evaluation the values for the Ravi Syphon-Dipalpur project had not been available. However, as shown in Table 5, page 1 of the Ravi Syphon Project Review the values finally determined are so close to the weighted average for the eleven projects that its omission is inconsequential for the Tarbela evaluation.

The following appendix table (A6-1) gives the range of values per incremental acre foot of water determined in project areas, the weighted average at watercourse head and the corresponding value at dam site. The latter is based on an assumed loss factor of an average 45 percent. The conversion from watercourse values to dam site values has been done to facilitate the extrapolation of benefits to the full availability from Tarbela at dam site.

APPENDIX TABLE A6–1

PROJECTED INCREMENTS OF STORAGE USE AT WATERCOURSES AND USABLE RECHARGE FROM STORAGE, IN CANAL COMMAND GROUPS

Potential River (or reservoir) supply	Headworks	Offtaking Link and Carrier Canals	Canal Commands directly Served	Development CCA (Thousand acres)	Incremental Storage Use at Watercourse in Scarce Water Period (MAF)			Increase in Usable Recharge from Storage (MAF)		
					1975	1985	Ultimate	1975	1985	Ultimate
Kabul & Swat	Amandara		Upper Swat	276	−0.15	−0.30	−0.36	−0.06	−0.10	−0.14
	Munda		Lower Swat, Doeba and Sholgara	169	−0.03	−0.09	−0.12	−0.01	−0.05	−0.05
	Kabul River		Kabul River, Jui Sheikh and Inundation	123	0.02	−0.07	−0.11	−0.01	−0.04	−0.06
	Warsak		Warsak High Level Right and Left Bank	119	0.01	0.02	0.13	—	—	0.04
			Subtotal (Kabul & Swat)	687	−0.15(−6%)	−0.44(−8%)	−0.46(−3%)	−0.08	−0.19	−0.21
Indus (Tarbela) Only	Jinnah		Thal	1,641	−0.56	−0.44	−0.36	−0.01	0.12	0.52
	Chasma	CJ Link	Paharpur	104	0.03	—	0.01	0.02	−0.01	−0.01
	Taunsa	TP Link	Muzaffargarh	656	0.14	0.22	0.05	0.10	0.16	0.03
			D.G. Khan	872	0.57	0.47	0.61	0.33	0.21	0.24
			Subtotal (Indus-Tarbela)	3,273	0.18(7%)	0.25(4%)	0.31(2%)	0.44	0.48	0.78
Indus (Tarbela), Jhelum (Mangla) and/or Chenab										
Northern group:	Trimmu	TS Link	Rangpur	344	−0.05	−0.05	−0.07	−0.05	−0.05	−0.06
		Haveli	Haveli	143	0.01	0.01	0.01	−0.01	0.03	0.01
	Sidhnai	SNB Link	Sidhnai	754	−0.01	0.04	0.23	0.02	0.08	0.14
			Pakpattan below SM Link	319	−0.02	0.01	0.29	—	0.01	0.06
			Mailsi below SM Link	677	0.56	0.38	0.62	0.29	0.19	0.27
			Bahawal below MB Link	596	0.10	0.23	0.45	0.02	0.08	0.15
	Panjnad		Panjnad and Abbasia	1,455	0.17	0.82	0.73	0.01	0.10	0.10
			Subtotal (Northern group)	4,288	0.76(28%)	1.44(26%)	2.26(19%)	0.28	0.44	0.67

Lower Indus group:	Gudu		Ghotki	513	0.10	0.26	0.19	0.06	0.08	0.06
			Begari Sind	693	—	—	0.23	—	—	−0.03
			Desert and Pat	382	—	—	0.07	—	—	—
	Sukkur		North West	633	0.05	−0.24	−0.18	0.05	−0.01	−0.03
			Rice	337	—	—	0.16	—	—	—
			Dadu	394	0.05	0.01	0.07	0.02	−0.03	−0.06
			Khairpur West	252	−0.07	−0.05	−0.06	−0.06	−0.06	−0.07
			Khairpur East	330	0.10	0.29	0.41	—	—	—
			Rohri	2,480	−0.06	0.75	1.80	−0.15	0.22	0.32
			Eastern Nara	1,643	.38	1.40	2.57	—		—
	Ghulam		Kalri Baghar	274	—	.03	.34	—	—	—
	Mohammed		Pinyari and Fuleli	897	−0.02	−0.03	−0.42	—	—	—
			Lined Channel	152	0.09	0.17	0.44	—	—	—
			Subtotal (Lower Indus)	8,980	0.62(23%)	2.59(47%)	5.62(46%)	−0.08	0.20	0.19
			Subtotal [(Indus-Tarbela), Jhelum (Mangla) and/or Chenab]	13,268	1.37(51%)	4.03(73%)	7.88(65%)	0.20	0.64	0.86
Jhelum (Mangla) only	Mangla	Upper Jhelum Canal	Upper Jhelum	543	−0.13	−0.19	−0.32	−0.03	−0.03	−0.01
	Rasul	RQ Link	Lower Jhelum	1,500	−0.06	−0.02	+0.19	0.04	−0.01	0.05
			Subtotal (Jhelum-Mangla)	2,043	−0.19(−6%)	−0.21(−3%)	−0.13(−1%)	0.01	0.04	0.04
Chenab and/or Jhelum (Mangla)										
	Khanki/ Qadirabad	QB Link	Lower Chenab	2,981	−0.02	−0.26	−0.03	0.08	−0.03	0.23
	Balloki	BS Link	Lower Bari Doab	1,575	+0.16	−0.02	+0.46	0.07	0.08	0.27
			Dipalpur below BS Link	611	+0.22	+0.38	+0.54	0.13	0.21	0.31
	Suleimanke		Fordwah & E. Sadiqia	1,362	+0.31	+0.39	+1.87	0.06	0.11	0.15
			Pakpattan above SM Link	939	+0.32	+0.35	+0.54	0.20	0.13	0.32
			Mailsi above SM Link	15	+0.01	—	−0.01	—	—	—
	Islam		Qaim	42	—	—	−0.01	—	—	—
			Bahawal above MB Link	51	—	+0.01	+0.03	—	—	0.02
			Subtotal (Chenab and Jhelum-Mangla)	7,576	0.99(37%)	0.86(16%)	3.44(28%)	0.54	0.50	1.30

APPENDIX TABLE A6-1 (Continued)

PROJECTED INCREMENTS OF STORAGE USE AT WATERCOURSE, AND USABLE RECHARGE FROM STORAGE, IN CANAL COMMAND GROUPS

Potential river (or reservoir) supply	Headworks	Offtaking Link and Carrier Canals	Canal Commands directly Served	Development CCA (Thousand acres)	Incremental Storage Use at Watercourse in Scarce Water Period (MAF)			Increase in Usable Recharge from Storage (MAF)		
					1975	1985	Ultimate	1975	1985	Ultimate
Chenab only	Marala	MR Link	MR Link	105	—	—	−0.02	—	.01	—
		Upper Chenab Canal	Upper Chenab Canal	1,445	+0.31	+0.66	+0.87	0.08	0.36	0.63
		BRBD Link	Ravi Syphon-Dipalpur Link (internal use)	595	+0.10	+0.12	+0.02	0.03	0.09	0.03
			Dipalpur above BS Link	372	+0.05	+0.19	+0.27	0.13	0.12	0.22
			Sub-total (Chenab-Marala)	2,517	0.46(17%)	0.97(18%)	1.14(9%)	0.24	0.57	0.88
			Total for Basin	29,364	2.67	5.45	12.18	1.35	1.96	3.65

APPENDIX TABLE A6–2
AVERAGE VALUES PER ACRE-FOOT OF INCREMENTAL WATER AS DETERMINED ON THE BASIS OF PROJECT EVALUATIONS

Year	Range of Values	Weighted Average Values: At W/C Head	Weighted Average Values: At Dam Site	Year	Range of Values	Weighted Average Values: At W/C Head	Weighted Average Values: At Dam Site
		(Rs.)				(Rs.)	
1975	4.5– 46.9	36.9	20.3	2001	94.6–160.1	122.7	67.5
1976	10.6– 49.6	39.2	21.6	2002	96.5–163.3	125.2	68.9
1977	15.5– 53.6	41.9	23.0	2003	98.4–166.6	127.7	70.2
1978	18.9– 59.1	48.3	26.6	2004	100.4–169.9	130.3	71.7
1979	22.4– 66.8	54.1	29.8	2005	102.4–173.3	132.9	73.1
1980	25.4– 73.2	58.5	32.2	2006	104.4–176.8	135.6	74.6
1981	28.4– 80.4	63.3	34.8	2007	106.5–180.3	138.3	76.1
1982	31.0– 87.7	67.7	37.2	2008	108.6–183.9	141.1	77.6
1983	33.5– 93.8	71.8	39.5	2009	110.8–187.6	143.9	79.1
1984	36.7–101.0	76.1	41.9	2010	113.0–191.4	146.8	80.7
1985	37.9–107.7	79.3	43.6	2011	115.3–195.2	149.7	82.3
1986	42.3–111.3	82.4	45.3	2012	117.6–199.1	152.7	84.0
1987	46.7–115.0	85.6	47.1	2013	120.0–203.1	155.8	85.7
1988	51.5–118.9	89.1	49.0	2014	122.4–207.2	158.9	87.4
1989	56.8–122.8	92.5	50.9	2015	124.8–211.3	162.1	89.2
1990	62.4–127.0	96.1	52.9	2016	127.3–215.5	165.3	90.9
1991	68.3–131.4	98.9	54.4	2017	129.8–219.8	168.6	92.7
1992	74.8–134.0	101.3	55.7	2018	132.4–224.2	172.0	94.6
1993	80.8–136.7	104.0	57.2	2019	135.0–228.7	175.4	96.5
1994	82.4–139.0	106.8	58.7	2020	137.7–233.3	178.9	98.4
1995	84.0–142.2	108.9	59.9	2021	140.5–238.0	182.5	100.4
1996	85.7–145.0	111.1	61.1	2022	143.3–242.8	186.2	102.4
1997	87.4–147.9	113.3	62.3	2023	146.2–247.7	190.0	104.5
1998	89.1–150.9	115.6	63.6	2024	149.1–252.7	193.8	106.6
1999	90.9–153.9	117.9	64.8	2025	152.1–257.8	197.7	109.3
2000	92.7–157.0	120.3	66.2	2026	155.1–263.0	202.7	111.5
				2027	158.2–268.3	206.7	113.7

APPENDIX TABLE A6-3
TARBELA PROJECT
Storage Availability and Benefits of Tarbela Deliveries as Estimated under Varying Assumptions

	Study Group 1965 Report			Modified Consultant's Approach[b]							Evaluation Based on Average Values of Incremental Water in Project Areas[c]				
Year	Storage Avail-ability	Value/ Acre-Foot[a]	Total Benefits	Rabi Quantity	Total Benefits	Value/ Acre-Foot	Scarce Rabi Quantities	Benefits of Tarbela De-liveries	Net Recharge Benefits	Total Benefits	Storage Avail-ability	Value/ Acre-Foot	Benefits of Tarbela De-liveries	Net Recharge Benefits	Total Benefits
	(MAF)	(Rs.)	(Rs. Mill.)	(MAF)	(Rs. Mill.)	(Rs.)	(MAF)			(Rs. Mill.)	(MAF)	(Rs.)			(Rs. Mill.)
1975	8.6	52	447	5.6	360	64	5.0	320	7.1	327.1	5.0	20.3	102	7.5	109.5
1976	8.5	58	491	8.2	404	49	7.3	358	13.5	371.5	8.6	21.6	186	15.3	201.3
1977	8.3	61	506	8.2	447	55	7.3	402	19.7	421.7	8.4	23.0	193	22.0	215.0
1978	8.2	68	554	8.1	491	61	7.2	439	26.9	465.9	8.2	26.6	218	30.2	248.2
1979	8.0	73	581	8.1	536	66	7.2	475	33.5	508.5	8.0	29.8	238	38.4	276.4
1980	7.9	76	604	8.1	581	72	7.2	518	40.5	558.5	7.9	32.2	254	46.7	300.7
1981	7.7	82	628	8.1	610	75	7.2	540	46.3	586.3	7.7	34.8	268	52.9	320.9
1982	7.6	85	649	8.0	615	77	7.1	547	57.4	604.4	7.6	37.2	283	67.3	350.3
1983	7.4	88	652	8.0	624	78	7.1	554	61.8	615.8	7.4	39.5	292	73.8	350.3
1984	7.3	89	652	8.0	632	79	7.1	561	73.4	634.4	7.3	41.9	306	87.6	393.6
1985	7.1	92	656	7.9	640	81	7.0	567	82.1	649.1	7.1	43.6	310	99.2	409.2
1986	7.0	94	661	7.6	637	84	6.9	580	91.9	671.9	7.0	45.3	317	112.2	429.2
1987	6.8	97	662	7.5	627	84	6.8	571	99.2	670.2	6.8	47.1	320	120.8	440.8
1988	6.7	100	668	7.5	622	83	6.8	564	102.8	666.8	6.7	49.0	328	125.7	453.7
1989	6.6	102	671	7.4	612	83	6.7	556	105.8	661.8	6.6	50.9	336	129.3	465.3
1990	6.4	92	589	7.2	604	84	6.5	546	107.9	653.9	6.4	52.9	339	132.8	471.8
1991	6.3	93	586	7.2	604	84	6.5	546	107.7	653.7	6.3	54.4	343	131.8	474.8
1992	6.2	95	589	7.0	592	85	6.4	544	107.2	651.2	6.2	55.7	345	130.5	475.5
1993	6.0	97	582	6.8	585	86	6.2	533	107.4	640.4	6.0	57.2	343	130.5	473.5
1994	5.9	99	584	6.8	579	85	6.2	527	106.7	633.7	5.9	58.7	346	130.5	476.5
1995	5.7	100	570	6.7	567	85	6.1	519	105.4	624.4	5.7	59.9	341	127.0	468.0
1996	5.6	102	571	6.5	554	85	5.9	502	103.4	605.4	5.6	61.1	342	124.6	466.6
1997	5.4	104	562	6.4	554	87	5.8	505	101.7	606.7	5.4	62.3	336	123.4	459.4
1998	5.3	106	562	6.2	531	86	5.6	482	98.8	580.8	5.3	63.6	337	119.8	456.8
1999	5.1	108	551	6.1	510	84	5.5	462	95.4	557.4	5.1	64.8	330	115.0	445.0

2000	5.0	109	545	5.8	502	87	5.4	470	91.3	561.3	5.0	66.2	331	109.2	440.2
2001	4.8	111	533	5.6	496	89	5.2	463	—	—	4.8	67.5	324	106.8	430.8
2002	4.7	113	534	5.4	490	91	5.0	455	—	—	4.7	68.9	324	103.2	427.2
2003	4.5	115	518	5.2	484	93	4.8	446	—	—	4.5	70.2	316	100.8	416.8
2004	4.4	118	519	4.9	478	98	4.6	451	—	—	4.4	71.7	315	97.2	412.2
2005	4.2	120	504	4.8	471	98	4.5	441	79.4	520.4	4.2	73.1	307	94.8	401.8
2006	4.1	122	500	4.6	454	99	4.3	426	—	—	4.1	74.6	306	91.2	397.2
2007	3.9	124	484	4.5	437	97	4.2	407	—	—	3.9	76.1	297	88.8	385.8
2008	3.8	126	479	4.3	420	98	4.0	392	—	—	3.8	77.6	295	85.2	380.2
2009	3.6	129	464	4.2	403	96	3.9	374	—	—	3.6	79.1	285	83.5	368.5
2010	3.5	131	459	4.0	386	97	3.7	359	65.8	424.8	3.5	80.7	282	79.2	361.2
2011	3.3	133	439	3.8	368	97	3.5	340	—	—	3.3	82.3	272	76.8	348.8
2012	3.2	135	432	3.5	351	100	3.3	330	—	—	3.2	84.0	269	73.2	342.2
2013	3.0	138	414	3.4	333	98	3.2	314	—	—	3.0	85.7	257	70.2	327.2
2014	2.9	140	406	3.2	315	98	3.0	294	—	—	2.9	87.4	253	66.0	319.0
2015	2.7	143	386	3.0	298	99	2.8	277	51.8	328.8	2.7	89.2	241	62.4	303.4
2016	2.6	145	377	2.8	278	99	2.6	257	—	—	2.6	90.9	236	58.1	294.1
2017	2.4	147	353	2.6	257	99	2.4	238	—	—	2.4	92.7	222	54.0	276.0
2018	2.3	150	345	2.5	248	99	2.3	228	—	—	2.3	94.6	218	50.4	268.4
2019	2.1	153	321	2.3	227	99	2.1	208	—	—	2.1	96.5	203	47.2	250.2
2020	2.0	155	310	2.2	218	99	2.0	198	36.3	234.3	2.0	98.4	197	43.2	240.2
2021	1.8	158	284	1.9	196	103	1.8	185	—	—	1.8	100.4	181	38.4	219.4
2022	1.7	161	274	1.8	187	104	1.7	177	—	—	1.7	102.4	174	34.8	208.8
2023	1.5	164	246	1.6	165	103	1.5	155	—	—	1.5	104.5	157	31.2	188.2
2024	1.4	168	235	1.5	155	103	1.4	144	—	—	1.4	106.6	149	26.4	175.4
2025	1.2	171	205	1.3	133	102	1.2	122	19.0	141.0	1.2	109.3	131	22.8	153.8
2026	1.1	174	191	1.2	123	103	1.1	113	—	—	1.1	111.5	123	19.4	142.4
2027	1.0	177	177	1.1	113	103	1.0	103	—	—	1.0	113.7	114	15.6	129.6

[a] Based on weighted average for firm supplies of moderate input level and temporary supplies of low input level; excluding provision of "make-up" water.

[b] The modification consists of increasing the water quantities producing the assessed IACA benefits. Water quantities are increased to 112.5% between 1975 and 1985, to 110% between 1985 and 2000, and 107.5% thereafter. The ratio of "scarce rabi water" to total rabi water of 1:1.35 is based on the calculated irrigation requirements for wheat shown in the IACA project reports for Dipalpur Above BS (1:1.26), Dipalpur Below BS (1:1.35 and Ravi Syphon (1:1.31). These ratios had to be reduced in order to allow for the aggregation of additional watercourse availabilities with storage availabilities at reservoir site.

[c] Based on weighted average values of incremental water availabilities in eleven priority project areas totalling 5.2 million acres CCA and scheduled for an increasing absorption of additional surface water averaging 2.4 MAF by 1985. This evaluation is based on the incremental production attainable from an integrated cropping pattern for a complete agricultural cycle. It does not distinguish between availability at different seasons. The values beyond 1990 for which no groundwater projects data are available have been extrapolated in accordance with the trend of growth performance assumed under the project up to that point. On the assumption that the increase in storage availability represents only a relatively small increase in relation to total availability this evaluation makes use of total storage availabilities over time.

APPENDIX TABLE A6-4
EVALUATION BASED ON STUDY GROUP'S 1965 REPORT[a]

	1st Phase Study					Discounted at 13.3%	
	Irrigation[b] Benefits	Power Benefits	Total Benefits	Capital Costs	O&M Costs	Costs	Benefits
				(Rs. million)			
1965				10.0		8.826	—
1966				65.7		51.181	—
1967				78.1		53.698	—
1968				393.2		238$613	—
1969				436.5		233.795	—
1970		− 3.1	−3.1	428.4		202.521	−1.465
1971		−62.7	−62.7	482.7		201.404	−26.161
1972		−39.4	−39.4	488.2	10.4	163.362	−14.510
1973		−14.4	−14.8	368.4	10.4	123.123	−4.811
1974		91.4	91.4	228.7	10.4	67.159	26.221
1975	447.0	260.4	707.4	56.6	10.4	16.965	179.117
1976	491.0	217.1	708.1		10.4	2.324	153.247
1977	506.0	33.2	539.2		10.4	2.051	106.356
1978	554.0	49.2	603.2		10.4	1.811	105.013
1979	581.0	20.0	601.0		10.4	1.598	92.348
1980	604.0	− 1.7	602.3		10.4	1.410	81.688
1981	628.0	− 5.4	622.6		10.4	1.245	74.525
1982	649.0	7.9	656.9		10.4	1.099	69.400
1983	652.0	131.0	783.0		10.4	0.970	73.012
1984	652.0	29.8	681.8		10.4	0.856	56.112
1985	656.0	52.6	708.6		10.4	0.755	51.472
1986	661.0	53.6	714.6		10.4	0.667	45.815
1987	662.0	53.2	715.2		10.4	0.588	40.471
1988	668.0	52.8	720.8		10.4	0.519	36.000
1989	671.0	53.1	724.1		10.4	0.458	31.909
1990	589.0	53.9	642.9		10.4	0.405	25.103
1991	586.0	55.9	641.9		10.4	0.357	22.042
1992	589.0	49.9	638.9		10.4	0.315	19.354
1993	582.0	45.1	627.1		10.4	0.278	16.775
1994	584.0	40.3	624.3		10.4	0.246	14.740
1995	570.0	35.6	605.6		10.4	0.217	12.620
1996	571.0	31.0	602.0		10.4	0.191	11.072
1997	562.0	27.7	589.7		10.4	0.169	9.573
1998	562.0	42.0	604.0		10.4	0.149	8.654
1999	551.0	42.0	593.0		10.4	0.132	7.499
2000	545.0	42.0	587.0		10.4	0.116	6.552
2001	533.0	42.0	575.0		10.4	0.102	5.664
2002	534.0	42.0	576.0		10.4	0.090	5.008
2003	518.0	42.0	560.0		10.4	0.080	4.298
2004	519.0	42.0	561.0		10.4	0.070	3.800
2005	504.0	42.0	546.0		10.4	0.062	3.264
2006	500.0	42.0	542.0		10.4	0.055	2.860
2007	484.0	42.0	526.0		10.4	0.048	2.450
2008	479.0	46.0	525.0		10.4	0.043	2.158
2009	464.0	64.4	528.4		10.4	0.038	1.917
2010	459.0	127.9	586.9		10.4	0.033	1.879
2011	439.0	123.1	562.1		10.4	0.029	1.589
2012	432.0	55.6	487.6		10.4	0.026	1.216
2013	414.0	42.0	456.0		10.4	0.023	1.004
2014	406.0	42.8	448.8		10.4	0.020	0.872
2015	386.0	50.0	436.0		10.4	0.018	0.748
						1,380.312	1,373.394

[a] In the 1965 Report, irrigation benefits were based on the provision of a "make-up" water compensation for the loss in storage capacity due to siltation. In order to keep the analyses comparable, this analysis is based on prorating total benefits to the water quantity made available by Tarbela

[b] Based on benefits attainable with moderate input level as defined in the 1965 Report.

APPENDIX TABLE A6–5
MODIFIED IACA EVALUATION

	Benefits				Costs		Benefit Cost Ratio		Rate of Return	
Year	Power Benefits	IACA Net Recharge Value	IACA Mod. Eval. Total Benefits	Total Benefits	Capital Costs	O&M Costs	Benefits Discounted at 8%	Costs Discounted at 8%	Benefit at 12.5%	Cost at 12.5%
					(Rs. millions)					
1965	—	—	—	—	10.0		—	9.3	—	8.9
1966					65.7		—	56.3	—	51.9
1967					78.1		—	62.0	—	54.8
1968					393.2		—	289.0	—	245.5
1969					436.5		—	297.1	—	242.2
1970	(−) 3.1			(−) 3.1	428.4		(−) 2.0	270.0	(−) 1.5	211.3
1971	(−)62.7			(−)62.7	482.7		(−)36.6	281.6	(−)27.5	211.6
1972	(−)39.4			(−)39.4	433.2	10.4	(−)21.3	239.7	(−)15.4	172.9
1973	(−)14.8			(−)14.8	368.4	10.4	(−) 7.4	189.5	(−) 5.1	131.2
1974	91.4			91.4	223.7	10.4	42.3	108.4	28.2	72.1
1975	260.4	7.1	320	587.5	56.6	10.4	252.0	28.7	160.8	18.3
1976	217.1	13.5	358	588.6		10.4	233.7	4.1	143.2	2.5
1977	33.2	19.7	402	454.9		10.4	167.3	3.8	98.4	2.2
1978	49.2	26.9	439	515.1		10.4	175.4	3.5	99.0	2.0
1979	20.0	33.5	475	528.5		10.4	166.6	3.3	90.3	1.8
1980	(−) 1.7	40.5	518	556.8		10.4	162.5	3.0	84.6	1.6
1981	(−) 5.4	46.3	540	580.9		10.4	157.0	2.8	78.4	1.4
1982	7.9	57.4	547	612.3		10.4	153.2	2.6	73.5	1.2
1983	131.0	61.8	554	746.8		10.4	173.0	2.4	79.7	1.1
1984	29.8	73.4	561	664.2		10.4	142.5	2.2	63.0	1.0
1985	52.6	82.1	567	701.7		10.4	139.4	2.1	59.2	0.9
1986	53.6	91.9	580	725.9		10.4	133.5	1.9	54.4	0.8
1987	53.2	99.2	571	723.4		10.4	123.2	1.8	48.2	0.7
1988	52.8	102.8	564	719.6		10.4	113.5	1.6	42.6	0.6
1989	53.1	105.8	556	714.9		10.4	104.4	1.5	37.6	0.6
1990	53.9	107.9	546	707.8		10.4	95.7	1.4	33.1	0.5
1991	55.9	107.7	546	709.6		10.4	88.3	1.3	29.5	0.4
1992	49.9	107.2	544	701.1		10.4	81.3	1.2	25.9	0.4
1993	45.1	107.4	533	685.5		10.4	73.6	1.1	22.5	0.3
1994	40.3	106.7	527	674.0		10.4	67.0	1.0	19.7	0.3
1995	35.6	105.4	519	660.0		10.4	60.7	1.0	17.1	0.3
1996	31.0	103.4	502	636.4		10.4	54.2	0.9	14.7	0.2
1997	27.7	101.7	505	634.4		10.4	50.0	0.8	13.0	0.2
1998	42.0	98.8	482	622.8		10.4	45.5	0.8	11.4	0.2
1999	42.0	95.4	462	599.4		10.4	40.5	0.7	9.7	0.2
2000	42.0	91.3	470	603.3		10.4	37.8	0.6	8.7	0.2
2001	42.0	88.9	463	593.9		10.4	34.4	0.6	7.6	0.1
2002	42.0	86.5	455	583.5		10.4	31.3	0.6	6.6	0.1
2003	42.0	84.1	446	572.1		10.4	28.4	0.5	5.8	0.1
2004	42.0	81.6	451	574.6		10.4	26.4	0.5	5.2	0.1
2005	42.0	79.4	441	562.4		10.4	24.0	0.4	4.5	0.1
2006	42.0	76.7	426	544.7		10.4	21.5	0.4	3.9	0.1
2007	42.0	74.0	407	523.0		10.4	19.1	0.4	3.3	0.1
2008	46.0	71.3	392	509.3		10.4	17.2	0.4	2.9	0.1
2009	64.4	68.6	374	507.0		10.4	15.9	0.3	2.5	0.1
2010	127.9	65.8	359	522.7		10.4	16.0	0.3	2.4	0.1
2011	123.1	63.0	340	526.1		10.4	14.1	0.3	2.1	0.0
2012	55.6	60.2	330	445.8		10.4	11.1	0.3	1.6	0.0
2013	42.0	57.4	314	413.4		10.4	9.5	0.2	1.3	0.0
2014	42.8	54.8	294	391.6		10.4	8.4	0.2	1.1	0.0
2015	50.0	51.8	277	378.8		10.4	7.5	0.2	0.9	0.0
							3,352.5	1,884.8	1,448.0	1,443.0

B/C at 8% = 1.8%
Rate of Return = 12.5%

APPENDIX TABLE A6-6

EVALUATION BASED ON AVERAGE VALUES OF INCREMENTAL WATER IN PROJECT AREAS AND ON CONSULTANT'S POWER BENEFITS ESTIMATES

	Benefits of Tarbela Deliveries	Net Recharge Benefits	Power Benefits	Associated Costs of Remodelling	Total Benefits	Capital Costs	O & M Costs	Benefit Cost Ratio, Discounted: Costs at 8%	Benefit Cost Ratio, Discounted: Benefits at 8%	Discounted at 8.4%: Costs	Discounted at 8.4%: Benefits
					(Rs. millions)						
1965						10.0		9.3	—	9.225	—
1966						65.7		56.3	—	55.912	—
1967						78.1		62.0	—	61.315	—
1968						393.2		289.0	—	284.771	—
1969						436.5		297.1	—	291.634	—
1970			(−) 3.1		(−) 3.1	428.4		269.9	(−) 2.0	264.042	(−) 1.911
1971			(−)62.7		(−)62.7	482.7		281.7	(−)36.6	274.456	(−)35.650
1972			(−)39.4		(−)39.4	433.2	10.4	239.7	(−)21.3	232.679	(−)20.666
1973			(−)14.8		(−)14.8	368.4	10.4	189.5	(−) 7.4	183.293	(−) 7.161
1974			91.4		91.4	223.7	10.4	108.4	42.3	104.498	40.799
1975	102.0	2.5	260.4	(−) 0.9	363.9	56.6	10.4	28.7	156.1	27.590	149.851
1976	186.0	3.1	217.1	(−) 1.9	404.3		10.4	4.1	160.6	3.951	153.586
1977	193.0	3.9	33.2	(−) 2.8	227.3		10.4	3.8	83.6	3.645	79.656
1978	218.0	7.5	49.2	(−) 3.8	270.9		10.4	3.5	92.3	3.362	87.579
1979	238.0	11.2	20.0	(−) 4.7	264.5		10.4	3.3	83.4	3.102	78.884
1980	254.0	14.9	(−) 1.7	(−) 5.6	261.6		10.4	3.0	76.4	2.861	71.973
1981	268.0	18.5	(−) 5.4	(−) 6.5	274.6		10.4	2.8	74.2	2.640	69.695
1982	283.0	25.2	7.9	(−) 7.4	308.7		10.4	2.6	77.3	2.435	72.279
1983	292.0	28.3	131.0	(−) 8.3	443.0		10.4	2.4	102.6	2.246	95.686
1984	306.0	35.4	29.8	(−) 8.5	362.7		10.4	2.2	77.8	2.072	72.271
1985	310.0	40.1	52.6	(−) 8.7	394.0		10.4	2.1	78.3	1.912	72.424
1986	317.0	45.5	53.6	(−) 8.8	407.3		10.4	1.9	74.9	1.764	69.067
1987	320.0	50.7	53.2	(−) 9.0	414.9		10.4	1.8	70.7	1.627	64.904
1988	328.0	54.9	52.8	(−) 9.1	426.6		10.4	1.6	67.3	1.501	61.563
1989	336.0	58.9	53.1	(−) 9.3	438.7		10.4	1.5	64.1	1.385	58.403
1990	339.0	63.6	53.9	(−) 9.5	447.0		10.4	1.4	60.4	1.277	54.897

1991	343.0	65.4	55.9	(−) 9.6	454.7	10.4	1.3	56.9	1.178	51.515
1992	345.0	65.9	49.9	(−) 9.7	451.1	10.4	1.2	52.3	1.087	47.147
1993	343.0	67.7	45.1	(−) 9.9	445.9	10.4	1.1	47.9	1.003	42.992
1994	346.0	69.2	40.3	(−)10.0	445.5	10.4	1.0	44.3	0.925	39.625
1995	341.0	69.4	35.6	(−)10.2	435.8	10.4	0.9	40.1	0.853	35.759
1996	342.0	69.1	31.0	(−)10.3	431.8	10.4	0.9	36.8	0.787	32.685
1997	336.0	69.2	27.7	(−)10.5	422.4	10.4	0.8	33.3	0.726	29.496
1998	337.0	69.2	42.0	(−)10.6	437.6	10.4	0.7	32.0	0.670	28.189
1999	330.0	69.0	42.0	(−)10.8	430.2	10.4	0.7	29.1	0.618	25.565
2000	331.0	67.5	42.0	(−)10.9	429.6	10.4	0.7	26.9	0.570	23.551
2001	324.0	67.9	42.0	(−)10.5	423.4	10.4	0.6	24.6	0.526	21.413
2002	324.0	67.9	42.0	(−)10.2	423.7	10.4	0.6	22.7	0.485	19.767
2003	316.0	68.0	42.0	(−) 9.8	416.2	10.4	0.5	20.7	0.448	17.913
2004	315.0	68.0	42.0	(−) 9.4	415.6	10.4	0.5	19.1	0.413	16.501
2005	307.0	68.5	42.0	(−) 9.1	408.4	10.4	0.4	17.2	0.381	14.958
2006	306.0	69.1	42.0	(−) 8.8	408.3	10.4	0.4	16.1	0.351	13.796
2007	297.0	68.8	42.0	(−) 8.5	399.3	10.4	0.4	14.6	0.324	12.446
2008	295.0	68.3	46.0	(−) 8.2	401.1	10.4	0.4	13.6	0.299	11.534
2009	285.0	67.0	64.4	(−) 8.0	408.4	10.4	0.3	12.8	0.276	10.833
2010	282.0	66.0	127.9	(−) 7.7	468.2	10.4	0.3	13.6	0.254	11.457
2011	272.0	64.6	123.1	(−) 7.3	452.4	10.4	0.3	12.2	0.235	10.213
2012	269.0	63.0	55.6	(−) 6.9	380.7	10,4	0.3	9.5	0.217	7.928
2013	257.0	61.6	42.0	(−) 6.6	354.0	10.4	0.2	8.1	0.200	6.801
2014	253.0	60.3	42.8	(−) 6.3	349.8	10.4	0.2	7.5	0.184	6.199
2015	241.0	59.4	50.0	(−) 5.9	344.5	10.4	0.2	6.8	0.170	5.632
							1,884.8	1,993.6	1,838.375	1,832.042

B/C Ratio = 1.1
Rate of Return = 8.4%

APPENDIX TABLE A6-7

EVALUATION BASED ON AVERAGE VALUES OF INCREMENTAL WATER IN PROJECT AREAS WITH STUDY GROUP'S ASSESSMENT OF POWER BENEFITS

	Benefits of Tarbela Deliveries	Net Recharge Benefits	Power Benefits	Associated Costs of Remodelling	Total Benefits	Capital Costs	O&M Costs	Benefit Cost Ratio		Rate of Return	
								Costs at 8%	Benefits at 8%	Costs at 9.2%	Benefits at 9.2%
					(Rs. millions)						
1965			—		—	10.0		9.259	—	9.158	—
1966			—		—	65.7		56.327	—	55.096	—
1967			2.4		2.4	78.1		61.998	1.905	59.977	1.843
1968			10.9		10.9	393.2		289.014	8.012	276.518	7.665
1969			45.1		45.1	436.5		297.075	30.694	281.107	29.044
1970			(–) 50.9		(–) 50.9	428.4		269.965	(–) 32.076	252.647	(–)30.018
1971			155.2		155.2	482.7		281.651	90.558	260.687	83.817
1972			137.7		137.7	433.2	10.4	239.665	74.395	219.387	68.101
1973			186.3		186.3	368.4	10.4	189.494	93.196	171.556	84.374
1974			7.2		7.2	223.7	10.4	108.434	3.335	97.090	2.986
1975	102.0	2.5	(–) 36.8	(–) 0.9	66.8	56.6	10.4	28.735	28.649	25.446	25.370
1976	186.0	3.1	(–) 69.8	(–) 1.9	117.4		10.4	4.130	46.621	3.617	40.832
1977	193.0	3.9	(–)127.0	(–) 2.8	67.1		10.4	3.824	24.673	3.312	21.371
1978	218.0	7.5	212.8	(–) 3.8	434.5		10.4	3.541	147.930	3.033	126.728
1979	238.0	11.2	138.7	(–) 4.7	383.2		10.4	3.279	120.801	2.778	102.350
1980	254.0	14.9	97.9	(–) 5.6	361.2		10.4	3.036	105.431	2.544	88.346
1981	268.0	18.5	47.0	(–) 6.5	327.0		10.4	2.811	88.378	2.329	73.242
1982	283.0	25.2	(–)110.3	(–) 7.4	190.5		10.4	2.603	47.672	2.133	39.074
1983	292.0	28.3	(–) 49.5	(–) 8.3	262.5		10.4	2.410	60.824	1.953	49.306
1984	306.0	35.4	94.3	(–) 8.5	427.2		10.4	2.231	91.655	1.789	73.482
1985	310.0	40.1	109.6	(–) 8.7	451.0		10.4	2.066	89.594	1.638	71.040
1986	317.0	45.5	125.7	(–) 8.8	479.4		10.4	1.913	88.181	1.500	69.151
1987	320.0	50.7	129.5	(–) 9.0	491.2		10.4	1.771	83.659	1.374	64.884
1988	328.0	54.9	133.3	(–) 9.1	507.1		10.4	1.640	79.969	1.258	61.341
1989	336.0	58.9	136.2	(–) 9.3	521.8		10.4	1.519	76.192	1.152	57.801
1990	339.0	63.6	139.5	(–) 9.5	532.6		10.4	1.406	72.008	1.055	54.027
1991	343.0	65.4	144.3	(–) 9.6	543.1		10.4	1.302	67.989	0.966	50.451

1992	345.0	65.9	144.3	(−) 9.7	545.5	10.4	1.206	63.231	0.885	46.405
1993	343.0	67.7	144.3	(−) 9.9	545.1	10.4	1.116	58.504	0.810	42.464
1994	346.0	69.2	144.3	(−)10.0	549.5	10.4	1.034	54.608	0.742	39.200
1995	341.0	69.4	144.3	(−)10.2	544.5	10.4	0.957	50.103	0.679	35.571
1996	342.0	69.1	144.3	(−)10.3	545.1	10.4	0.886	46.443	0.622	32.610
1997	336.0	69.2	144.3	(−)10.5	539.0	10.4	0.820	42.521	0.570	29.529
1998	337.0	69.2	144.3	(−)10.6	539.9	10.4	0.760	39.437	0.522	27.086
1999	330.0	69.0	144.3	(−)10.8	532.5	10.4	0.703	36.015	0.478	24.464
2000	331.0	67.5	144.3	(−)10.9	531.9	10.4	0.651	33.310	0.438	22.378
2001	324.0	67.9	144.3	(−)10.5	525.7	10.4	0.603	30.483	0.401	20.254
2002	324.0	67.9	144.3	(−)10.2	526.0	10.4	0.558	28.241	0.367	18.558
2003	316.0	68.0	144.3	(−) 9.8	518.5	10,4	0.517	25.776	0.336	16.752
2004	315.0	68.0	144.3	(−) 9.4	517.9	10.4	0.479	23.839	0.308	15.323
2005	307.0	68.5	144.3	(−) 9.1	510.7	10.4	0.443	21.767	0.282	13.837
2006	306.0	69.1	—	(−) 8.8	366.3	10.4	0.410	14.456	0.258	9.088
2007	297.0	68.8	—	(−) 8.5	357.3	10.4	0.380	13.056	0.236	8.118
2008	295.0	68.3	—	(−) 8.2	355.1	10.4	0.352	12.014	0.216	7.388
2009	285.0	67.0	—	(−) 8.0	344.0	10.4	0.326	10.777	0.198	6.555
2010	282.0	66.0	—	(−) 7.7	340.3	10.4	0.302	9.871	0.181	5.938
2011	272.0	64.6	—	(−) 7.3	327.3	10.4	0.279	8.791	0.166	5.230
2012	269.0	63.0	—	(−) 6.9	325.1	10.4	0.259	8.085	0.152	4.757
2013	257.0	61.6	—	(−) 6.6	312.0	10.4	0.239	7.184	0.139	4.181
2014	253.0	60.3	—	(−) 6.3	307.0	10.4	0.222	6.546	0.128	3.767
2015	241.0	59.4	—	(−) 5.9	294.5	10.4	0.205	5.814	0.117	3.309
							1,884.8	2,241.1	1,750.3	1,759.4

B/C Ratio = 1.2:1
Rate/Return = 9.2%

APPENDIX TABLE A6-8

WATERCOURSE REQUIREMENTS AND SUPPLIES BY SOURCES SYSTEM SUMMARY—1985 CONDITION

	MAF	%
System Totals:		
Watercourse Requirements	116.5	100.0
Groundwater	42.1	36.1
Surface Water (incl. Tarbela 4.29 = 3.7%)	74.4	63.9

Monthly Distribution (rounded):

	Surface Water[a]		Tarbela		Groundwater		Total	
Month	MAF	percent/ month	MAF	percent/ month	MAF	percent/ month	MAF	percent/ 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

[a] Exclusive of Tarbela.

Annex 7

REVIEW PROCEDURES FOR GROUNDWATER PROJECTS INCLUDING A DETAILED REVIEW OF ONE PROJECT

Introduction

This Annex is concerned with the tubewell projects identified and formulated by IACA within the canal commanded areas of the Indus Plains. The selection of priorities, the priority status of each project, and the integration of projects with those presently ongoing in West Pakistan into an internally consistent groundwater development program, are all dealt with in Chapters III and IV. The Study Group's review of IACA's proposals and its conclusions[1] are given below in Part A. Part B deals with the specifics of the public tubewell project known as "Dipalpur Below the BS Link."

Review Procedures

Project Preparation

IACA has identified and formulated 12 public tubewell projects. As far as available information would permit, it has appraised the technical and organizational aspects and the financial and economic feasibility of each of these projects. In the course of a major study of this kind, IACA could not undertake the detailed investigations required to produce definitive project reports. IACA's findings must therefore be regarded as preliminary and subject to confirmation or modification in the light of more detailed engineering, agricultural, and economic studies required to produce final project reports and enable the preparation of tender documents.

The extent and depth of further investigations would vary for each project area but in general they should cover the items listed under five subheadings: technical feasibility, agriculture, project operation, financial aspects, and economic aspects.

Technical Feasibility. The following studies and investigations would have to be carried out to determine the technical feasibility and detailed cost estimates of the proposed projects:

- Topographic surveys as required for detailed project design.
- Additional groundwater surveys as required including depth to water table, groundwater quality, physical properties of the aquifer(s) including safe yields, groundwater movements and possibilities of saline groundwater movements and intrusion, requirements of drainage including those for tile drainage where applicable, and flood protection.
- Detailed survey of canal system and watercourses serving the project area, including existing canal discharge capacities, canal regime stabilities under existing and projected conditions and requirements for enlargement, remodelling and re-alignment.

[1] IACA's Comprehensive Report, Volumes 12, 14, 16 and 20.

• Approximate siting of individual tubewells including determination of capacities, specifications for wells and equipment, appurtenant structures including those required for mixing of surface and groundwater.

• Survey of electrification requirements including alignment of transmission lines and specifications of equipment required for energizing the number and capacities of wells determined.

• Survey of existing transport systems serving the project areas, including needs for extension, improvement, realignment, etc.

• Preparation of detailed procurement and construction schedules for all physical works to be included under the projects.

Agriculture. The following studies and investigations should be carried out to determine the agricultural benefits likely to be derived from the implementation of the projects proposed:

• Correlation of existing soil surveys of the project area and their supplementation as required including delineation of areas affected by salinity and alkalinity; attention would need to be given to possible soil texture problems because of their relevance for irrigation practices, and to reclamation requirements.

• Survey of noncommanded areas within or adjacent to project areas for possible inclusion under the projects.

• Land use classification to determine the agricultural production potential of the project area.

• Updating of inventory of existing private tubewell development including area density, capacities and types of wells, relationship of well installation and farm size, areas commanded and distribution of private tubewell water with a view to providing a basis for decision on possible public interference with private development.

• Verification of intensities and cropping patterns assumed in project proposals, both for fresh groundwater and mixing zones, crop water requirements, estimates of current costs and value of agricultural production, projections for crop production and livestock production, requirements of physical onfarm inputs, and marketing prospects.

• Assessment of onfarm input requirements, prospects of supply and supporting services.

Project Operation. The following aspects should be reviewed for the individual project areas to outline operational procedures for the projects:

• The operational requirements for the integration of surface and groundwater supplies in relation to water requirements of the project cropping patterns.

• Areas in which mixing of surface water with groundwater would be required and their mixing ratios.

• Operational procedures needed to relate canal deliveries to mixing requirements and water demands for cropping patterns proposed for mixing zones and accordingly operational procedures for tubewells in mixing zones.

• Possibilities for substitution of surface water by groundwater should be further investigated.

Financial Aspects. The financial implications of the project proposals should be reviewed with regard to the following aspects:

• Preparation of detailed investment cost estimates, including expenditures schedules commensurate with construction schedules and broken down into foreign exchange and local currency requirements, as well as estimates of operation and maintenance expenditures.

- Assessment of capacity of ultimate beneficiaries to recover project costs.

Economic Aspects. The economic evaluation of the project proposals and feasible alternatives for each project should be verified in the light of the findings of the above outlined studies and investigations. The project discussed in Part B offers an example of what needs to be done.

Project Management

As discussed in Chapter VI-B, IACA has proposed that after completion of project construction, the operation of the project and the provision of supporting services would be carried out by the regular line departments, specifically the Departments of Irrigation and Agriculture. It has further proposed that these activities would be coordinated through a Project Field Force (PFF) which would consist of a chairman appointed from the Civil Service of Pakistan (CSP) and ranking officers representing the line departments most directly concerned in the project area. The PFF would operate under the auspices of the Land and Water Development Board (LWDB). The Chairman of the PFF would not have direct authority over the officers of the line departments but would be responsible for monitoring the project and ensuring that the development objectives were being achieved.

The Study Group thoroughly endorses IACA's emphasis on monitoring and keeping careful check on the progress of the project, but does not wholly agree with IACA's proposals for project management in other aspects. In general, it would favor a form of integrated project management similar to that presently adopted by the ADC and LWDB. As discussed in Chapter VI-B, the Study Group feels that the integration of substantial increases in water availability with rapid agricultural development including the essential agricultural extension services and greatly increased onfarm inputs is a demanding task requiring a high degree of coordination and overall direction. The Government has recognized this need in the past and has made institutional provision for integrated project management under the ADC and LWDB. Under this concept the Irrigation Department should, in the Study Group's opinion, continue to operate the main surface water supply system and deliver supplies to the project area. The integration of surface supplies with groundwater within the project areas would be the responsibility of the project management which would need to be kept advised of likely surface deliveries. The coordination of surface water deliveries between the Irrigation Department and the project management would take place at the level of the LWDB.

The project management would continue to be responsible for all services within the project area only so long as this would be considered necessary. When an appropriate stage of development and organization has been reached, the initial project management would withdraw. It would be replaced by some more permanent arrangement incorporating full farmer participation and local authorities while the line departments would resume direct responsibility for providing their normal services.

Recovery of Costs

No policy decision has been taken by the Government of Pakistan with regard to the water charges to be levied on beneficiaries of public tubewell projects.

Because of the integrated use of surface and groundwater supplies, any such decision will have to be made in the context of Basinwide development. In the opinion of the Study Group, every effort should be made to make the projects self-liquidating. This would require consolidated water charges (for both surface and groundwater) ranging from Rs. 30 to Rs. 40 per cropped acre. The Study Group would favor a system of water charges which would provide incentives for the increase of cropped acres, i.e. based on CCA rather than cropped acres. Initial periods, however, of no recovery or gradually increasing recovery schedules may need to be introduced to stimulate the immediate and effective use of the water resources developed.

General Approach and Design Criteria

Scope and Size of Projects. IACA's proposals are based on an integrated exploitation of groundwater by public tubewells, designed in capacity, area density, and rate of utilization to extract from the aquifer the estimated average annual recharge. As designed, the projects would enable a stabilization of the groundwater table at a level of around 10 to 15 feet. In most cases, this would require a higher rate of pumping in the early period of the projects in order to lower the water table to this depth.

In its project formulation, IACA has taken the view that until the water table has been lowered to a depth of about 10 feet no additional surface water should be admitted to the project area. The Study Group would not support the rigid application of this principle. The relationship between additional water applications and water table rise would appear to allow considerable latitude, and in the Study Group's opinion, temporary rises in water table may be tolerated in the interest of rapid growth of production.

Varying proportions of areas underlain by groundwater which would require mixing with good quality surface water are included in the projects. The pumping period in the mixing zones would be extended to take advantage of surface supplies for mixing within the existing operational procedures of canal systems, but cropping intensities in the mixing zones would in most cases not be as high as in fresh groundwater zones. This factor was taken into account by IACA when estimating the average cropping intensities at full irrigation applications for project areas.

IACA has assessed the water requirements on the basis of full delta related to ultimate levels of production and irrigation practice and so provides for a level of water availability considerably in excess of water applications used at present levels of farming (see Chapter II). The proposed projects, together with additional surface water supplies, would enable farmers to increase water applications on the existing cropped acreage to full delta and also to expand cropped acreage up to an average intensity of about 150 percent.

Projects cover areas within which the development characteristics and constraints are as similar as possible. In order to facilitate integration with the existing system of surface water distribution, the areas covered by individual projects generally coincide with the canal commands. In certain cases this criterion is modified to take into account local conditions of groundwater depth or quality and agricultural factors. The smallest unit to form part of a project is a distributary canal, because surface water releases cannot be controlled downstream of a distributary head.

IACA has generally adopted a minimum size of tubewell project of about 500 wells, covering slightly more than a quarter of a million acres, in the belief that competitive tenders could not be expected for smaller contracts and staff requirements would be out of proportion to the size of the schemes. The average size of the 12 groundwater projects proposed is about half a million acres. The size of tubewell projects could be reduced further, especially if construction is carried out by force account. Care should be taken, however, that contiguous areas in size consistent with at least the smallest controllable unit of surface water distribution are being covered by a project. Only in the latter case can a satisfactory integration of surface and groundwater be achieved under public control.

Installed Tubewell Capacity. The requirements for groundwater have been estimated in relation to surface water availability. The installed capacity is designed to enable the full integration of groundwater with variable surface water supplies at a level which would ensure full supplies to the project areas in any month in four years out of five. Requirements in the mixing zones, where groundwater would have to be mixed with surface water before being used for irrigation, have been considered separately from those of the fresh groundwater zones where tubewell water would be applied directly to the crops.

In the mixing zones, the amount of groundwater used is determined by the total watercourse requirements and the adopted mixing ratios are shown in Table A7-1. It would be necessary for adequate surface water deliveries to be made available to mixing zones in all years despite low flows that may occur in the river system. In detailed project investigations, account would also have to be taken of the fact that surface water deliveries cannot be varied within the area served by a single distributary canal which may serve both fresh groundwater and mixing areas.

In fresh groundwater zones, further design objectives have been to minimize projects costs, to relate power demand with power availability, and to obtain the most efficient use of all available water resources. When river flows are high, the canals to these zones would be run full and groundwater pumped only to make up residual requirements. In the months of April, May and June, surface water would, as far as possible, be supplied in preference to groundwater in order to increase hydro energy generation and alleviate load constraints of the power system. As the

TABLE A7–1

PROPOSED MIXING RATIOS FOR PUBLIC TUBEWELL PROJECT

	All Regions Except Lower Indus		Lower Indus Region	
Groundwater Quality Zone	Deep Groundwater Quality (ppm TDS)	Average Mixing Requirements (surface water to groundwater)	Deep Groundwater Quality (ppm TDS)	Average Mixing Requirements (surface water to groundwater)
Fresh	Less than 1,000	No restriction	Less than 1,000	No restriction
Mixing	1,000–2,000	1 :1	1,000–2,000[a]	1:1
	2,000–3,000	2½:1		
Saline	More than 3,000	Not used	More than 2,000	Not used

[a] The lower limit allows for the more rapid increase in groundwater salinity with aquifer depth in the Lower Indus Region.

installed tubewell capacity is determined by peak pumping requirements, surface water supplies in the remaining months would be regulated in order to avoid high pumping peaks over short periods of time. As stated above, these principles would require further attention in the course of detailed project preparation to take account of the operational problems on distributary canals which serve both fresh groundwater and mixing zones.

On these principles, the theoretical pumping capacity necessary to meet the groundwater requirements in association with surface supplies for full development has been estimated. The theoretical capacity has then been increased by 15 percent to allow for uncertainties in design criteria and for daily shutdowns required to reduce peak demands on the power system mainly in April and May. The daily shutdowns have been estimated in cooperation with the Power Consultant[1] and are expected to be for periods of about two hours on 75 percent of the public tubewells in usable groundwater zones, phased over the four hours of peak power demand. The proportion of 75 percent represents approximately the ratio of tubewells in fresh groundwater zones to the total public tubewells installed for irrigation.

The capacity of individual tubewells would be limited by the hydrological conditions of the aquifer. In favorable circumstances, the output would be four to five cusecs but in many cases it would be less than four cusecs. Subject to these hydrological limitations, individual tubewell capacities would be determined by the estimated groundwater requirements for individual watercourses or for two or more water courses where it would be desirable and convenient that one tubewell serve more than one watercourse. Hydrological conditions and the exigencies of mixing surface water with the groundwater would require generally lower capacities in the mixing zones than in the fresh groundwater zones.

The exact number of tubewells of each capacity would have to be determined by detailed surveys of the watercourses in each project area. For the purposes of project planning, IACA has assumed that capacities would generally vary between two and five cusecs with possibly a few smaller wells in mixing zones. The detailed analysis of Upper Rechna area, contained in the SCARP IV Report prepared by Tipton and Kalmbach, Inc. for WAPDA, indicates an average tubewell capacity in fresh groundwater zones of about four cusecs. This average figure has been adopted in IACA's project proposals. In the mixing zones, IACA estimates that average capacities would be about three cusecs in zones with deep groundwater quality from 1,000 to 2,000 ppm TDS and two cusecs in zones with deep groundwater quality from 2,000 to 3,000 ppm TDS.

Type of Tubewell, Location and Discharge Control. The design of the tubewells would depend on experience gained from ongoing projects in West Pakistan and the state of technology at the time that contracts would be prepared for tender. The depth of the wells would vary from a general average of about 340 feet for five cusec wells to 200 feet for two cusec wells. IACA anticipates the use of fiberglass screens and sees no reason to depart from the present practice of using electrically powered shaft-driven pumps. A high standard of maintenance is recommended in order to achieve the high and sustained standard of tubewell operation assumed.

Tubewells would generally be sited as near as possible to the heads of the watercourses which they are designed to serve. IACA considers that the widespread in-

[1] Stone and Webster Overseas Consultants, Inc.

stallation of tubewells to discharge directly into canals would not be desirable in the next decade as it would entail extensive enlargement of the canal system and so introduce additional constraints on the rate of development. In mixing zones, tubewells discharging into canals would also have the undesirable side effect of causing an accumulation of dissolved solids towards the tail of the system. Nonetheless, tubewells discharging into the canal system would have some advantages. They would be of uniformly high capacity and would improve the flexibility in operation of the canal system. It is, therefore, probable that later developments would include tubewells sited in this way and in special cases they may be justified on a small scale during the decade to the mid-1970's.

In the mixing zones, the practical difficulties of mixing may require subminor canals to be constructed to carry mixed water parallel to the existing distributary or minor canals. The best methods of operation for mixing would need to be determined through experience.

Project Evaluation

Mode of Development. The priorities for groundwater development have been established by IACA in the broader context of Basin development. To decide on the mode of development (public or private), for each of the 12 projects, IACA has made a comparison between the proposed public tubewell project (Case 1) and as an alternative continued private tubewell development (Case 2). In those cases where the rate of return on the incremental investment and the rate of development, as measured by the growth of Net Production Value (NPV), is superior under the public alternative IACA has recommended this mode of development. To determine the rate of return on total investment in public tubewell projects, a comparison has also been made against the growth in NPV attainable "without" further water development (Case 3).

The Study Group in its project evaluation has generally followed the same procedure but—in keeping with recent experience—has adopted a somewhat more optimistic view than IACA with regard to the rate of private tubewell installation and their probable utilization in specific areas in the absence of public development. The Study Group has also assumed a somewhat higher rate of yield growth than IACA prior to the occurrence of the projects as well as in the absence of public tubewell development (Case 2) in accordance with the discussion of yields in Chapter II. These adjustments tend to strengthen the case for private groundwater development. In its review of the proposed mode of development, the Study Group has also had regard to the broader aspect of overall growth of agricultural production. In a particular project area, on the basis of a straight comparison, a public project may be superior to private development but, if the productive capacity of the private development is considerable, the overall effect on agricultural growth may be improved if the scarce public resource was deployed in areas less suited to private initiative.

Economic Evaluation. For purposes of determining the return on investment, IACA has assessed the effects of the projects on agricultural production on the basis of the increase in production, or incremental NPV, attributable to each project. This has been done by comparing the NPV "with" the project to the NPV "without" the project. The latter is the NPV assumed to result if no additional tubewells were installed after the scheduled starting date for project construction.[1]

IACA has further assessed the effects of public tubewell projects by comparison with continued private development and relating the incremental production to the incremental costs of public projects over continued private development. In its project reviews (one example is given in Part B), the Study Group has departed from this approach inasmuch as it has related total public project costs to the incremental benefits and added to the benefit streams, in a separate analysis, potential savings accruing to the private sector. In its project reviews, the Study Group also employed yield growth assumptions somewhat at variance with IACA (as described several paragraphs below). Because of the different production levels arising from these changes, the Study Group also adjusted the onfarm costs and assumed that in both "with" and "without" cases farm costs would amount to about 32 percent of gross production value in 1975 and rise to about 36 percent by 1985. This is the same relationship as in IACA's "with" case. In order to determine the beneficial effects of water development, the Study Group has assumed that the rates of application of agricultural inputs not dependent on additional water (other than mechanization requirements, and hired labor) would be similar in both the "with" and "without" cases. The incremental NPV thus measures essentially the contribution of the additional water made available as a result of tubewell projects. This incremental NPV is then related to the total capital and operating costs of tubewell projects to determine the rates of return.

Not all of the increase in production is due to tubewell water alone, however, and most of the tubewell projects, after providing for water table control, would make use of increased quantities of surface water as well. In order to arrive at the incremental benefits attributable to the tubewell projects only, the Study Group has allocated the incremental benefits "with" the project to the two sources of additional water combined. This procedure permits the calculation of an average value per additional acre-foot of incremental water supplied to the project area from both sources. The additional surface water used in the project areas, over and above the historical deliveries, varies from project to project and has been determined from the annual water budgets prepared by IACA. The quantities of additional surface water in different years have been valued at the average value per acre-foot of all additional water for those years. The allocation of benefits to additional surface water, determined in this manner, has then been subtracted from the total incremental NPV to derive an estimate of the incremental benefits due to tubewells alone. For certain projects where the reverse is true, i.e., where the project area would absorb less surface water than under historical deliveries, the value of surface water savings (computed in the same manner) has been added to incremental benefits from the project on the assumption that the water saved would find a beneficial use outside the specific project area roughly equivalent to that within the project area.[2] The allocation of incremental benefits to additional surface water supplies accounts to a large extent for the differences in evaluation results between IACA and the Study Group.

[1] This "without" case is based on the hypothetical assumption that no further groundwater development—private or public—would take place. Its sole purpose is as an aid in the assessment of the beneficial effect of the provision of incremental water supplies.

[2] It is recognized that this is only a rough approximation. Inasmuch as water will become increasingly scarce as development proceeds, the Study Group feels, however, that this would not be an undue bias in favor of the tubewell projects.

The Study Group has made upward adjustments in IACA's public tubewell cost estimates amounting to about 20 percent in total, primarily in order to provide a greater allowance for contingencies at this early stage of project preparation as well as allowing for additional work for construction of subminor canals in mixing zones and watercourses improvements likely to be needed for the immediate and efficient distribution of greatly increased watercourse deliveries. The cost of providing infrastructure, support services, and project operation and maintenance have also been charged against incremental benefits. In conformity with IACA procedures, onfarm production costs have been subtracted directly from the Gross Production Value (GPV) in arriving at the NPV for the "with" and "without" cases.

The Study Group has followed IACA's estimates of cropping intensities and cropping patterns, but, as pointed out above, has made some adjustments in the yield growth patterns. Although for the "with" case, current yields and ultimate yields by the year 2000 are the same as those adopted by IACA, the Study Group has tended to smooth out the increase in yields between reference years for the "with" case (the exception being increases in excess of 6 percent per annum which realistically cannot be achieved). This process of smoothing out increases has the effect of eliminating the automatic and rapid responses of yields to the sudden availability of greatly increased water supplies as assumed in the IACA projections. In the Study Group's opinion, such a rapid growth of yields is not likely to occur from increased water availability alone except in cases where crucial shortages are being eliminated.

For the "without" case, the Study Group has generally assumed higher future yields than IACA has used. This is particularly true for the important cash crops of cotton, wheat, sugarcane, fruit, and vegetables where the yield projections of the "with" case have been used. The main considerations which have led the Study Group to adjust upward the IACA projections for the "without" cases are as follows.

First, the existing irrigation water availability is presently less than IACA's estimated ultimate full delta requirements but approaches a level of about 80 percent of full delta on average except for the Sutlej and Panjnad Left Bank areas. At these levels of water supplies and with no expansion of cropped acreage, the Study Group considers that farmers would be selective in deciding the water applications given to different crops. It has therefore been assumed that farmers would apply close to full irrigation requirements to the major cash crops while continuing underirrigation of the noncash crops. The extent to which such priority allocation could be exercised would vary between project areas.

Second, operating on a much reduced cropped acreage and a level of farm inputs similar to that of the "with" case, farmers would be able to compensate to some extent for lower deltas by other inputs and improved husbandry practices on the smaller cropped acreage.

Third, farmers could, to a limited extent, counteract effects of waterlogging and salinity at the lower levels of cropping intensity by adjusting their cropping programs in accordance with the degree to which their lands become affected.

IACA's estimates of livestock population have been derived from the Census of Agriculture (1960) and adjusted to allow for growth between 1960 and 1965. On the basis of animal feed available from fodder, crop residues, and grazing, expressed in terms of total digestible nutrients (TDN), IACA has calculated the probable output of milk, meat, and animal by-products. Work animals have the first claim on the available TDN at the rate (in 1965) of 1,035 kilograms per animal unit per year, and the balance of TDN is assumed to be devoted to the production of milk and meat on the basis of a calculated TDN-to-product relationship. The Study Group projections of gross production value from livestock in the "with" cases are somewhat lower than those of IACA resulting from the lower estimates of fodder yields and crop residues following from the adjustments of yield growth for crops other than fodder. The Study Group has used IACA's TDN-to-product relationship. In the "without" cases, however, the higher feed availability from increased crop residues resulting from the Study Group's yield assumptions have not been translated into higher gross production values from animal husbandry because of the reservations the Study Group has with regard to the comparability of TDN derived from fodder and from crop residues.

Associated Agricultural Inputs

It would be essential to develop a high level of agricultural extension and supply services in any project area to achieve the standard of agricultural production assumed in either the "with" or "without" case. The main productive inputs, in addition to improved irrigation supplies and better husbandry practices, would be fertilizers, better seeds, and timely and adequate plant protection. No attempt has been made to estimate the physical quantities required. These inputs would be expected to grow at a considerable rate as reflected in the assumed on-farm expenditures.

Absorption of the physical quantities of inputs represented by the estimated on-farm expenditures in the project areas would require considerable extension efforts as well as improvements in the supply system. Furthermore, their adoption would depend upon the decision of numerous farmers who would need to be given adequate incentives and stimulation for their use. In addition, the availability of credit would be equally important to the realization of the assumed input levels. The Study Group feels that the growth of production projected in the project areas depends as much on the increased use of onfarm inputs and better husbandry practices as it does on the availability of additional irrigation water, and therefore would emphasize the need for adequate provision of such inputs, especially in the project areas. In the course of detailed project preparation the above aspects should be accorded the attention and weight which their importance merits.

Alternative Private Development

Because the project areas selected by IACA are all located in usable groundwater zones, an alternative to a public tubewell project would in all cases be for farmers to continue installation of privately owned wells. In IACA's project formulation, public and private tubewells have been assumed to be mutually exclusive within the same area, i.e., a public tubewell project would displace existing private tubewells and inhibit further private installations. IACA has analyzed the reports and records of private tubewell development up to 1965 in the Punjab; and from this analysis, IACA projected general trends and used these trends to estimate the number of private tubewells likely to be installed in the project areas during the life span of the public project. On this basis, IACA estimates that the annual rate of growth of private tubewell installations would vary amongst the project areas from almost zero in the Sind to about 20 percent in the Bari Doab area in the Punjab. On the basis of the rates of private installations projected for each project area, IACA has made a comparison with the public tubewell project proposals. The extent of private tubewell coverage in 1965 ranged from 3 to 50 percent of the project areas. In 1975, the extent of private tubewell coverage is projected to range from 13 to 66 percent, and in 1985 from 27 to 84 percent. The highest private tubewell densities are to be found in the Punjab, especially the Bari Doab, while the lowest densities occur in the Sind.

The actual quantity of water made available by private tubewell depends not only on the number but also on the capacity and the utilization rate of the wells. IACA has examined this aspect of private tubewell development and has found considerable variations due to reasons which include land tenure problems, electricity supplies, mechanical breakdowns, disputes over sale of water, and fluctuations in surface supplies. IACA has found that a one-cusec well pumping for about 2,400 hours a year appears reasonably typical of the present situation. This pumping rate is equivalent to about 200 acre-feet a year from each private tubewell.

IACA's projections for private tubewell development as an alternative in some project areas appear rather low. The Study Group in its evaluation has made three adjustments. First, in a number of project areas, the rate of private tubewell installations projected by IACA for the period prior to a possible public project would be maintained in the absence of public development given appropriate stimulation. Whilst increasing the rate of installation in keeping with this view, the Study Group has, however, retained the ceiling introduced by IACA for private well installations in each project area.

Second, for purposes of comparison, the Study Group has assumed that a maximum of 120 acres could be served by one private tubewell as compared with IACA's figure of 100 acres. While this may overstate somewhat the average coverage provided by each private well, especially as density increases, it should be more representative of the possible total coverage though possibly at higher rates of installation and the acceptance of some overcapacity and associated higher investment. This has been recognized in the Study Group's evaluation by higher capital costs and O&M expenditures.

Third, the Study Group has further assumed an annual average pumpage per tubewell of 225 acre-feet compared with IACA's figure of 200 acre-feet. The implied utilization rate of 30 percent, as against IACA's of 27 percent, would appear feasible but would represent an improvement over past performance which, in the Study Group's opinion, can be anticipated in the absence of public development.

IACA's projections for the future rate of private tubewell installations were based on recent historical trends which came about with little public support and guidance and extended only over short periods. The Study Group, in making the above adjustments, has departed from this approach and expects private tubewell development would be actively promoted in the absence of public development. In particular, additional support for private groundwater development would be required in the form of technical advice and services, credit facilities, and counsel for cooperative use of private wells especially for smaller farms.

A Public Tubewell Project
Dipalpur Below the B.S. Link
The Project

The public tubewell project would consist of providing additional irrigation supplies and water table control for 611,000 acres of commanded culturable area (CCA) below the Balloki-Suleimanke (B.S.) Link along the right bank of the Sutlej River. The area is situated in the administrative district of Montgomery and comprises the whole of Dipalpur Canal Command below the B.S. Link. It is commandable by the Dipalpur Canal on the Sutlej River. This canal, being above the network of link canals to be completed in the Punjab as part of the replacement works of the Indus Waters Treaty (1960), would not be directly affected by diversions to and from these links. However, after the implementation of the Treaty (1970) the proposed area would receive all its surface supplies from the Marala Headworks on the Chenab River. The disused bed of the Old Beas River traverses the northern half of the project area. The distribution of the groundwater quality is as given in Table A7-2.

About 28 percent of the project area (171,000 acres CCA) has groundwater table within 10 feet of ground level and 25 percent of this area is assumed to be effectively waterlogged. IACA considers that the soils within the project area are generally suitable for irrigated agriculture. However, as a result of under-irrigation and the high water table, there are localized areas of severe salinity, the extent of which would need to be determined in the course of project preparation.

Available statistics on farm size relate to the Tehsil Dipalpur (Montgomery District), in which the greater part of the project area is situated. Table A7-3 relates to that Tehsil. The average farm size in the project area is about 12 acres, and is thus larger than the average for the Punjab as a whole. IACA observes that fragmentation of farms affects some 70 percent of the farming in the area. Only about 12 percent of the total farms are above 25 acres in size. About one-fourth of the farms and approximately one-half the farm area are owner-occupied. The relatively low standards of farming are largely due to the nonperennial surface water supply, high water table, and the sizeable number of large farms having a high percentage of land as culturable waste. A considerable growth of private tubewell installation (1,470 wells installed by 1965) has nevertheless taken place in recent years.

The project would increase water availability in the area from 1.09 MAF existing in 1965 to 2.38 MAF at full development. This increase in irrigation

TABLE A7-2
GROUNDWATER QUALITY ZONES OF THE PROJECT

Groundwater Quality Zone	Project Area	
	percent	'000 acres
Less than 1,000 ppm TDS	59	362
1,000–3,000 ppm TDS	41	249
Total	100	611

TABLE A7-3
FARM SIZE AND LAND TENURE SITUATION

Farm Size	Percent of Farms	Percent of Farm Area
Less than 5 Acres	46	7
5 to 25 Acres	42	45
Over 25 Acres	12	48
Owner Operated	24	44
Owner-cum-tenant	13	—[a]
Tenant Operated	63	56

[a] Included under owners and tenants.

supplies would be sufficient to support a growth in cropped acreage from 623,000 acres[1] (102 percent intensity) in 1969 to 917,000 acres (150 percent) in 1985.

Physical Works

The physical works of the project would consist of the installation of some 850 public tubewells and appurtenant works. Out of this total, 473 wells of four cusec average capacity would be in the fresh groundwater zones of the project area (59 percent, or 362,000 acres CCA), and 377 wells of three cusec average capacity would be in the zone underlain by groundwater requiring mixing with surface water (41 percent, or 249,000 acres CCA).

In its Bari Doab Regional Development Report, IACA has proposed the canalization of the old bed of the Beas River in order to provide the much needed surface drainage to benefit this and other projects. It is proposed that the Sukh Beas Drainage Project, as it would be known, be completed by 1972. The Study Group has excluded both estimated costs of the Sukh Beas Project and projected benefits from the present analysis.

Construction Schedule

The installation of the public tubewells would extend over approximately five years. On the assumption that the project would be brought into operation in accordance with the Basinwide water development program, construction should proceed according to the schedule outlined in Table A7-4. IACA's Report is a first attempt to formulate this project with regard to its technical, agricultural, financial and economic implications. As such, it is in many respects based on

[1] Perennials counted twice. If perennial acreage were counted only once, cropping intensity would be 97.7 percent.

TABLE A7-4
PRELIMINARY CONSTRUCTION SCHEDULE AS PROPOSED BY IACA

	1970/71	1971/72	1972/73	1973/74	1974/75
			(no. of wells)		
Drilling and Construction	90	360	360	40	—
Electrification	—	90	360	360	40
Wells in Operation	—	90	450	810	850

general information applicable to larger areas rather than on specific investigations. Further detailed project preparation would have to be initiated in due course if the project were to be implemented as scheduled above.

Cost Estimates and Expenditure Schedule

The Study Group has estimated the total financial requirements of the project, at present prices, at about Rs. 153.6 million, equivalent to $32.3 million. This would include the categories listed in Table A7-5. Details of the cost estimates are given in Appendix Table A7-1. The foreign exchange component of the project would be about 43 percent of total project costs, or about $13.9 million equivalent.

Expenditures would be spread over approximately five years, in accordance with the schedule in Table A7-6. A more detailed expenditure schedule is given in Appendix Table A7-2.

Recovery of Project Expenditures

On the basis of the above cost estimates, a preliminary assessment has been made of the charges required to recover over its lifetime the total costs of this project, including operation and maintenance expenditures. The average annual rate of recovery under these conditions would be about Rs. 18.9 million, as shown in Table A7-7. This would be equivalent to about Rs. 31 per acre CCA or Rs. 21 per cropped acre at the stage of full development. Existing water rates average about Rs. 7 per cropped acre. Future water rates to recover total project costs and O&M plus existing water charges, would have to be in the neighborhood of Rs. 28 per cropped acre or about Rs. 42 per acre CCA. This would be about 9 percent of the expected net value of production per cropped acre in 1985.

TABLE A7-5
SUMMARY COST ESTIMATES

	Local Currency	Foreign Exchange	Total
		(Rs. mill.)	
Project Preparation	3.0	2.6	5.6
Tubewells	18.9	27.3	46.2
Electrification	12.3	18.6	30.9
Other Civil Works	13.1	2.0	15.1
Subtotal	47.3	50.5	97.8
Overheads	15.4	4.8	20.2
Contingencies	11.9	10.5	22.4
Subtotal	27.3	15.3	42.6
Interest During Construction	13.2	—	13.2
Total	87.8	65.8	153.6

TABLE A7-6
SUMMARY EXPENDITURE SCHEDULE
(Based on IACA's Proposed Construction Schedule)

	1970/71	1971/72	1972/73	1973/74	1974/75
Tubewells and Associated Works	15.4	39.6	41.0	6.4	0.2
Electrification	—	5.4	21.6	21.5	2.5
Total	15.4	45.0	62.6	27.9	2.7

The Irrigation Regime

The mean quantities of surface and groundwater, which would be made available with the public project, and the comparison with the irrigation water availability likely to prevail if no further private tubewells were installed after 1969, are summarized in the water budget attached as Appendix Table A7-3 and Figure 1. With the project, the total water availability at watercourse head would be about 2.38 MAF at the stage of full development. Of this, 1.01 MAF would be provided by public tubewells and 1.37 MAF by canal supplies. Some 0.61 MAF of groundwater would substitute for previous private exploitation, i.e. the net increase of groundwater availability due to the project would be about 0.40 MAF. Total surface water availability at watercourse heads would increase from 0.71 MAF in 1965 to 1.37 MAF at full development, or by 0.66 MAF. The total quantity of water to be pumped to lower the water table to an average depth of 10 feet would be about 0.20 MAF. No additional surface supplies would be admitted into the project area until the water table had been permanently lowered.

For the project area as a whole, the water availability per acre of CCA would be enhanced from 2.65 acre-feet in 1965 to 3.9 acre-feet in 1985. This would support the projected increase of cropping intensity from 83 percent in 1965 to 150 percent in 1985, while simultaneously eliminating underirrigation on the existing cropped acreage.

One alternative to the public tubewell project would be further irrigation development through the continued installation of private tubewells over the entire project area. Table A7-8 shows water availability and potential intensity growth as projected for alternative forms of groundwater development.

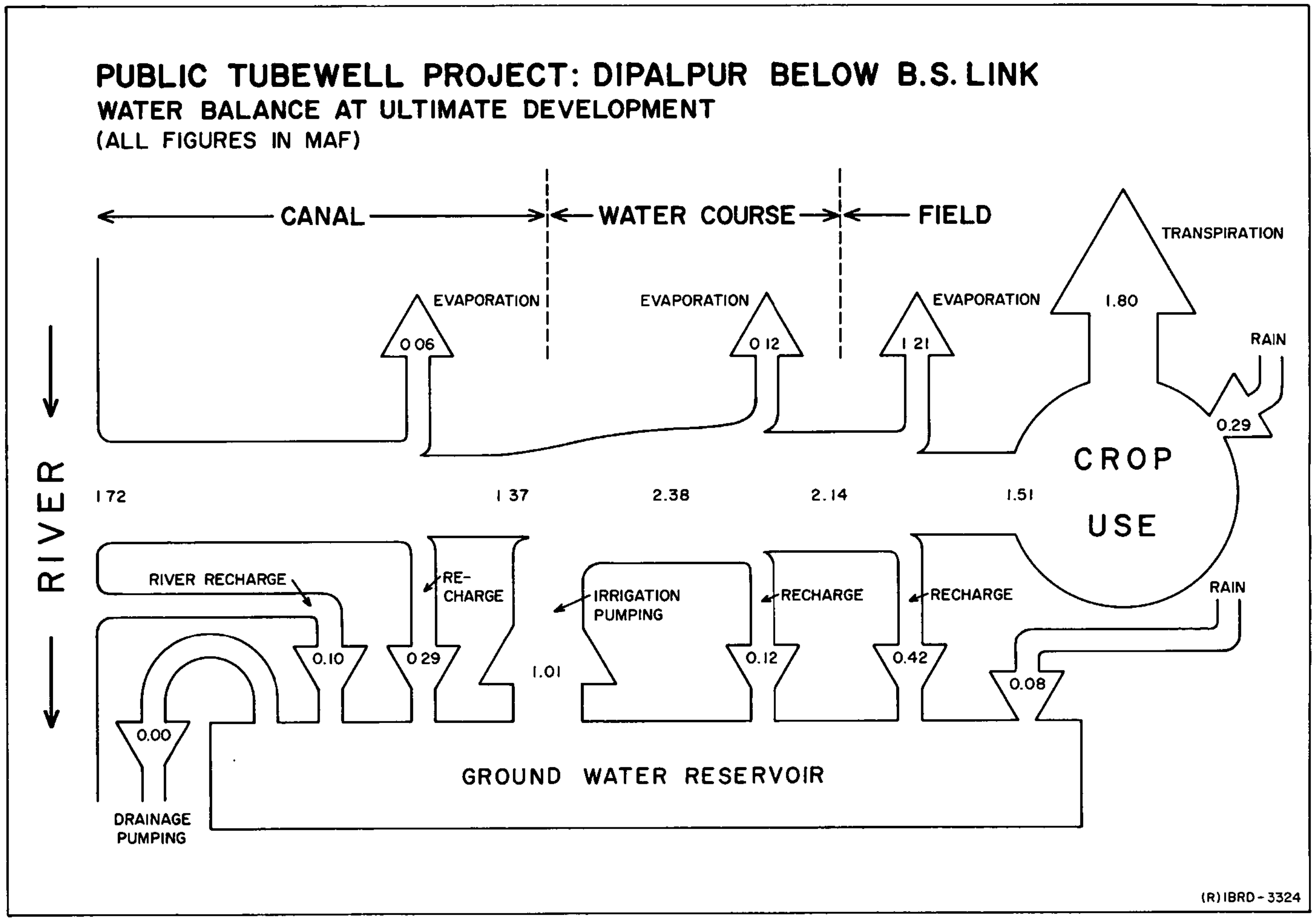
TABLE A7-7
ANNUAL COSTS FOR OPERATION, MAINTENANCE AND RECOVERY OF CAPITAL

	Annual Costs
	(Rs. mill.)
Capital Costs[a] (Annuity at 6% over 20 years for Rs. 102.6 million)	8.9
Operation and Maintenance[b] (Including staff costs, repairs, electricity and recovery of power investment)	10.0
Total	18.9

[a] Based on recovery of project investment, including project preparation and interest during construction, but without costs of electrification.

[b] Average annual costs, based on weighted average over lifetime of the project.

ANNEX VII
FIGURE 1



PUBLIC TUBEWELL PROJECT: DIPALPUR BELOW B.S. LINK
WATER BALANCE AT ULTIMATE DEVELOPMENT
(ALL FIGURES IN MAF)

TABLE A7-8
WATER AVAILABILITY AND CROPPING INTENSITY (1975 AND 1985)
UNDER ALTERNATIVE FORMS OF GROUNDWATER DEVELOPMENT

	1975		1985	
	Private	Public	Private	Public
Number of Wells	5,130[a]	850	5,130[a]	850
Surface Supplies (MAF)	1.06	1.06	1.37	1.37
Annual Pumpage (MAF)	0.89	0.89	1.02	1.01
Total Annual Watercourse Delivery (MAF)	1.95	1.95	2.39	2.38
Cropping Intensity (percent)	124	124	150	150
Acres Cropped ('000)	758	758	917	917
Acre-Feet/Acres Cropped	2.6	2.6	2.6	2.6

[a] Private wells of one cusec capacity.

Provided private investment in tubewells would be forthcoming as shown above, it is evident that either private or public tubewell development would be capable of pumping annual recharge. Both forms of development would appear capable of providing water table control and water supplies sufficient to eliminate under-irrigation and increase cropping intensities to about 150 percent.

It should be noted that there exists a sizeable area (approximately 40 percent of the project) that would be waterlogged and require continuous mixing with surface water. Therefore, although the table above assumes that the overall pumping by the private tubewell alternative would be adequate for taking care of recharge, there would still exist the technical problem of regulating effectively the mixing required within the project. This suggests that the private tubewell alternative might not be suited for the entire project area.

Agricultural Development

The project area is one of the few backward areas of the Bari Doab, although less so than the adjacent Dipalpur Above B.S. Link Canal Command where soil salinity is more of a problem.

The cropping intensity for the project area was estimated to be about 83 percent in 1965, compared with an average for the whole of the Bari Doab of 102 percent. The main kharif crops are rice, cotton, fodder and coarse grain. The main rabi crop is wheat, together with fodder and maize. The proportion of perennial crops—sugarcane, fruit and vegetables—is relatively low because of unreliable rabi irrigation supplies. The value of crop production in 1965 was estimated at Rs. 74 million, and livestock production was estimated at Rs. 42 million, giving a total GPV of Rs. 116 million (Rs. 190 per acre CCA). The total annual GPV is expected to grow to Rs. 167 million by 1970.

Considerable progress has been made in the past with the installation of private tubewells. The total number installed was estimated at 1,470 in 1965, or an average of about one well per 400 acres. IACA estimates the number of private tubewells would be about 2,900 in 1970, but if a public project is implemented, further private tubewell development would stop and public wells would gradually

TABLE A7-9
GROWTH OF CROPPED ACREAGE

Year	Intensity (percent)	Cropped Acreage[a] ('000 Acres)
1965	83	506
1970 (start of project)	102	623
1975 (project completed)	124	758
1985	150	917
1991	150	917

[a] Perennial crops counted twice.

substitute for existing private wells. The increased surface water availability of Tarbela supplies in the system plus public tubewell development should support an intensity growth as given in Table A7-9.

For purposes of evaluation, the Study Group has assessed the growth of agricultural production in the project area "with" public groundwater as well as "without" additional water development. In accordance with the cropping intensity, cropping patterns and yield growth projected for the respective cases (for details see Appendix Table A7-4 and A7-5), the incremental GPV would be expected to develop about as set forth in Table A7-10. On this basis the GPV of the project area would more than triple and the level of production would be about 65 percent higher than that of the "without" case.[1] The GPV per acre CCA would increase from Rs. 190 to about Rs. 740 as compared to Rs. 447 per acre CCA in the "without" case. As set forth in Chapter VI, nonwater input levels are expected to rise substantially throughout West Pakistan; thus appreciable increases in onfarm expenditures would be expected in both the "with" and "without" cases. To achieve the above projected growth of production, great efforts would have to be made to make available the quantities of nonwater inputs required to sustain such growth. Allowing for the increased onfarm expenditures and associated current project costs, as well as deducting an allocation of benefits resulting from additional surface water absorption and drainage,[2] the incremental NPV for reference years is expected to develop as follows over the lifetime of the project as set forth in Table

[1] See Appendix Tables A7-6 and A7-7 for detailed projections of GPV growth.

[2] A separate assessment has been made of the effects on future production if the Sukh Beas Drainage Scheme would not be implemented. Since no costs for the drainage project have been included under the tubewell project, the differential production increment has been deducted from the benefits attributable to groundwater development.

TABLE A7-10
GROWTH OF GPV "WITH" AND "WITHOUT" GROUNDWATER DEVELOPMENT

	"Without" Additional Groundwater			"With" the Project			Incremental GPV
Year	Crops	Livestock	Total	Crops	Livestock	Total	Total
			(Rs. million)				
1965	74	42	116	74	42	116	—
1970	104	63	167	104	63	167	—
1975	125	76	201	153	76	229	28
1985	181	92	273	284	168	452	179

TABLE A7-11

INCREMENTAL NET BENEFITS ATTRIBUTABLE TO PUBLIC GROUNDWATER DEVELOPMENT[a]

	1975	1985	1991
	(Rs. Million)		
NPV "With"	152	279	331
NPV "Without"	131	169	197
Incremental NPV	21	110	134
Allocation to Surface Water	10	73	88
Allowance for Infrastructure and Services	—	2	2
Increase in O&M Expenditures	−3[b]	−2[b]	−2[b]
Total Associated Costs	7	73	88
Incremental Net Benefits Attributable to the Project (Incremental NPV less Total Associated Costs)	14	37	46

[a] For details see Appendix Tables A7–6 and A7–8.

[b] It should be noted that incremental O&M expenditures in the public tubewell project are *negative* i.e., operation and maintenance costs of public tubewells are less than those that would be necessary, to maintain the private wells in operation at the beginning of public tubewell construction.

A7-11. A comparison between the public project and the alternative private development (see Appendix Tables A7-9, A7-10 and A7-11) indicates that, after due allowance for all costs, the discounted benefits attainable from the public project in 1991 would be about the same as those from continued private well installations.

Farmer Incentives

The benefits obtainable under the project should provide considerable incentives for the farmers. Based on 10 acres CCA, the average farm income would be expected to improve as given in Table A7-12. The results given in the table are average expectations for the project area as a whole, but individual farmers with private tubewells at their disposal would be expected to achieve above average farm incomes because they would have flexibility of operation. In absolute terms, farmers' income with the public project would grow on average from about Rs. 950 per farm of 10 acres CCA in 1975 to more than 1,900 in 1990. It should also be noted that substantial private development already exists in the area, and is projected to continue at a high rate.

Project Evaluation

On the basis of the modifications made to the IACA evaluation procedures, the Study Group has assessed the likely results of the project (Table A7-13). This compares with IACA's assessment[1] of incremental NPV (before allocation of benefits to surface water and drainage) of 982 million, and a rate of return on incremental costs only of 47 percent. The calculations pertaining to the Study Group's evaluation are given in Appendix Tables A7-8 and A7-9.

[1] IACA's Comprehensive Report, Volume 16, Annexure 15A, Chapter 4 (public project) and Appendix 1 (private alternative).

TABLE A7–12
COMPARISON OF CHANGES IN FARM INCOME PER FARM OF 10 ACRES CCA UNDER ALTERNATIVE FORMS OF DEVELOPMENT

	1975			1985			1990		
	Without	Private	Public	Without	Private	Public	Without	Private	Public
Cropping Intensity (percent)	102	124	124	102	150	150	102	150	150
GPV (Rs.)	2,144	2,448	2,488	2,766	4,566	4,566	3,224	5,417	5,417
Onfarm Expenditures (Rs.)	1,015	1,146	1,146	1,571	2,570	2,570	1,817	3,044	3,044
Water Charges[a] (Rs.)	333	528	396	333	546	414	333	546	414
Total Current Expenditures (Rs.)	1,348	1,674	1,542	1,904	3,116	2,984	2,150	3,590	3,458
Farm Income (Rs.)	796	814	946	862	1,450	1,582	1,074	1,827	1,959

[a] Water charges pertaining to the "Without" additional tubewell cases consist of:

(i) Surface water charges at Rs. 7 per acre cropped	Rs. 71
(ii) O&M tubewells existing in 1972	Rs. 195
(iii) Amortization (6 percent over 10 years) of existing wells	Rs. 67
Total	Rs. 333

Water charges for private tubewell development in 1985 consist of:

(i) Surface water charges at Rs. 7 per acre cropped	Rs. 105
(ii) O&M for Private Tubewells	Rs. 327
(iii) Amortization (6 percent over 10 years) of private wells	Rs. 114
Total	Rs. 546

Water charges for public tubewell development consist in 1985 of the following:

(i) Surface water charges at Rs. 7 per acre cropped	Rs. 105
(ii) O&M and amortization (6 percent over 20 years)	Rs. 309
Total	Rs. 414

The private alternative has also been evaluated by the Study Group in accordance with the procedures discussed earlier. On this basis, and allowing for the provision of additional surface water, because of sufficient drainage effects, continued private development would give a rate of return of 49 percent. This reflects the considerably lower investment requirements under the private alternative. The total discounted incremental NPV attainable under the private alternative would be equal to that attainable under the public project. This form of development would allow savings relative to the outlays projected for public development of the entire project area to approximately Rs. 154 million. Details of the evaluation of the private alternative are given in Appendix Tables A7-10 and A7-11.

Conclusion

In the absence of a detailed appraisal, the preceding analysis should be considered as indicative only. The estimated rate of return of 36 percent on total investment in the public project, after deducting the benefits attributable to increased surface supplies and drainage, would support the inclusion of this project in the

TABLE A7-13
RESULTS OF PROJECT EVALUATION

Incremental NPV[a] (present worth at 8%)	Rs. 192 million
Benefit/Cost Ratio (at 8%)	45.0 to 1
Rate of Return:	
(a) exclusive of potential private savings	12%
(b) inclusive of potential private savings	36%

[a] After allocation of benefits to additional surface water and the provision of drainage.

Action Program. On the other hand, continued private development by 1970 as projected by IACA would be about 2,400 pumps, or enough to cover the portion of the total project area underlain with fresh groundwater (less than 1,000 ppm TDS). This projection rests on the observations that extensive private coverage already exists, and active private investment in tubewells is likely to continue. The presumption therefore follows that such investment is an economic use of the private resources of the farmers. Cropping intensity and the general level of production in the area of private development would be similar to that projected for the public project. A public tubewell project has been tentatively included in the Study Group's Action Program. However, a more limited objective for public development appears feasible and should be given careful consideration in the course of project preparation. Careful monitoring of further private performance should be undertaken to determine whether private progress achieves the levels of installation and coverage projected in this review. Detailed project preparation for public development should be carried out with the objective of providing the decision basis for the scope of public development and continued private well installations in portions of the project area.

APPENDIX TABLE A7-1
PUBLIC TUBEWELL PROJECT—DIPALPUR BELOW BS LINK
REVISED COST ESTIMATE AND FINANCIAL REQUIREMENTS

	Local Currency	Foreign Exchange		Total	
	(Rs. mill.)	(Rs. mill.)	($ equiv.)[a]	(Rs. mill.)	($ equiv.)
Project Preparation[b]	3.0	2.6	0.55	5.6	1.18
Tubewell Project					
Tubewells	18.9	27.3	5.75	46.2	9.73
Appurtenant Structures	7.0	2.0	0.42	9.0	1.89
Watercourse Improvement[c]	6.1	—	—	6.1	1.28
Duties and Taxes[d]	4.4	—	—	4.4	0.93
Engineering and Administration[e]	3.6	2.9	0.61	6.5	1.37
Subtotal	40.0	32.2	6.78	72.2	15.20
Contingencies[f]	8.0	6.4	1.35	14.4	3.03
Total Tubewell Project	48.0	38.6	8.13	86.6	18.23
Electrification					
Distribution	2.2	3.4	0.72	5.6	1.18
Transmission	10.1	15.2	3.20	25.3	5.33
Duties and Taxes[d]	5.6	—	—	5.6	1.18
Engineering and Administration[e]	1.8	1.9	0.40	3.7	0.78
Subtotal	19.7	20.5	4.32	40.2	8.47
Contingencies[f]	3.9	4.1	0.86	8.0	1.68
Total Electrification	23.6	24.6	5.18	48.2	10.15
Interest During Construction					
Tubewell Project[g]	10.4	—	—	10.4	2.19
Electrification[h]	2.8	—	—	2.8	0.59
Subtotal	13.2	—	—	13.2	2.78
Total Financial Requirements	87.8	65.8	13.86	153.6	32.33

[a] Rate of exchange used, 1:4.75.
[b] Estimated at 5 percent direct costs before contingencies.
[c] Estimated at Rs. 10/acre CCA.
[d] Estimated at 15 percent of foreign exchange component of direct costs before engineering and administration.
[e] Estimated at 10 percent of direct costs after duties and taxes.
[f] Estimated at 20 percent of direct costs after duties and taxes and engineering and administration.
[g] Estimated at 6 percent per annum for two-year period for each individual phase of tubewell construction.
[h] Estimated at 6 percent per annum for one-year period.

APPENDIX TABLE A7–2
PUBLIC TUBEWELL PROJECT—DIPALPUR BELOW THE BS LINK

	Costs Based on Study Group's Estimates 1970/71	1971/72	1972/73	1973/74	1974/75	Total
			(Rs. mill.)			
Project Preparation[a]	5.6	—	—	—	—	5.6
Tubewells, Structures and Watercourses	6.5	26.0	26.0	2.8	—	61.3
Duties and Taxes	0.5	1.9	1.8	0.2	—	4.4
Engineering	0.7	2.8	2.7	0.3	—	6.5
Contingencies	1.5	6.1	6.1	0.7	—	14.4
Subtotal	9.2	36.8	36.6	4.0	—	86.6
Interest During Construction	0.6	2.8	4.4	2.4	0.2	10.4
Total Tubewell Project	9.8	39.6	41.0	6.4	0.2	97.0
Electrification	—	3.3	13.1	13.0	1.5	30.9
Duties and Taxes	—	0.6	2.3	2.4	0.3	5.6
Engineering and Administration	—	0.4	1.6	1.5	0.2	3.7
Contingencies	—	0.8	3.4	3.4	0.4	8.0
Subtotal	—	5.1	20.4	20.3	2.4	48.2
Interest During Construction	—	0.3	1.2	1.2	0.1	2.8
Total Electrification	—	5.4	21.6	21.5	2.5	51.0
Total Financial Requirements	15.4	45.0	62.6	27.9	2.7	153.6

[a] Incurred prior to beginning of construction.

APPENDIX TABLE A7–3
PUBLIC TUBEWELL PROJECT—DIPALPUR BELOW THE B.S. LINK
COMPARATIVE SUMMARY WATER BUDGET "WITH" THE PROJECT AND "WITHOUT" ADDITIONAL TUBEWELLS

	1965	1975		1985		Net Increase "With" the Project		
	Existing	"With" the Project	"Without" Additional Tubewells	"With" the Project	"Without" Additional Tubewells	Surface Water	Groundwater	Total
				(MAF)				
Surface Supplies: Total:	0.71	1.06	0.71	1.37	0.71	0.66	—	0.66
Thereof during October to May[a]	0.12	0.47	0.12	0.69	0.12	0.57	—	0.57
Groundwater Supplies:	0.38	0.89	0.61[b]	1.01[c]	0.61[b]	—	0.40	0.40
Total Supplies:	1.09	1.95	1.32	2.38	1.32	0.66	0.40	1.06

[a] Release period during which reservoirs would be operated for irrigation requirements.
[b] Based on IACA's figures of 2,900 private tubewells in operation by 1970 and an average utilization rate of about 27 percent per annum.
[c] This would include substitution for existing private groundwater exploitation (0.38 MAF) as well as those of further increase in private groundwater extraction.

APPENDIX TABLE A7–4
Public Tubewell Project—Dipalpur Below BS Link
Yield Projections "With" the Project
(maunds per acre)

	Present	IACA Projection				Study Group Projection			
	1965	1970	1975	1985	2000	1970	1975	1985	2000
Kharif:									
Fine Rice	16.0	16.6	21.5	30.0	40.0	17.7	20.7	30.0	40.0
Coarse Rice	18.0	19.0	25.0	38.0	50.0	19.9	23.3	34.0	50.0
Cotton	8.0	8.8	12.0	17.0	22.0	8.8	10.3	15.1	220.0
Maize	13.0	13.8	17.0	26.0	38.0	14.3	16.8	24.5	38.0
Fodder	220.0	235.0	320.0	430.0	550.0	242.9	284.4	412.6	550.0
Pulses	6.0	6.3	7.5	10.0	14.0	6.6	7.8	11.2	14.0
Others	6.0	—	—	—	—	—	—	—	—
Jowar	7.0	—	—	—	—	—	—	—	—
Rabi:									
Wheat	13.0	14.3	20.0	28.5	35.0	14.3	16.8	26.7	35.0
Fodder	540.0	550.0	700.0	840.0	1,000.0	596.2	698.1	993.8	1,000.0
Oilseeds	6.5	6.7	8.0	12.0	16.0	7.2	8.4	12.2	16.0
Gram	8.5	8.6	10.0	14.0	18.0	9.4	11.0	15.8	18.0
Pulses	6.0	—	—	—	—	—	—	—	—
Others	6.0	—	—	—	—	—	—	—	—
Maize	13.0	13.8	17.0	26.0	38.0	14.3	16.8	24.5	38.0
Perennials:									
Sugarcane (Gur)	33.0	36.0	50.0	65.0	80.0	36.4	42.6	61.8	80.0
Fruit	80.0	75.0	60.0	130.0	170.0	88.3	102.0	130.0	170.0
Vegetables	140.0	145.0	170.0	200.0	250.0	145.0	170.0	200.0	250.0

APPENDIX TABLE A7–5
Public Tubewell Project—Dipalpur below the BS Link Yield
Projections "Without" Additional Tubewells
(maunds per acre)

	Present	IACA's Projection				Study Group's Projection			
	1965	1970	1975	1985	2000	1970	1975	1985	2000
Kharif:									
Fine Rice	16.0	16.6	18.0	21.0	32.0	17.7	20.7	30.0	40.0
Coarse Rice	18.0	19.0	20.0	27.0	40.0	19.9	23.3	34.0	50.0
Cotton	8.0	8.8	9.4	11.0	14.5	8.8	9.7	11.9	16.0
Maize	13.0	13.8	14.0	15.5	18.0	14.3	15.8	19.3	26.0
Fodder	220.0	235.0	250.0	260.0	320.0	242.9	268.2	326.9	440.0
Pulses	6.0	6.3	6.5	7.2	9.0	6.6	7.3	8.9	12.0
Other	6.0	—	—	—	—	—	—	—	—
Jowar/Bajra	7.0	—	—	—	—	—	—	—	—
Rabi:									
Wheat	13.0	14.3	15.3	17.0	23.0	14.3	16.8	26.8	35.0
Fodder	540.0	550.0	560.0	650.0	750.0	596.2	658.3	802.4	1,080.0
Oilseeds	6.5	6.7	6.9	8.5	11.0	7.2	7.9	9.7	13.0
Gram	8.5	8.6	8.8	11.5	14.0	9.4	10.4	12.6	17.0
Maize	13.0	13.8	14.7	17.5	21.0	14.3	15.8	19.3	26.0
Pulses	6.0	—	—	—	—	—	—	—	—
Other	6.0	—	—	—	—	—	—	—	—
Perennials:									
Sugarcane (Gur)	33.0	36.0	39.0	46.0	56.0	36.4	42.6	61.8	80.0
Fruit	80.0	75.0[a]	85.0	105.0	130.0	88.3	102.0	130.0	170.0
Vegetables	140.0	145.0	150.0	170.0	200.0	154.6	170.0	200.0	250.0

[a] Yields take account of increased acreage, not all of which will be bearing fruit.

APPENDIX TABLE A7-6

PUBLIC TUBEWELL PROJECT—DIPALPUR BELOW THE BS LINK REVISED PROJECTION OF PRODUCTION "WITH" THE PROJECT

	1975				1985				1991			
	Cropped Acres	Yields (mds/acre)	Production ('000 mds)	GPV (Rs. mill.)	Cropped Acres	Yields (mds/acre)	Production ('000 mds)	GPV (Rs. mill.)	Cropped Acres	Yields (mds/acre)	Production ('000 mds)	GPV (Rs. mill.)
Kharif:												
Coarse Rice	18,300	23.3	426.4	3.688	12,200	34.0	414:8	3.588	12,200	39.6	483.1	4.179
Fine Rice	30,100	20.7	623.1	9.128	48,900	30.0	1,467.0	21.492	48,900	33.6	1,643.0	24.070
Cotton	111,000	10.3	1,143.3	34.299	146,600	15.1	2,213.7	66.411	183,300	17.5	3,207.8	96.234
Maize	18,300	16.8	307.4	5.687	24,400	24.5	597.8	11.059	30,600	29.2	893.5	16.530
Fodder	97,800	284.4	27,814.3	—	110,000	412.6	45,386.0	—	122,200	462.8	56,554.2	—
Pulses	12,200	7.8	95.2	1.999	24,400	11.2	273.3	5.739	24,400	12.2	297.7	6.252
Subtotal	287,700			54.801	366,500			108.289	421,600			147.265
Rabi:												
Wheat	244,400	16.8	4,105.9	53.377	244,400	26.7	6,525.5	84.832	189,400	29.7	5,625.2	73.128
Fodder	79,400	698.1	55,429.1	—	91,700	993.8	91,131.5	—	97,800	996.2	97,428.4	—
Oilseeds	18,300	8.4	153.7	3.612	18,300	12.2	223.3	5.248	18,300	13.6	248.9	5.849
Gram	30,500	11.0	335.5	4.781	24,400	15.8	385.5	5.493	12,200	16.7	203.7	2.903
Maize	6,100	16.8	102.5	1.896	18,300	24.5	448.4	8.295	18,300	29.2	534.4	9.886
Green Manure	24,400	—	—	—	55,000	—	—	—	61,100	—	—	—
Subtotal	403,100			63.666	452,100			103.868	397,100			91.766
Perennial:												
Sugarcane	21,400	42.6	911.6	16.409	24,400	61.8	1,507.9	27.142	18,300	68.5	1,253.6	22.565
Fruit	5,900	102.0	601.8	6.620	12,200	130.0	1,586.0	17.446	18,300	168.8	3,089.0	33,979
Vegetables	6,100	170.0	1,037.0	11.407	12,200	200.0	2,440.0	26.840	12,200	218.6	2,666.9	29.336
Subtotal	66,800			34.436	97,600			71.428	97,600			85.880
GPV of Crops				152.903				283.585				324.911
Animal Husbandry[a]				75.500				168.400				210.900
Total GPV				229.403				451.985				535.811
Onfarm Costs[b]				72.769				162.714				192.892
Total NPV				156.634				289.271				342.919

[a] Based on IACA's projection but reduced proportionately for 1975 and 1985 in keeping with reduction of yield levels, including those of fodder.

[b] 1975—32% of GPV
1985—36% of GPV
1991—36% of GPV

APPENDIX TABLE A7-7

PUBLIC TUBEWELL PROJECT—DIPALPUR BELOW THE B.S. LINK REVISED PROJECTION OF PRODUCTION "WITHOUT" THE PROJECT

		1973			1975			1985			1991		
	Cropped Acres	Yields (mds/acre)	Production ('000 mds)	GPV (Rs. mill.)	Yields (mds/acre)	Production ('000 mds)	GPV (Rs. mill.)	Yields (mds/acre)	Production ('000 mds)	GPV (Rs. mill.)	Yields (mds/acre)	Production ('000 mds)	GPV (Rs. mill.)
Kharif:													
Coarse Rice	18,300	20.7	378.8	3.977	23.3	426.4	3.688	34.0	622.2	5.382	39.6	724.7	6.269
Fine Rice	27,500	18.4	506.0	8.602	20.7	569.2	8.339	30.0	825.0	12.086	33.6	924.0	13.537
Cotton	91,700	9.2	843.6	25.308	10.3	944.5	28.335	15.1	1,384.7	41.541	17.5	1,604.8	48.144
Maize	15,200	14.9	226.5	4.190	15.8	240.2	4.444	19.3	293.4	5.428	21.7	329.8	6.101
Fodder	85,500	252.8	21,614.4	—	268.2	22,931.1	—	326.9	27,950.0	—	368.1	31,472.6	—
Pulses	8,600	6.9	59.3	1.245	7.3	62.8	1.319	8.9	76.5	1.606	10.0	86.0	1.806
Subtotal	246,800			43.322			46.125			66.043			75.857
Rabi:													
Wheat	204,700	14.9	3,050.0	39.650	16.8	3,439.0	44.707	26.7	5,465.5	71.052	29.7	6,079.6	79.035
Fodder	73,300	620.5	45,482.6	—	658.3	48,253.4	—	802.4	58,815.9	—	903.4	66,219.2	—
Oilseeds	14,000	7.5	105.0	2.468	7.9	110.6	2.599	9.7	135.8	3.191	10.9	152.6	3.586
Gram	28,700	9.8	281.3	4.008	10.4	298.5	4.254	12.6	361.6	5.153	14.2	407.5	5.807
Maize	3,100	14.9	46.2	.855	15.8	49.0	.906	19.3	59.8	1.106	21.7	67.3	1.245
Subtotal	323,800			46.981			52.466			80.502			89.673
Perennial:													
Sugarcane	18,300	37.9	693.6	12.485	42.6	779.6	14.033	61.8	1,130.9	20.356	68.5	1,253.6	22.565
Fruit	3,700	94.5	349.6	3.846	102.0	377.4	4.151	130.0	481.0	5.291	168.8	624.6	6.871
Vegetables	4,200	160.9	675.8	7.434	170.0	714.0	7.854	200.0	840.0	9.240	218.6	918.1	10.099
Subtotal	52,400			23.765			26.038			34.887			39.535
GPV of Crops				114.068			124.629			181.432			205.065
Animal Husbandry[a]				68.1			75.5			92.2			113.0
Total GPV				182.168			200.129			273.632			318.065
Onfarm Costs[b]				58.294			64.041			98.508			114.503
Total NPV				123.874			136.088			175.124			203.562

[a] Based on IACA's projection.
[b] 1973—32% of GPV.
1975—32% of GPV.
1985—36% of GPV.
1991—36% of GPV.

APPENDIX TABLE A7-8

PUBLIC TUBEWELL PROJECT—DIPALPUR—BELOW BS LINK CALCULATION OF RATE OF RETURN

Year	NPV "With" the Project[e]	NPV "Without" the Project	Incremental NPV	Cost of[a] Additional Surface Water	Incremental NPV after Allocation to Surface Water	Infrastructure and Services[b]	O&M Costs	Attributable Increment[c]	Potential Private Savings	Attributable Increment Including Potential Private Savings	Capital Costs of Project	Rate of Return: Net Benefits at 12%[c]	Rate of Return: Net Benefits at 36%[d]	Rate of Return: Project Costs at 12%[c]	Rate of Return: Project Costs at 36%[d]
							(Rs. million)								
1971	—	—	—	—	—	—	—	—	14.9	14.9	14.3	—	10.9	12.8	10.5
1972	123.9	123.9	—	—	—	—	0.97	−1.0	14.9	13.9	34.9	−0.8	7.5	28.0	18.8
1973	127.8	127.8	—	—	—	—	5.05	−5.1	14.9	9.8	34.8	−3.7	3.9	25.0	13.8
1974	138.4	131.8	6.6	—	6.6	0.2	8.33	−1.9	14.9	13.0	3.8	−1.2	3.8	2.4	1.1
1975	149.2	136.1	13.1	7.2	5.9	0.2	8.74	−3.0	14.9	11.9		−1.7	2.5		
1976	164.7	139.6	25.1	13.7	11.4	0.4	8.94	2.1	14.9	17.0		1.1	2.7		
1977	178.7	143.2	35.5	19.5	16.0	0.6	8.94	6.5	14.9	21.4		3.0	2.5		
1978	193.6	146.8	46.8	25.8	21.0	0.7	9.14	11.2	14.9	26.1		4.6	2.2		
1979	206.6	150.6	56.0	31.6	24.4	0.9	9.24	14.3	14.9	29.2		5.3	1.8		
1980	220.4	154.5	65.9	38.0	27.9	1.0	9.34	17.6	14.9	32.5		5.8	1.5		
1981	233.5	158.4	75.1	44.4	30.7	1.1	9.34	20.3	14.9	35.2		6.0	1.2		
1982	245.7	162.5	83.2	50.1	33.1	1.2	9.34	22.6	14.9	37.5		6.0	0.9		
1983	256.7	166.6	90.1	55.1	35.0	1.2	9.44	24.4	14.9	39.3		5.8	0.7		
1984	268.3	170.9	97.4	59.6	37.8	1.3	9.64	26.9	14.9	41.8		5.7	0.6		
1985	279.2	175.1	104.1	63.9	40.2	1.4	9.64	29.2	14.9	44.1		5.6	0.4		
1986	287.2	179.6	107.6	66.1	41.5	1.5	9.64	30.4	14.9	45.3		5.2	0.3		
1987	295.4	184.2	111.2	68.3	42.9	1.5	9.84	31.6	14.9	46.5		4.8	0.2		
1988	303.9	188.9	115.0	70.6	44.4	1.6	9.84	33.0	14.9	47.9		4.5	0.2		
1989	312.7	193.8	118.9	72.5	46.4	1.6	9.84	35.0	14.9	49.9		4.3	0.1		
1990	321.6	198.7	122.9	75.5	47.4	1.7	9.84	35.9	14.9	50.8		3.9	0.1		
1991	330.9	203.6	127.3	78.2	49.1	1.7	9.84	37.6	14.9	52.5		3.7	0.1		
						Rate of Return[c] = 12%						67.8	44.3	68.2	44.3
						Rate of Return[d] = 36%									

[a] Charged at average value per acre-foot of total incremental water availability:

	Incremental NPV	Incremental Water Availability	Value/acre-foot of Incremental Availability
	(Rs. mill.)	(MAF)	(Rs.)
1975	13.1	0.63	20.8
1980	65.9	1.01	65.2
1985	104.1	1.06	98.2
1991	127.3	1.06	120.1

Absorption of surface water based on IACA intensity projections beginning in 1975 at 0.345 MAF to 1991 at 0.667 MAF.

[b] Allowance for public expenditures on infrastructure and intensified technical and advisory services.

The allowance includes: 1.85% of attributable increment for roads.
1.65% of attributable increment for supporting services.

Charged on incremental NPV after allocation to surface water only.

[c] Excluding Potential Private Savings.

[d] Including Potential Private Savings.

[e] NPV reduced by 3.5% to take account of increases resulting from improvements in drainage.

APPENDIX TABLE A7–9
PUBLIC TUBEWELL PROJECT—DIPALPUR BELOW THE BS LINK
Benefit/Cost Ratio

Year	Incremental NPV After Allocation to Surface Water	Project Costs Including O&M, Services, and Infrastructure		Discounted at 8% Benefits	Discounted at 8% Costs	
		(Rs. Mill.)				
		a	b		a	b
1971	—	14.3	−0.6	—	13.2	−0.5
1972	—	35.9	21.0	—	30.8	18.0
1973	—	39.9	25.0	—	31.7	19.9
1974	6.6	12.3	−2.6	4.9	9.0	−1.9
1975	5.9	8.9	−6.0	4.0	6.1	−4.1
1976	11.4	9.3	−5.6	7.2	5.9	−3.5
1977	16.0	9.5	−5.4	9.3	5.5	−3.2
1978	21.0	9.8	−5.1	11.3	5.3	−2.8
1979	24.4	10.1	−4.8	12.2	5.1	−2.4
1980	27.9	10.3	−4.6	12.9	4.8	−2.1
1981	30.7	10.4	−4.5	13.2	4.5	−1.9
1982	33.1	10.5	−4.4	13.1	4.2	−1.7
1983	35.0	10.6	−4.3	12.9	3.9	−1.6
1984	37.8	10.9	−4.0	12.9	3.7	−1.4
1985	40.2	11.0	−3.9	12.7	3.5	−1.2
1986	41.5	11.1	−3.8	12.1	3.2	−1.1
1987	42.9	11.3	−3.6	11.6	3.1	−1.0
1988	44.4	11.4	−3.5	11.1	2.9	−0.9
1989	46.4	11.4	−3.5	10.8	2.6	−0.8
1990	47.4	11.5	−3.4	10.2	2.5	−0.7
1991	49.1	11.5	−3.4	9.8	2.3	−0.7
				192.1	153.8	4.4

B/C ratio at 8%[a] = 1.3
B/C ratio at 8%[b] = 45.0[c]

[a] Before deduction of Potential Private Savings.
[b] After deduction of Potential Private Savings.
[c] If potential private savings are added to benefit stream rather than netted out from cost stream, the Benefit/Cost ratio would be 2.2; that is,

Present worth of benefits: 192.1
Present worth of savings: 149.6 B/C ratio (341.7/153.8) = 2.2
Total 341.7

APPENDIX TABLE A7-10

PUBLIC TUBEWELL PROJECT—DIPALPUR BELOW THE BS LINK

PRIVATE ALTERNATIVE—RATE OF INSTALLATION AND INCREMENTAL WATER AVAILABILITY

Year	Number of Wells in Operation[a]	Increase in Private Wells during Project Period	Replacement of Additional Wells	Incremental Number of Wells in Operation	Incremental[b] Water Availability (MAF)
1965	1,470				
1966	1,764				
1967	2,117				
1968	2,540				
1969	3,048				
1970	3,658	610		610	0.14
1971	3,914	256		866	0.19
1972	4,188	274		1,140	0.26
1973	4,481	293		1,433	0.32
1974	4,795	314		1,747	0.39
1975	5,130	335		2,082	0.47
1976	5,130	—		2,082	0.47
1977	5,130	—		2,082	0.47
1978	5,130	—		2,082	0.47
1979	5,130			2,082	0.47
1980	5,130		610	2,082	0.47
1981	5,130		256	2,082	0.47
1982	5,130		274	2,082	0.47
1983	5,130		293	2,082	0.47
1984	5,130		314	2,082	0.47
1985	5,130		335	2,082	0.47
1986	5,130		—	2,082	0.47
1987	5,130		—	2,082	0.47
1988	5,130		—	2,082	0.47
1989	5,130		—	2,082	0.47
1990	5,130		610	2,082	0.47
1991	5,130		256	2,082	0.47

[a] Rate of installation: 20% p.a. compound growth between 1965 and 1970.
7% p.a. compound growth between 1970 and 1975.
(This rate of installation accepts the ceiling for coverage with private tubewells stated in the IACA Project Report.)

[b] Assume rate of average utilization: 30%.
Each well would pump for about 2,630 hours and produce 225 acre-feet per annum.

APPENDIX TABLE A7-11
PUBLIC TUBEWELL PROJECT—DIPALPUR BELOW THE B.S. LINK
RATE OF RETURN OF PRIVATE TUBEWELL ALTERNATIVE

Year	Incremental NPV After Allocation to Surface Water	Infra-structure and Services[a]	O & M Costs[b]	Capital Costs[c]	Total Costs	Benefit/Cost Ratio: Costs at 8%	Benefit/Cost Ratio: Benefits at 8%	Rate of Return: Costs at 25.4%	Rate of Return: Benefits at 25.4%
			(Rs. mill.)						
1970	—	—	2.4	6.1	8.5	7.8	—	6.8	—
1971	—	—	3.4	2.6	6.0	5.1	—	3.8	—
1972	—	—	4.4	2.7	7.3	5.8	—	3.7	—
1973	6.6	0.2	5.6	2.9	8.7	6.4	4.9	3.5	2.7
1974	5.9	0.2	6.8	3.1	10.1	6.9	4.0	3.3	1.9
1975	11.4	0.4	8.1	3.3	11.8	7.4	7.2	3.0	2.9
1976	16.0	0.6	8.1	—	8.7	5.1	9.3	1.8	3.3
1977	21.0	0.7	8.1	—	8.8	4.8	11.3	1.4	3.4
1978	24.4	0.9	8.1	—	9.0	4.5	12.2	1.2	3.2
1979	27.9	1.0	8.1	—	9.1	4.2	12.9	0.9	2.9
1980	30.7	1.1	8.1	6.1	15.3	6.6	13.2	1.3	2.5
1981	33.1	1.2	8.1	2.6	11.9	4.7	13.1	0.8	2.2
1982	35.0	1.2	8.1	2.7	12.0	4.4	12.9	0.6	1.8
1983	37.8	1.3	8.1	2.9	12.3	4.2	12.9	0.5	1.6
1984	40.2	1.4	8.1	3.1	12.6	4.0	12.7	0.4	1.3
1985	41.5	1.5	8.1	3.3	12.9	3.8	12.1	0.3	1.1
1986	42.9	1.5	8.1	—	9.6	2.6	11.6	0.2	0.9
1987	44.4	1.6	8.1	—	9.7	2.4	11.1	0.2	0.8
1988	46.4	1.6	8.1	—	9.7	2.2	10.8	0.1	0.6
1989	47.4	1.7	8.1	—	9.8	2.1	10.2	0.1	0.5
1990	49.1	1.7	8.1	6.1	15.9	3.2	9.8	0.1	0.4
						98.2	192.1		

B/C Ratio at 8% = 2.0

[a] Based on a charge of 3.5% of incremental NPV as under public tubewell program.
[b] Based on average annual O&M costs per tubewell of Rs. 3,900.
[c] Based on average cost per tubewell of Rs. 10,000 and assumed rate of installation.

Annex 8

PROSPECTS FOR SUPPLY, DISTRIBUTION AND USE OF FERTILIZER IN WEST PAKISTAN[1]

The use of chemical fertilizers in West Pakistan seems more firmly established than in East Pakistan, and the task of winning acceptance by farmers is not a source of major concern, at least not from a perspective of the mid-1960's. The major obstacles to substantial increases in offtake appear to lie within the distribution system.

Offtake During the Second Plan

It is difficult to obtain an accurate picture of fertilizer offtake in West Pakistan for this period. Distribution was dispersed under different agencies, and consistent aggregate estimates are not available. Three sets of offtake figures are presented in Appendix Table A8-1—one by the Planning Commission, one by USAID, and one by an independent source (for the two years, 1963/64 and 1964/65). The Planning Commission estimates show a continuous increase in offtake throughout the Second Plan period, reaching a total of 97,000 tons of N during 1964/65. The USAID estimates show a reduction in sales in 1962/63, following a decrease in the subsidy rate to 25 percent. This fall in offtake was reported in discussion with Government officials in West Pakistan, but is not reflected in the official estimates. The USAID estimate for 1964/65 is also below the Planning Commission figure. The independent estimate resulted from attempts to adjust the offtake figures to correspond with reports of fertilizer shortages in 1964. It is based on the assumption that the Rural Supply Cooperative Corporation (RSCC) inventory records for 1963/64 showed larger stocks than were actually on hand, and this may have been because fertilizers had been actually released to farmers but were reported as still in stock. The adjustment therefore, increases the estimated offtake for 1963/64, and correspondingly decreases the estimated offtake for 1964/65.

There was agreement among all agencies concerned, including USAID, that fertilizers were in short supply at the end of the period, and that more could be sold at the prevailing price than were available. There were frequent reports of black market prices for fertilizer, but the prices actually paid could not be verified. It therefore seems plausible that increased quantities would have been purchased at 1964/65 prices, but the quantities required to clear the market at these prices are not known. Moreover, there are no data which can be used to make such an estimate.

Production and Imports

As of 1965, production facilities were operating at three locations: Daudkhel (ammonium sulphate); Multan (calcium ammonium nitrate and urea); and

[1] Based on the prospects for fertilizer production, distribution and use assessed by a World Bank mission report, Feb/March 1966.

TABLE A8-1
FERTILIZER OFFTAKE IN WEST PAKISTAN, 1960–65

Year	Planning Commission	AID	Independent Estimate
		(in tons of Nitrogen)	
1960/61	31,100	31,706	—
1961/62	37,200	41,003	—
1962/63	42,900	33,066	—
1963/64	62,400	67,913	76,100[a]
1964/65	97,000[a]	77,917[a]	83,300[a]

[a] Estimated.

Lyallpur (super phosphate). Total capacity was 64,420 tons of N and 3,060 tons of P_2O_5. Actual production in any one year since 1960/61 did not exceed 45,000 tons of N.

Offtake began to exceed domestic production in 1963/64, but imports were not increased until stocks had been depleted. The shortage which occurred at the end of the Second Plan period reflected the failure to increase imports during 1964/65 (when they actually declined). Actual offtake in 1965/66, according to data presented by the Planning and Development Department, was at the level of total supplies including 45,450 tons of N imports, or about equal to that for 1964/65. Figures for the production, import, and total supply of fertilizers in West Pakistan are shown in Table A8-2.

Estimated Offtake for Third Plan Period

There are several estimates of the volumes which might be absorbed by 1969/70, and these are shown in Table A8-3. The estimate given in the Third Plan documents by the Planning Commission is the most conservative and reflects an earlier stage of thinking about fertilizer requirements than is true for the other estimates. Estimates in reports by Drs. Nagelstein and Vermaat are apparently based on optimum application of fertilizers to all crops in areas where fertilizers have been shown (through fertilizer trials) to yield economic returns. As nearly as can be determined, these optimum applications were reduced by one-half and given as the minimum requirements for 1969/70, but details of the estimation method used were not given in Dr. Nagelstein's report. If this analysis of the estimate is correct, it represents a measure of the theoretical potential for fertilizer use, rather than a considered estimate of probable offtake.

TABLE A8-2
FERTILIZER SUPPLIES, 1960–65

Year	Production	Imports	Total Supply
		(in tons of N.)	
1960/61	10,917	36,467	47,384
1961/62	13,112	51,335	64,447
1962/63	40,790	10,084	50,874
1963/64	43,757	10,084	53,841
1964/65	44,206	3,199	47,405
1965/66	45,000[a]	45,440[a]	90,440[a]

[a] Estimated.

TABLE A8-3
ESTIMATED FERTILIZER REQUIREMENTS BY 1969/70
(on a 1960-64 base)

	N	P_2O_5	K_2O
	(in tons of nutrients)		
I. Third Plan Program	198,000	37,000	15,000
II. Planning Department W. P.	280,000	85,000	15,000
III. Esso Standard Eastern	270,462	86,830	—
IV. Nagelstein/Vermaat[a]	340,000	210,000	110,000

[a] Estimate represents about half the expert's assessment of crop requirements.

The Planning and Development Department estimates (Government of West Pakistan) represent a revision of earlier thinking. The revised thinking was based on raising Third Plan foodgrain targets to a level of self-sufficiency by the end of the Third Plan period; it was assumed this could be done by the addition of 130,000 tons of nutrients to the fertilizer targets for 1969/70, with 70 percent of this addition going on foodgrains. These estimates also called for more balanced use of fertilizers than in the past. The other estimate shown was prepared by Esso Standard Eastern in assessing the market for its proposed urea plant at Mari. No estimate was made for potassic fertilizers, but those for N and P_2O_5 are remarkably close to the new estimates prepared by the Planning Department. The Esso estimate is based on a division-by-division estimate of the acreage expected to be using fertilizer by 1969/70, and the quantities which would be applied per acre for different crops.

Production Plans for 1965–75

The Government of West Pakistan as of 1966 planned on an increase in nitrogen producing capacity to 560,900 tons of N. This represented an increase of 496,480 tons of N in capacity, or 670 percent. In terms of actual fertilizers, it is an increase of 1,618 tons of nitrogenous fertilizers of the following kinds: urea, ammonium sulphate, and calcium ammonium nitrate. There were also plans to produce an additional 69,000 tons of P_2O_5, the nutrient equivalent of 182,000 tons of phosphatic fertilizer. The planned capacity, and the stage of approval (as of March 1966) for each proposed plan, are shown in Table A8-4. It is difficult to forecast how much of the proposed capacity at the stage of "Finance Sanctioned" would actually become available during the Third Plan period.

Distribution System

In the mid-1960's, the distribution system was in a state of change. The ADC had been responsible for all fertilizer distribution up to 1964. From that date to mid-1965, the distribution was divided between the ADC, West Pakistan Industrial Development Corporation (PIDC), and the RSCC. The PIDC and ADC together distributed 75 percent of all domestic production and 75 percent of all imports through private dealers, with PIDC retaining the larger share of domestic production. The remaining 25 percent of domestic production and imports was distributed through cooperatives by the RSCC.

TABLE A8-4
PRODUCTION, EXISTING IN 1965 AND PROPOSED

Location	Type of Fertilizer	Capacity in Fertilizers	Capacity in Nutrients	
			N	P_2O_5
		in tons		
Existing				
Daudkhel	Amm. Sulph.	50,000	10,500	—
Multan	Ca. Amm. Nitr.	103,000	26,780	—
Multan	Urea	59,000	27,140	—
Lyallpur	Super Phosph.	18,000	—	3,060
Subtotal		230,000	64,420	3,060
Construction Approved				
Daudkhel	Amm. Sulph.	40,000	8,400	—
Multan	Ca. Amm. Nitr.	60,000	15,600	—
Multan	Urea	15,000	6,900	—
Lyallpur	Super Phosph.	32,000	—	5,440
Esso	Urea	173,000	79,580	—
Subtotal		320,000	110,480	5,440
Finance Sanctioned				
Kandhkot	Urea	500,000	230,000	—
Karachi	TSP	150,000	—	69,000
Daudkhel	Amm. Sulph.	600,000	156,000	—
Subtotal		1,250,000	386,000	69,000
Total		1,800,000	560,900	77,500

Source: Planning and Development Department—Government of West Pakistan, March 1966.

After July 1965, the RSCC began distributing 75 percent of the total available supply of fertilizers through its cooperatives. The ADC was allocated 25 percent for distribution in its project areas and for use in the promotion of improved seed in all parts of West Pakistan. This change appeared to be a temporary arrangement to curtail some of the then existing black market in fertilizers. The Government felt that private dealers were taking advantages of the shortage in supplies, and that cooperatives would ration the limited supplies more equitably among members and other farmers without charging black market prices. It was expected that reliance on the RSCC would probably be retained only until there were sufficient supplies to remove shortages, after which consideration should again be given to using private dealers as retail agents.

One element of private sales activity was scheduled to become active when the Esso urea plant at Mari began production, in 1968. Esso would depend on its own distribution and sales organization to sell the output of the plant, and would support this sales effort by a technical service group of agronomists who would work with farmers to determine proper fertilizer requirements in individual areas. The Government has not permitted Esso to market imported fertilizers, but it can sell directly the quantities produced at its Mari plant. Esso does not intend to provide any credit for fertilizer purchases, but salesmen are supposed to assist farmers in obtaining credit through normal channels.

Although distribution arrangements through RSCC were not expected to be permanent, it is useful to set forth the inadequacies of the immediate situation. The RSCC was not well-equipped for the immediate task. It did not have an accurate present stock position of its cooperative outlets, and its reporting and checking procedures were poor. It had no storage facilities of its own, and did not seem concerned about storage needs. The cooperatives were financially weak, but had to pay in advance for fertilizers they received from RSCC. This may require new loans to cooperatives from sources other than the RSCC. The number of cooperative sales outlets was inadequate to cover the total market area in the past, but at this point in history there were no other sources from which farmers could buy (outside of ADC project areas). While the RSCC had a workable distribution plan, the organization did not have the staff or the support necessary to fulfill the function it had agreed to carry out.

Storage Facilities

The RSCC planned to rent godown space in market towns as the need arose. It is noted that, as a general rule, such space is poor in quality and small in size. For the remainder of storage needs, the RSCC planned to rely on godowns of the cooperatives. About 2,500 such godowns are scheduled for construction during the Third Plan period, with capacities ranging from 50 to 175 tons. Assuming an average capacity of 100 tons, this would give a total of 250,000 tons of local storage space, plus whatever storage the RSCC could rent in different market centers.

Using the West Pakistan Planning and Development Department estimates of offtake by 1969/70 (e.g., 280,000 tons of N; 85,000 tons of P_2O_5; and 15,000 tons of K_2O), the actual volume of fertilizers handled could be upwards of one million tons. Transportation problems were likely to become acute and there would be need to accumulate stocks at the local level in anticipation of seasonal peak periods. The storage problem was presumably under further careful study, but it seemed probable that the anticipated storage facilities would not be adequate to ensure availability of fertilizers to farmers in time for their peak requirements.

Credit Facilities

The RSCC fertilizer distribution plan stipulated that all fertilizer sales would be for cash. In a situation of short supply, lack of credit is not likely to be a major factor deterring fertilizer use. As long as shortages of supply exist at the official price, additional credit for fertilizer purchases would contribute nothing.

Fertilizer credit has been issued through the cooperatives in the past. Cooperatives may grant credit to farmers up to amounts determined either by the share holdings of the borrower, or some multiple of the land revenue he pays. Cooperatives in turn borrow from the Cooperative Banks. The cooperative credit opportunities are available for other agricultural inputs. When the RSCC arrangement went into effect, the cooperative service societies had a sizeable debt (of about Rs. 50 million) outstanding from earlier periods when fertilizer was distributed through them for credit.

Transport

The capacity of the transport system to handle fertilizer supplies over the short term, during which imports would remain dominant, was associated with the need for wheat imports. The capacity of the railroad to move bulk commodities from Karachi port was about 150,000 tons per month, or 1.8 million tons per year. Assuming that wheat imports amounted to, say, as much as 1 to 1.5 million tons, and that one-fifth of wheat imports remained in Karachi, there would be a demand on the railroads of 800 thousand to 1.2 million tons per year. Assuming imports of fertilizers of 153,820 tons of N, which might mean an actual tonnage (assuming two-thirds in urea and one-third in ammonium sulphate) of about 500,000 tons. In such a situation, the combined transportation requirements of wheat and fertilizers would use nearly all the available railroad capacity from the port. With smaller wheat imports, or larger proportions of urea, the pressure on the railroads would be somewhat less. There could be problems of timing, of course, involved with uneven flow of imports, and there could be difficulties in moving fertilizers to up-country points in time for seasonal peak requirements. As wheat imports decline, and as domestic production of fertilizers increases (starting in 1968 with the Esso plant), the transport situation would change.

Planning Outlook

Long-run needs require distribution through an agency established and equipped to carry out a strong fertilizer promotion campaign. The use of private dealers could expand the number of retail outlets so that all farmers may acquire fertilizers easily, and on time. Cooperatives could continue to serve as fertilizer sales points in the future, but sole reliance on them unduly restricts the potential market coverage. A mixture of private dealers and cooperative sales outlets seems preferable. Planning should therefore take into consideration the development of a distribution system which includes private dealers for some part of total retail sales, and also establish a wholesale agency which could acquire personnel with sales promotion, movement and storage, and technical competence and experience to carry out an effective fertilizer program. In this connection, Esso's plans for its sales and distribution system could provide a possible model for adoption.

There is need to study storage requirements very carefully. During the period when private dealers were being used for retail sales, some complaints against them were registered by the ADC, particularly that dealers would not lift adequate stocks in advance of peak demand periods. This difficulty might be overcome by a series of discounts based on the willingness of dealers to take stocks off-season and in large quantities. This might encourage private dealers to acquire their own storage facilities, and shift some of the burden of storage to the private sector. Loans for construction of fertilizer storage by dealers should also be studied.

The heavy emphasis on nitrogenous fertilizers in West Pakistan has led to an imbalance in the use of different plant nutrients. The N/P ratio in 1964 was 33:1, using the "independent" estimate of N given in Table A8-1. On the basis of Planning Commission estimates, it might have been even lower. No potassic fertilizers were being used at all. The Government felt there was inadequate proof of potash response, and thus has been hesitant to recommend it to farmers. The FAO Soil Fertility Investigations do indicate a need for potash, however, and in much larger porportion than was being projected for the Third Plan. The implication would be that the projected offtake of nitrogen cannot be sustained indefinitely without greater efforts to promote the use of phosphatic, and perhaps potassic fertilizers. This would be taken into account in drawing up import needs and plans for construction of domestic production capacity.

Government policy in regard to subsidies for agriculture has been cautious. For instance, the subsidy level was reduced from 50 percent to about 30 percent of cost, in 1965, with a decision on further reductions apparently being postponed until there was an opportunity to test the market under the conditions of increased supplies. Caution seems to be a wise approach until the supply and demand situation is thoroughly classified. Since a larger offtake will result in larger subsidy costs to Government at a given rate, there will probably be pressures to reduce the subsidy rate as offtake increases. Before acceding to such pressure, however, there should be a careful study of the pattern of market growth to determine whether subsidized prices are still needed as an incentive to encourage farmers to use fertilizers.

Estimates of Future Offtake

The base period used for estimating future offtake was the Second Plan, as discussed earlier. Using the figure for 1964/65 based on an independent estimate for nitrogen offtake (see Table A8-1). The rate of growth for the five-year period was 27 percent. On the basis of Planning Commission estimates, the rate was somewhat higher. Also, offtake probably would have been higher if supplies had been available, and this fact implies a somewhat higher rate. Still, assuming a rate of 27 percent per annum, the estimated offtake would be 275,200 tons of N by 1969/70. If the further assumption is made that the NPK ratio would be improved to 6:2:1 by 1969/70, offtake would also include 82,600 tons of P_2O_5 and 41,300 tons of K_2O.

This estimate is very close to the estimates for N and P_2O_5 provided by the Government of West Pakistan and Esso and shown in Table A8-3. Since these were made by independent procedures, the tendency for all three estimates to cluster around the figure of 275,000 tons of N and 85,000 tons of P_2O_5 argued in favor of these quantities as realistic projections of future offtake. Also, strong efforts were being made to introduce Mexican wheat into West Pakistan, and this would require large applications of nitrogen to give significant yield improvements over local varieties. Thus continuation of the high annual rate of increase seemed quite plausible.

This estimate would appear to justify half of the proposed nitrogen production capacity (Table A8-4) by 1970, or at least the inclusion of the capacity represented by the Daudkhel plant from among those which had been sanctioned. It should be noted that an offtake of 275,000 tons of N, 85,000 tons of P_2O_5, and say 40,000 tons of K_2O, will require a very efficient distribution, handling and storage organization. The magnitude of the problem will depend on the kinds of fertilizer used. Excluding the quantities produced and distributed by Esso, the total quantities of fertilizers to be handled by the Government would range, say, from about 800,000 tons to slightly over one million tons. The smaller figure assumes additional nitrogen would be produced or imported in the form of urea; the larger assumes the additional nitrogen would be available as ammonium sulphate.

TABLE A8-5
PROJECTED FERTILIZER PRODUCTION AND DEMAND
(in '000 tons of nutrient)

Year	Estimated Demand		Production		Surplus (+) or Deficit (−)	
	N	P_2O_5	N	P_2O_5	N	P_2O_5
1965/66	106	8	64	3	(−) 42	(−) 5
1966/67	134	14	64	3	(−) 70	(−) 11
1967/68	171	26	80	9	(−) 91	(−) 17
1968/69	217	47	135	78	(−) 82	(+) 31
1969/70	275	85	175	78	(−)100	(−) 7
1970/71	306	105	353	78	(+) 47	(−) 27
1971/72	341	130	531	78	(+)190	(−) 52
1972/73	379	155	531	78	(+)152	(−) 77
1973/74	422	195	531	78	(+)109	(−)117
1974/75	470	235	531	78	(+) 61	(−)157

For the period beyond 1969/70, it seemed probable that the annual growth in demand would decline somewhat below the rate estimated for the late 1960's. The most promising market areas would be the irrigated acreage in the Province, and fertilizer use on this acreage should be fairly widespread by the Fourth Plan period. Further expansion in demand would therefore come largely from farmers who are already using some fertilizer (but are beginning to use larger quantities per acre than in the past), and from higher cropping intensities. Demand from farmers using fertilizers for the first time should be less of a factor in the future total demand for fertilizers. The stimulus coming from initial adoption of the new Mexican wheat varieties would also be less, although gradual increases should continue as farmers move toward application at the optimum rates for the new varieties.

The estimates for 1974/75 are therefore based on the following assumptions. First, the culturable irrigated acreage in West Pakistan would be about 29 million acres in 1974/75, and the average intensity of cultivation would be about 107 percent. The total irrigated acreage cropped would thus be about 37 million acres.

Second, farmers would be applying an average of about 35 pounds of nitrogen per acre on 31 million acres, or a total of 470,000 tons of N.

Third, assuming continuing efforts to improve the balance in fertilizer application, for 1974/75 the NP ratio is taken to be 2:1. The estimated demand for phosphatic fertilizer would then be 235,000 tons of P_2O_5.

The estimated annual increase in requirements, and comparison against estimated growth of local production capacity, is given in Table A8-6. Demand for fertilizers should continue to grow after 1974/75 as cropping intensities increase toward an ultimate level of about 150 percent, and as the average application per acre rises toward the optimum levels for the different crops grown. However, total offtake would be expected to grow at substantially reduced rates.

TABLE A8–6
AREA COVERED BY FERTILIZERS AT REFERENCE YEARS
(percentage of cropped acreage)

		Wheat		Cotton		Fine Rice		Sugarcane		Kharif Fodder		Rabi Fodder	
		N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5
Punjab	1965	15	—	30	—	20	—	—	—	—	—	—	—
	1975	50	50	60	30	50	30	70	30	20	—	—	20
	1985	70	70	80	60	70	50	80	60	50	30	30	40
	2000	85	85	90	90	90	90	90	90	75	75	75	75
Sind	1965	10	—	13	—	6	—	45	—	—	—	—	—
	1975	25	25	40	20	—	—	50	15	20	—	—	—
	1985	70	70	70	40	—	—	75	40	40	30	20	30
	2000	85	85	90	90	—	—	90	90	70	70	75	75
Outside Areas	1965	—	—	—	—	—	—	—	—	—	—	—	—
	1975	15	—	—	—	—	—	—	—	5	—	—	—
	1985	25	15	—	—	—	—	—	—	10	5	—	10
	2000	40	25	—	—	—	—	—	—	15	10	—	20

TABLE A8–7
FERTILIZER APPLICATIONS PER CROPPED ACRE[a] AT REFERENCE YEARS
(pounds of nutrients)

		Wheat		Cotton		Fine Rice		Sugarcane		Kharif Fodder		Rabi Fodder	
		N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5
Punjab	1965	30	30	50	—	45	30	75	—	50	—	—	100
	1975	50	30	40	30	30	30	60	30	60	—	—	50
	1985	75	50	50	40	50	40	75	35	75	20	20	75
	2000	90	60	60	50	70	50	100	40	90	30	20	100
Sind	1965	30	—	50	—	30	30	75	—	50	—	—	100
	1975	50	25	40	20	—	—	60	20	60	—	—	—
	1985	75	40	50	35	—	—	75	30	75	20	20	75
	2000	90	60	60	50	—	—	100	40	90	30	20	100
Outside Areas	1965	—	—	—	—	—	—	—	—	—	—	—	—
	1975	25	—	—	—	—	—	—	—	10	—	—	—
	1985	40	25	—	—	—	—	—	—	15	5	—	25
	2000	50	30	—	—	—	—	—	—	25	10	—	40

[a] Cropped acreage actually receiving fertilizers.

Annex 9

THE PROGRAM FOR ARTIFICIAL INSEMINATION

Extracts

General

Pakistan's agriculture is based on bullock power. According to the 1960 census, some seven million bullocks and 2.5 million other work animals (equines, buffaloes, camels) provide the bulk of the draft requirements. There, figures indicate that the Pakistani farmer depends heavily on draft-type bovines, bred from draft-type cows. Such cows are generally speaking poor milk producers (since no selection was exercised for this quality). The water buffalo provides the bulk of West Pakistan's milk supply. According to the same census, there were four million cows and five million water buffaloes whose milk production on average was about twice that of the draft cows.

Although current yields are better, the buffalo-cow is not a very efficient convertor of roughage into milk because of higher requirements for body maintenance and the secretion of milk high in fat content. Moreover, the ultimate potential of milk production of buffaloes is not as high as that of dairy-type zebus such as Sahiwal and Red Sindi. Both these breeds are available in West Pakistan.

With increasing mechanization, the need of draft stock will decline while Pakistan will have to safeguard its growing demand of milk for human consumption. Therefore, the future policy should aim at gradually replacing both draft and buffalo stock by improved dairy stock. Sahiwal and Red Sindi would be the breeds of choice as both are adapted to climatic and other conditions in Pakistan—the Sahiwal in the Punjab (Montgomery) and Red Sindi in the South—and their potential for milk production has long been known.

Breeding of Sahiwal and Red Sindi Cattle

Since there is no herd registration book for these breeds of cattle, there is no reliable estimate of the numbers which are available in West Pakistan. Furthermore, there is a wide variability within the population and the question of classifying any individual as Sahiwal or Red Sindi is more of academic than of practical importance. What does matter is that pure bred Sahiwal and Red Sindi stock are being bred on Government Livestock Farms at Bahaduranagar and Malir, respectively. It can therefore be safely assumed that present numbers of certified stock are too small to provide Pakistan in the near future with enough high-grade stock by direct breeding methods. In view of the shortness of time, the most effective way to achieve results is by using artificial insemination (AI) on a large scale, making use of draft type and milk animals as dams.

Improvement by Upgrading

By using successive female offspring, always crossed to a male of the desired breed, it is possible to create a desirable herd. With four such "backcrosses," the final offspring will have a 31/32 proportion of the breed and, for all practical purposes, can be classified as pure bred. With zebu cattle this can be achieved in a period of some 13 to 15 years. By starting in 1965 from any draft-type cow, and consequently grading up, the offspring would be "pure bred" by 1980.

To guarantee quality stock, it is imperative to use only semen of the best bulls available; and by practising artificial insemination, the widest possible coverage is assured.

AI Organization

The AI Scheme in Pakistan was initiated at the College of Animal Husbandry in Lahore. In 1963 the AI section was transferred to the Directorate of Livestock Farms. According to the 1962/63 Annual Report of the Directorate, 924 animals (564 buffaloes and 360 cows) were inseminated. The total in the 1963/64 Report increased to 1,125 animals. It was anticipated that about 5,000 inseminations would be accomplished in the 1964/65 period. Semen has been shipped to other centers in the Basin.

It is of utmost importance to develop this young organization into a countrywide service.

Area to be Serviced

Ultimately, over 30 million acres would be irrigated in the Indus Basin, and this represents some 51,000 square miles or 132,000 km^2. Outside the Indus Basin, some 11,000,000 acres of barani and sailaba land would be cultivated.

Consequently, livestock (cattle) would be concentrated in an area of around 40 million acres. The AI organization should (eventually) cover this area.

According to the 1960 census, the density of livestock (cattle and buffaloes) in West Pakistan was as given in Table A9-1. According to these data, most of the cattle are concentrated in the Indus Basin, where there is an average density of 50 heads of cattle, 60 buffaloes and 60 work animals per topographical square mile. Bearing in mind that less than one-third of this area is under irrigation, and allowing for followers and bulls, the density of adult female cows and buffaloes per irrigated square mile can be estimated at some 80 and 90 head respectively. With increasing mechanization and decreasing numbers of draft animals the density of female stock would increase accordingly.

Development of AI Service

Recognizing the necessity to increase Pakistan's milk herd rapidly, and considering the area to be served and the expected density per surface unit, possible development of AI might follow the proposal outlined below.

It is assumed that about 12 million milk animals would be needed by the year 2000 to meet demands. Further, the period to get a Basin-wide organization "off the ground" will occupy some 10 years. Rapid expansion would thus only be feasible after 1975, depending on improved communications (telephones, road network), which are the most important requisites for the proper functioning of the AI program on the scale required. Thus:

1965–75: building-up period;
After 1975: period of rapid expansion (communications).

TABLE A9-1
DENSITY OF LIVESTOCK

Division	Total area in square miles	Density per square mile: Cattle	Buffaloes	Work Animals
Peshawar	28,153	20	15	22
D. I. Khan	11,130	25	5	19
Rawalpindi	11,206	102	67	101
Sargodha	17,095	82	105	88
Lahore	8,907	49	177	112
Multan	24,826	60	58	75
Bahawalpur	17,508	26	33	56
Khairpur	20,293	34	38	40
Hyderabad	36,821	24	16	20
Total/average Indus Plains	175,939	+50	+60	+60
Quetta	53,115	4	—	4
Kalat	72,944	1	—	3
Total/average	126,059	+3	—	+3.5
Karachi	8,405	15	1	7

Source: Livestock Production in West Pakistan, Bulletin No. 3, 1964, Directorate of Livestock Farms.

The ultimate magnitude of the organization depends, of course, on the goals set. This program is aimed at a level of one million inseminations by 1985 and five million inseminations by 2000.

The number of inseminations performed annually by each operator would increase as communications improve. It is assumed that the course of the program could be as given in Table A9-2.

TABLE A9-2
COURSE OF AI PROGRAM
A. Efficiency of Inseminations[a]

Year	Conditions	Inseminations/Inseminator/Year
1965	No rural telephone (or radio) network, few and bad roads	250
1975	Improved communications	1,000
1985	Improved communications	2,000
2000	Improved communications	3,000

[a] Including inseminations performed by relief personnel.

B. Number of Inseminators Required

Year	Inseminations × 1,000	Inseminations per Inseminator	Number of Inseminators Required
1965	5	250	20
1975	50	1,000	50
1985	1,000	2,000	500
2000	5,000	3,000	1,700

TABLE A9-3
AI CENTERS REQUIRED
A. Centers Operating

Year	Number
1965	10
1975	25
1985	250
2000	500

B. Centers to be Established

Period	Total	Per Year
1965–75	15	1.5
1975–85	225	22.5
1985–2000	250	17.0

It is assumed a team of two inseminators (later three inseminators in areas with very dense cattle populations) operating from an AI center and considering the area to be served, the number of AI centers to be established would be as given in Table A9-3.

On an average, it is assumed that the inseminators would operate in an irrigated area within a radius of 10 km. from the center. This area covers 121 sq. miles (314 km^2, 77,440 acres, 31,340 ha.). At present, the average cattle population on 121 (irrigated) square miles would amount to some 9,000–10,000 adult female cattle and some 10,000–11,000 adult buffaloes (the latter gradually to be replaced by dairy cows). Allowing for future increase in female stock as a result of mechanized farming, an area of 121 square miles can be considered to be of adequate size to accommodate two or even three inseminators. From the figures in Table A9-4, it can be concluded that by 2000 the total cultivated area would be covered, allowing for facilities in Karachi, Quetta and Kalat Divisions.

To ensure proper supply, coordination and supervision, it is supposed that one in every 10 AI centers will act as Head Center, supervising an area of 1,210 square miles (774,400 acres, 313,400 ha.). Again, each hundredth center, commanding an area of 12,100 square miles (radius about 125 miles, 7,744,000 acres, 3,134,000 ha.) as Regional Center is assumed to supply, coordinate and supervise its area. Finally, Headquarters at Lahore would supervise and coordinate the Regional Centers. The organizational structure is outlined in Table A9-5.

TABLE A9-4
AREA COVERED BY AI CENTERS

Year	Area in square miles	Area in acres × 1,000
1965	1,210	744
1975	3,025	1,936
1985	30,250	19,360
2000	60,500	38,720

TABLE A9-5
STRUCTURE OF THE AI ORGANIZATION

Year	Headquarters (Lahore)	Regional Centers	Head Centers	AI Centers	Total Centers
1965	1	—	—	9	10
1975	1	—	3	21	25
1985	1	3	25	221	250
2000	1	5	50	444	500

Staff and Personnel (Table A9-6). The whole organization should be responsible to the Director of Livestock Farms and daily supervision should be executed by a Director of AI stationed at Headquarters in Lahore. The Regional Centers are to be supervised by Regional AI Officers with a M.Sc. degree. The Head Centers should be supervised by AI Officers with a B.Sc. degree or comparable qualifications. The AI Centers finally would be supervised by Head Inseminators. Other graduate staff would be needed at Lahore Headquaters to conduct research, etc. Some three to four veterinary surgeons/biologists would be needed, assisted by laboratory personnel.

TABLE A9-6
STAFF REQUIREMENTS FOR AI ORGANIZATION
A. Technical—University Graduates

Year	Headquarters Lahore (M.Sc.)	Regional Centers (M.Sc.)	Head Centers (B.Sc.)	Total
1965	1 + 3	—	—	4
1975	1 + 3	—	3	7
1985	1 + 4	3	25	33
2000	1 + 4	5	50	60

B. Inseminators

Year	
1965	20
1975	50
1985	500
2000	1,700

C. Administrative Personnel (clerks and head clerks)

Year	Headquarters Lahore	Regional Centers	Head Centers	AI Centers	Total
1965	3	—	—	9	12
1975	3	—	6	21	30
1985	5	9	50	221	285
2000	5	15	100	444	564

D. Labor and Drivers
(approx.)

Year	Labor	Drivers
1965	20	1
1975	20	3
1985	40	30
2000	250	60

For the purpose of record keeping and accounting, the organization would have to depend on clerical staff. It is proposed to employ one clerk per AI Center, two clerks per Head Center, three clerks per Regional Center and five clerks at Headquarters.

To train and instruct the inseminators, two to four instructors are supposed to be on duty at Lahore Headquarters.

The labor requirement is closely related to the number of bulls kept by the organization. Drivers would be needed according to the vehicle-fleet of the organization.

Equipment (Table A9-7). In all probability, both "normal" and deep-frozen semen would be used during the coming decades. Deep-frozen semen requires freezing cabinets cooling to −80°C. (electric, solid CO_2, fluid nitrogen, etc.) and would only be handled at Lahore and Regional Centers. Head Centers and AI Centers will generally use "normal" semen, stored in refrigerators (electric or kerosine).

Other AI equipment would include artificial vaginas, collectors, glass-work, pipettes, syringes, sterilizing cabinets, microscopes, chemicals, diluters, thermos flasks, transport boxes, inseminators' bags, aprons, gloves, cleaning equipment, administration material, etc.

Transport (Table A9-8). Semen would be transported by air, road and rail. It is supposed that inseminators would use light motorbicycles. Head Centers and Regional Centers would operate one and two four-wheel drive vehicles respectively.

Buildings and Accommodation. Accommodation of the AI Centers is not governed by rigid rules. Inseminators may operate from veterinary hospitals, Union Council buildings or any other Government premises. Basically only one room would be needed. The same holds true for Head Centers, except that a minimum of two rooms would be needed. Regional Centers, however, would have to be established, but can be adjacent to other official buildings. The Lahore Center would need expansion. Headquarters, Regional Centers and some Head Centers would accommodate AI bulls (bull pens, stables, etc.).

Investment in stables is estimated at Rs. 2,000/bull.

AI Bulls. AI bulls to be stationed at Lahore, Multan, Khairpur, Hyderabad, Karachi, Peshawar, Quetta and other locations as deemed necessary. Decentralization of bulls would cut down on semen transport costs (two to three times per week in case of "normal semen") and bulls should be demonstrated to farmers in their areas.

TABLE A9-7
REFRIGERATION EQUIPMENT

Year	Semen Banks (deep-frozen)	Refrigerators (electric or kerosene)
1965	—	10
1975	1	25
1985	4	250
2000	6	500

TABLE A9-8
PERSONNEL TRANSPORT REQUIREMENTS

Year	Vehicles	Motorcycles
1965	1	20
1975	3	45
1985	30	500
2000	60	1,700

The number of bulls needed is open to discussion. It would technically be feasible to use a minimum of top quality bulls but such a policy would result in a narrow breeding basis. Table A9-9 gives expected nations per bull per year and bull requirements. Initially all bulls would be supplied by the Government Livestock Farms. In future the purchase of bulls from private breeders may be possible.

Impact of AI on the Milk Herd

As it is unlikely, and also undesirable, that AI will be made compulsory, it is not possible to define the impact of AI with any degree of accuracy. Eventually the farmer is the decisive factor. By using AI any farmer can raise milk production and in some 15 years can own "pure bred" cattle, even starting from scrub animals. It is to be anticipated that a growing number of farmers will abide by AI, but others will fail to keep in step and return to their old habits.

Also it is not to be expected that any organized Herd Book organization would emerge in Pakistan in the very near future. Therefore, it would not be possible to keep trace of all animals born from AI.

As a consequence, it would be safe to assume that, during the coming decades, more and more "grade animals" would participate in the production of milk for West Pakistan's human population. These "grade" cows (particularly the first cross) would on the average possess a greater milk production potential than their dams. However, it is only with better management, feeding and sanitation that higher yields would also be realized.

TABLE A9-9
BULL REQUIREMENTS
A. Inseminations per Bull per Year

Year	Number
1965	1,500
1975	2,000
1985	3,000
2000	5,000

B. AI Bulls (Sahiwal and Red Sindi)

Year	Inseminations × 1,000	No. AI Bulls (approx.)
1965	5	5
1975	50	25
1985	1,000	350
2000	5,000	1,000

A calculation of AI calves born is presented in Table A9-10. It is assumed that 1.8 inseminations would be needed for every calf born and that the female/male calf ratio would be 1:1.

Financial

It is not possible, within the limits of this study, to present a detailed outline concerning the investments required to launch the AI-organization along the proposed levels of input. Important items, such as buildings and accommodations cannot be defined in this stage, as no strict rules can be applied. Cost estimates in Table A9-11 are based on current levels of salaries, wages and costs, concerning the exploitation of the AI-organization in the year 2000. According to these estimates, the exploitation costs of the organization will amount to Rs. 15 million in the year 2000.

Having his cattle served always involves costs to the farmer, as upkeep of bull, service fee, etc. Therefore it is realistic to assume that the Pakistani farmer would have to pay for AI-services rendered. (Presently, AI is performed free of charges in West Pakistan.) The normal procedure is to charge the farmer for every first insemination and perform a second and third insemination of the same animal that has not taken, within a certain limit of time, free of charge.

However, as both the Sahiwal and Red Sindi are uniformly colored animals, and as it would not be possible to keep trace of individuals, it is proposed to charge per insemination performed. The fee to be paid is, again, open to discussion. But it should be borne in mind that the farmer, by means of the AI organization, is in a position to improve his stock considerably, warranting reasonable financial sacrifices on his part. To meet exploitation costs in 2000, the insemination fee would amount to Rs. 3 per insemination. By charging Rs. 5—which is a very reasonable fee—total revenues would amount to Rs. 25 million in 2000, leading to a balance of Rs. 10 million respectively.

Conclusions and Remarks

1. Recognizing the need to build up the milk herd of West Pakistan (Sahiwal, Red Sindi) in a relatively short span of time, the development of a countrywide Artificial Insemination Organization is of paramount importance.

2. The basis of such organization is already operating in West Pakistan, under the Directorate of Livestock Farms.

3. A preliminary attempt to envisage the AI organization has been made in this study. Goals have been set at a level of five million inseminations in the year 2000.

TABLE A9-10
NO. OF AI CALVES BORN (APPROX.)

Year	Total Calves Born	Heifer Calves Born
1965/66	2,778	1,389
1975/76	27,778	13,889
1985/86	555,555	277,778
2000/01	2,777,778	1,388,889

TABLE A9–11
ESTIMATES EXPLOITATION COSTS AI ORGANIZATION (2000)

A. Salaries and Wages			Rs. × 1,000
Inseminators @ Rs. 2,000	1,700		3,400
Graduate staff @ Rs. 6,000	60		360
Clerks @ Rs. 2,000	564		1,128
Instructors and Others			42
Drivers @ Rs. 2,000	60		120
Laborers @ Rs. 1,000	250		250
		Total Rs.	5,300

B. Transport			Rs. × 1,000
Motorbikes depr. 2 years incl. exploitation and spares @ Rs. 600/bike/year	1,700		1,020
Vehicles @ 15,000 km/year @ Rs. 1/km (all in)	60		900
Air freight, railroad			50
		Total Rs.	1,970

C. Exploitation Centers			Rs. × 1,000
AI equipment, electricity, kerosene, etc.			
AI Centers @ Rs. 1,000 (444)			444
Head-Centers @ Rs. 10,000 (50)			500
Regional Centers @ Rs. 25,000 (5)			125
Headquarters Lahore (1)			130
		Total Rs.	1,199

			Rs. × 1,000
Purchase AI bulls and upkeep @ Rs. 5,000/bull (useful life 5 years)	200		1,000
Upkeep Rs. 1,500/bull/year	1,000		1,500
		Total Rs.	2,500
Overhead administration 40% of total salaries			2,120
Upkeep and maintenance buildings/stables			750
Miscellaneous			1,161
		Grand Total Rs.	15,000

4. From the figures presented, it can be concluded that neither manpower, availability of bulls, transport facilities nor investments, can be considered as constraints. Financially, the organization can ultimately be made self-supporting or a paying proposition by adjusting the insemination fee between reasonable and realistic margins.

5. The early selection of AI bulls and increasing their numbers is of utmost importance.

6. It should be pointed out that constraints may be expected in the sphere of communications (rural telephone connections, roads) and the individual attitude of farmers (superstition, religious objections against AI, ignorance, etc.)

TABLE A9–12
CHARGEABLE INSEMINATIONS AND EXPLOITATION COSTS OF AI ORGANIZATION
(year 2000)

Inseminations × 1,000	Exploitation Costs × Rs. 1,000
5,000	15,000
Revenue	Balance (Rs. '000)
25,000	10,000

7. In our opinion, the ultimate success or failure of AI in Pakistan would depend on communications. The scheme calls for some 4,000 rural telephone connections within the Indus Basin. It should be also borne in mind that both mechanization and pest control are equally dependent on good rural communications.

8. The organization proposed pertains to the propagation of Sahiwal and Red Sindi. The same organization is, of course, capable of also inseminating buffaloes and draft cattle as practiced at present.

9. The organization is strictly a technical organization and should be operated as such. Any activities aiming at extension to farmers, breeding associations, milk control associations, etc. should be executed by other bodies (extension service, Rural Councils, etc.).

Annex 10

ASSUMPTIONS USED IN OUTPUT AND DEMAND PROJECTIONS

Definition of Developmental Activities Employed in GPV Projections

The major assumptions adopted by the Study Group in its projections of future agricultural production are summarized in Chapter VIII. This Annex provides further details on certain of these assumptions.

Ongoing Project Areas. The Study Group has adopted the following estimates of acreage included in the Ongoing Project areas:

SCARP I	1.080 million acres
SCARP II	1.551
SCARP III	0.934
SCARP IV	1.660
Subtotal SCARP I to IV	5.225
Khairpur (excluding saline areas)	0.300
Total Ongoing Project Areas	5.525 million acres

Deferred Project Areas. In estimating production from the Deferred Project Areas located within the canal commanded areas (CCA) of the Basin, the Study Group has found it useful to relate the projections to two categories of water availability up to 1975: (a) areas to be covered by private tubewells, and (b) the remainder of the canal commanded area. Further, because some of the expected private tubewell development in the Basin would take place within the IACA Project areas and the Ongoing Project areas, such private wells would need to be excluded from the total number of private tubewells in order to derive the number operating under category (a) above. The numbers of private tubewells estimated to be in operation in Deferred Project areas are therefore as follows:

	1965	1975
	(in thousand wells)	
Total Private Tubewells in Canal Commanded Areas	29.0	38.5
Less: Ongoing Project Areas	7.8	—
IACA Project Areas	5.6	1.0
Deferred Project Areas Tubewells	15.6	37.5

Private Tubewell Contribution. The contribution of private wells in the Ongoing Project areas and IACA Project areas is accounted for in the production estimates for these areas. The following assumptions were made for the Deferred Project areas in the Basin. The Study Group has assumed that during 1965–75 each private tubewell there would command about 100 acres CCA at a cropping intensity of 125 percent, though with some degree of underwatering. The estimated 15.6 thousand private wells in the Deferred Project areas would thus represent a CCA of 1.56 million acres, or a cropped acreage of 1.95 million acres in 1965. Since the full extent of the Deferred Project areas is 18.35 million acres CCA, the remainder is therefore 16.79 million acres CCA (18.35 million less 1.56 million acres). This remainder, which includes some of the best irrigated areas, was given practically no increase in cropping intensity (e.g., 96.0 percent), or a cropped acreage of 16.2 million acres.

The Study Group has assumed that a gradual change would take place in private tubewell operation between 1965 and 1975. For one thing, the number of private wells in the Deferred Project areas would increase from 15.6 thousand to 37.5 thousand over this period. Secondly, with rising yields (due to improvements in farming practice and increased inputs) there would be less incentive to underirrigate, and the CCA per tubewell would gradually drop to 80 acres. Thirdly, the cropping intensity would rise to 140 percent by 1975. The 37.5 thousand private tubewells expected by 1975 would thus command a CCA of 3.0 million acres and a cropped area of 4.2 million acres. The remainder of 15.35 million acres CCA (18.35 million less 3.0 million acres) was given a modest increase in cropping intensity to 105 percent by 1975, or a cropped acreage of 16.19 million acres. After 1975, the contribution of private tubewells is assumed to be replaced by further public groundwater development and by additional surface water, and an average intensity of 130 percent would be attained for all the Deferred Project areas by 1985. From 1985 to 2000, this intensity would gradually rise to a maximum of 150 percent. The growth rate applied to the Deferred Project areas after 1975 was similar to that used for the areas with projects because water availability by that time would be comparable in all commanded parts of the Basin.

Outside Areas. This area consists of lands within the Indus Basin, but not commanded by the canal system as well as cultivated lands outside the Basin which may partially benefit from small irrigation schemes. Considerable private tubewell development is also expected to take place in the outside areas increasing from an estimated 5,000 wells in 1965 to 25,000 wells by 1985. The acreage estimate used in the following tables is also assumed to represent the vast marginal grazing areas for which no reliable data are available.

Assumptions Used in Estimating Gross Value Added

The Study Group has attempted to follow official National Accounts procedures in preparing projections of gross value added by the agricultural sector. It has therefore been necessary to modify the methodology and assumptions used by IACA in certain respects because of the nature of the data. The major changes include the following.

1. An upward price adjustment because official 1959/60 prices are 5 percent above IACA prices.
2. The nonagricultural sector costs subtracted from the gross production value are estimates which relate to the input assumptions adopted by the Study Group in making its projections, rather than the cost allowances used in official estimates of gross value added or the IACA estimates.

TABLE A10–1

IACA's Projections of Growth of Agricultural Production

(production as total GPV in Rs. billions; cropped acreage in millions; yield as GPV per acre in Rs.)

	CCA Millions of Acres	1965 Cropped Acres	1965 GPV per Acre	1965 Total GPV	1975 Cropped Acres	1975 GPV per Acre	1975 Total GPV	1985 Cropped Acres	1985 GPV per Acre	1985 Total GPV	2000 Cropped Acres	2000 GPV per Acre	2000 Total GPV
Ongoing Project Areas	4.86	4.49	261	1.17	6.07	346	2.10	7.15	510	3.65	7.18	740	5.31
IACA Project Areas	5.65	5.25	229	1.20	6.89	348	2.40	8.40	518	4.35	8.42	762	6.40
Deferred Project Areas	18.92	18.61	236	4.40	20.27	304	6.09	22.57	485	10.95	28.54	707	20.18
Totals for Basin (Commanded)	29.43	28.35	239	6.77	33.23	319	10.59	38.12	497	18.95	44.14	722	31.89
Outside Areas (Noncommanded)	—	12.37	156	1.93	12.96	214	2.77	13.76	304	4.19	14.45	493	7.15
Totals for West Pakistan	—	40.72	213	8.70	46.19	289	13.36	51.88	446	23.14	58.99	666	39.04

TABLE A10–2

Compound Annual Growth from IACA's Projections[a]

(percentage per year)

	1965–75 Cropped Acres	1965–75 Yield	1965–75 Total GPV	1975–85 Cropped Acres	1975–85 Yield	1975–85 Total GPV	1985–2000 Cropped Acres	1985–2000 Yield	1985–2000 Total GPV	1965–2000 Cropped Acres	1965–2000 Yield	1965–2000 Total GPV
Ongoing Project Areas	3.0	2.8	6.0	1.6	4.0	5.7	0	2.5	2.5	1.4	3.0	4.4
IACA Project Areas	2.8	4.4	7.2	2.0	4.1	6.1	0	2.6	2.6	1.4	3.5	4.9
Deferred Project Areas	0.9	2.6	3.3	1.0	4.8	6.0	1.6	2.5	4.2	1.3	3.1	4.4
Totals for Basin (Commanded)	1.6	2.9	4.6	1.4	4.5	6.0	0.9	2.5	3.5	1.3	3.2	4.5
Outside Areas (Noncommanded)	0.5	3.2	3.7	0.6	3.5	4.2	0.3	3.3	3.6	0.4	3.4	3.8
Totals for West Pakistan	1.3	3.1	4.3	1.2	4.4	5.6	0.9	2.7	3.5	1.0	3.3	4.3

[a] The increase in livestock production attributed to the Outside Areas makes a major contribution to the growth of GPV. The relative contributions are:

Crops	2.3	2.1	1.5	2.0
Livestock	5.1	5.4	4.6	5.0

TABLE A10-3

STUDY GROUP'S PROJECTIONS OF GROWTH OF AGRICULTURAL PRODUCTION

(production as total GPV in Rs. billions; cropped acreage in millions; yield as GPV per acre in Rs.)

		1965			1975			1985			2000		
	CCA Millions of Acres	Cropped Acres	GPV per Acre	Total GPV	Cropped Acres	GPV per Acre	Total GPV	Cropped Acres	GPV per Acre	Total GPV	Cropped Acres	GPV per Acre	Total GPV
Ongoing Project Areas	5.53	5.03	261	1.30	7.51	375	2.82	8.29	551	4.57	8.29	760	6.30
IACA Project Areas	5.76	5.27	227	1.19	6.89	299	2.06	8.40	469	3.94	8.42	760	6.40
Deferred Project Areas	18.35	18.05	236	4.27	20.39	330	6.74	23.85	469	11.19	27.53	760	20.92
Totals for Basin (Commanded)	29.64	28.35	239	6.77	34.79	334	11.62	40.54	486	19.70	44.24	760	33.62
Outside Areas (Noncommanded)	—	12.37	156	1.93	13.05	216	2.81	13.76	305	4.19	14.45	493	7.15
Totals for West Pakistan	—	40.72	214	8.70	47.84	302	14.43	54.30	440	23.90	58.68	695	40.77

TABLE A10-4

COMPOUND ANNUAL GROWTH FROM STUDY GROUP'S PROJECTIONS

	1965–75			1975–85			1985–2000			1965–2000		
	Cropped Acres	Yield	Total GPV	Cropped Acres	Yield	Total GPV	Cropped Acres	Yield	Total GPV	Cropped Acres	Yield	Total GPV
Ongoing Project Areas	4.1	3.7	8.0	1.0	4.0	5.0	0	2.2	2.2	1.4	3.1	4.6
IACA Project Areas	2.7	2.8	5.6	2.0	4.6	6.7	0	3.3	3.3	1.4	3.5	4.9
Deferred Project Areas	1.3	3.4	4.7	1.6	3.5	5.2	0.9	3.3	4.2	1.2	3.4	4.7
Totals for Basin (Commanded)	2.1	3.4	5.5	1.5	3.9	5.4	0.6	3.0	3.6	1.3	3.4	4.7
Outside Areas (Noncommanded)	0.6	3.3	3.9	0.6	3.5	4.1	0.3	3.2	3.6	0.4	3.4	3.8
Totals for West Pakistan	1.6	3.5	5.2	1.3	3.9	5.2	0.5	3.0	3.6	1.0	3.4	4.5

3. An allowance of 4 percent of the gross value added by crops is provided to account for nonreporting areas, and this is the same allowance made in official estimates of gross value added. This allowance has been omitted in the IACA projections.

4. Gross value added by forestry and fishing have been omitted because the Study Group has no data available to it on which to base projections of future growth.

The fourth point is self-explanatory, but the other changes warrant further discussion.

The IACA farm-gate prices differ from the official 1959/60 prices in important respects. Some are lower and some are higher, but the net effect is to give a lower GPV for 1965 with IACA prices than with official prices. This may be seen in Table A10-5, where the IACA benchmark production estimates for 1965 have been valued at both IACA prices and official prices. Since official prices give an average value per ton which is 5 percent higher than the average value per ton with IACA prices, the Study Group has adjusted its projections of GPV upward by this percentage. This adjustment eliminates differences between Study Group and official projections resulting from the use of different price assumptions.

The Study Group's estimates of the costs of inputs received from other sectors are based on IACA's data primarily, with the exception of the cost of fertilizer and implements. The IACA estimate of the 1965 water charges for historic surface supplies has been retained (in absolute terms) through the year 2000. These appear unduly low in comparison with the estimates of O&M costs of all future facilities (including storage and canal remodelling), but this would remain true if no change in historic water charges were made. The estimated cost of fertilizer

TABLE A10–5
COMPARISON OF IACA'S AND GOV'T PRICES USING IACA ESTIMATES OF 1965 PRODUCTION OF MAJOR CROPS

Crop	IACA Production Estimates ('000 long tons)	IACA GPV (Rs. mill)	IACA Stated Price (per long ton)	IACA Implicit Price[c] (per long ton)	Gov't Price (per long ton)	Gov't GPV[d] (Rs. mill)
Rice	1,196[a]	589	517	492	545	652
Wheat	4,586	1,635	354	357	410	1,880
Barley	—	—	—	—	300	—
Jowar	669	205	299	306	358[e]	240
Bajra						
Maize	825	251	299	304	362	299
Gram	700	277	388	396	391	274
Sugarcane	14,715	721	50	49	51	750
Rape and Mustard	360	233	626	647	629[e]	226
Sesame						
Cotton	359[b]	880	2,450	2,451	1,971	708
Tobacco	13	28	2,722	2,154	2,537	33
Total	23,423	4,819				5,062
Average price:		Rs. 205.7 per long ton				Rs. 216.1 per long ton

[a] Estimated clean rice equivalent. [b] Lint cotton equivalent. [c] Derived from total GPV and production estimates. [d] Gov't prices and IACA quantities. [e] Weighted average price.

has been based on Study Group projections of fertilizer application, but valued at the prices payable by farmers net of Government subsidy. The subsidy rate has been assumed to be 30 percent of the total cost of fertilizer. Although such a subsidy rate cannot be specified for future years, expansion of domestic fertilizer manufacturing capacity and reduced costs of procurement should reduce the costs of fertilizer. The net-of-subsidy assumption thus envisages an upper limit to the price farmers would pay for fertilizer which may approximate the full cost of fertilizer as domestic supplies increase. The O&M cost of implements has been set at 60 percent of the estimated cost of mechanization (including the purchase of spare parts) in the reference years 1975, 1985, and 2000. The allowance for "miscellaneous" costs rises in future years to cover the probability that farmers would become more dependent on other sectors for inputs such as processed feed for livestock, transportation, building materials, and the like. The itemized costs for all categories are shown in Table A10-6 for the different reference years.

Official estimates of gross value added make allowance for the fact that crop statistics provided by the Government of West Pakistan do not cover certain non-reporting areas. The 4 percent allowance made by the Central Statistical Office to compensate for this undercoverage is somewhat arbitrary, but the Study Group has followed the same procedure in order to reduce this source of discrepancy between its projections and official estimates.

These adjustments to the Study Group's projections of GPV give estimates of the gross value added in the reference years, as illustrated in Table A10-7. These estimates of gross value added are not strictly comparable to the official estimates because Forestry and Fishery have been omitted, but it is more comparable than the IACA estimates. The average allowance of 5 percent for price adjustment may either overstate or understate the difference due to prices alone, depending on the

TABLE A10–6
STUDY GROUP'S COST ESTIMATES
(Rs. million)

	1965	1975	1985	2000
Current Costs of Additional Water[a]	100	400	600	800
Historic Water Charges	131	131	131	131
Seed	261	367	636	763[b]
Fertilizer	84	650	1,060	2,051
Plant Protection	—	65	206	726
Implements	38[c]	78[d]	234[e]	468[f]
Miscellaneous	87	216	538	1,325
Subtotal for Crops:	701	1,907	3,405	6,264
Veterinary Care	—	67	347	780
Total Costs	701	1,974	3,752	7,044

[a] Based on O&M costs of future facilities providing increases in irrigation supplied.
[b] 20 percent increase over 1985 costs to allow for better quality seed.
[c] 6,000 tractors × Rs. 25,000.
[d] .60 × Rs. 130 million.
[e] .60 × Rs. 390 million.
[f] .60 × Rs. 780 million.

TABLE A10–7
STUDY GROUP'S PROJECTIONS OF GROSS VALUE ADDED BY WEST PAKISTAN AGRICULTURAL SECTOR, EXCLUDING FORESTRY AND FISHERY

	1965	1975	1985	2000
Crops:		(Rs. million)		
GPV Crops	5,366	8,798	14,110	21,396
Plus: Price Adjustment (5.0%)	268	440	706	1,070
	5,634	9,238	14,816	22,466
Less Crop Costs	701	1,907	3,405	6,264
	4,933	7,331	11,411	16,202
Plus: Allowance (4%) for Nonreporting areas	197	293	456	648
Gross Value Added Crops	5,130	7,624	11,867	16,850
Livestock:				
GPV Livestock	3,327	5,614	9,786	19,373
Less: Livestock Costs	—	67	347	780
Gross Value Added Livestock	3,327	5,547	9,439	18,593
Total Gross Value Added:				
Crops and Livestock	8,457	13,171	21,306	35,443
Average Annual Growth Rate		4.5%	4.9%	3.5%

particular combination of crops assumed to be produced in any reference year beyond 1965, but it does eliminate some discrepancy due to the use of different price bases. The Study Group estimates also include an allowance for nonreporting areas. The estimates of gross value added by livestock in 2000 are apparently higher than the gross value added by crops, but this is mainly due to the inability to allocate costs more precisely. An important part of the "miscellaneous" costs would undoubtedly be incurred for livestock, and therefore the relative contribution to gross value added by crops should be about the same as in the estimates of gross production value.

IACA's Derivation of Elasticity Coefficients of Demand for Agricultural Products

As a base for deriving elasticity coefficients of demand for agricultural products, IACA used income elasticity coefficients estimated by FAO for all Pakistan.[1] To the extent that these coefficients were not directly representative of future demand elasticity for West Pakistan, IACA made a number of adjustments. The more important of these include:

1. The demand elasticity for cereals is projected to fall very sharply by 1985 to a point which indicates little further increases in per capita consumption of cereals beyond that date.
2. The elasticity of demand for sugar has been projected at levels below those generally assumed for developing countries experiencing increases in income. This results from IACA's findings that sugar consumption is already higher in West Pakistan than in other countries at a comparable stage of development. Sugar

[1] IACA's Comprehensive Report, Volume 2-B, Annexure 2.

TABLE A10–8
ELASTICITY COEFFICIENTS OF DEMAND FOR AGRICULTURAL PRODUCTS

			IACA			
			1975		1985	
	FAO[a]	1965	"High" Growth	"Low" Growth	"High" Growth	"Low" Growth
Cereals	0.50	0.55	0.25	0.35	0.05	0.05
Sugar and Gur	1.30	0.70	0.50	0.50	0.40	0.45
Pulses	0.30	0.30	0.30	0.30	0.30	0.30
Potatoes	—	0.50	0.50	0.50	0.50	0.50
Fruit and Vegetables	0.90	1.00	0.90	0.90	0.70	0.80
Fats and Oils	1.40	1.30	1.00	1.10	0.80	0.90
Milk and Milk Products	1.70	1.00	0.50	0.70	0.30	0.40
Meat	1.60	1.50	1.30	1.40	1.20	1.25
Eggs	2.20	2.00	1.70	1.90	1.50	1.60
Fish	1.50	1.40	1.10	1.20	0.90	1.00
Cotton	1.00	1.00	0.90	0.95	0.70	0.80

[a] Refers to all Pakistan.
Source: IACA's Comprehensive Report, Volume 2-B, page 17.

consumption is therefore not expected to rise as rapidly in the future in West Pakistan.

3. Similar reasoning has been followed in the case of milk and milk products. Present consumption is again high, in comparative terms, so the coefficients of demand elasticity have been adjusted downward for future years. In contrast to this, the coefficients for meat are somewhat higher because meat should become a more important source of protein and fats. This may imply a more drastic change in dietary habits and preference than is likely to occur.

Allowing for the above adjustments, IACA projected a set of demand elasticity coefficients which are compared against FAO's income elasticity coefficients in Table A10-8. The estimates of per capita consumption in future years are only moderately influenced by rather sizeable changes in the base year coefficients of elasticity. For example, a change of plus or minus 10 percent in the elasticity coefficient for cereals in the year 1965 would result in a change of about plus or minus 1 percent in the 1975 per capita consumption figure. A change of plus or minus 15 percent in the elasticity coefficient for 1975 would result in a change in per capita consumption of plus or minus 2 percent in 1985. This point is further demonstrated in the following illustration:

The IACA projections of per capita demand have been based on the following relationship:

$$Y_1/Y_0 - 1 = 2.3026\, e_0 . \log X_1/X_0$$

Where

Y_1 = per capita consumption in future reference year
Y_0 = per capita consumption in base reference year
e_0 = coefficient of demand elasticity in base reference year
X_1 = per capita GPP (expenditure) in future reference year
X_0 = per capita GPP (expenditure) in base reference year

To illustrate the effect of changes in demand coefficients, assume that the base year and future year estimates for a given commodity are:

Y_0 = 125 kg.
X_0 = Rs. 400
X_1 = Rs. 465
e_0 = 0.55.

Per capita consumption in the future reference year would then be:

$$Y_1/125 - 1 = (2.3026)(0.55) \log 465/400$$

or

$$Y_1 = (125)(1.08282)$$
$$= \underline{\underline{135 \text{ kg.}}}$$

If only the e_0 is changed, by a decrease of about 9 percent from 0.55 to 0.50, the resulting change in per capita consumption would be:

$$Y_1/125 - 1 = (2.3026)(0.50) \log 465/400$$

or

$$Y_1 = (125)(1.07530)$$
$$= \underline{\underline{134 \text{ kg.}}}$$

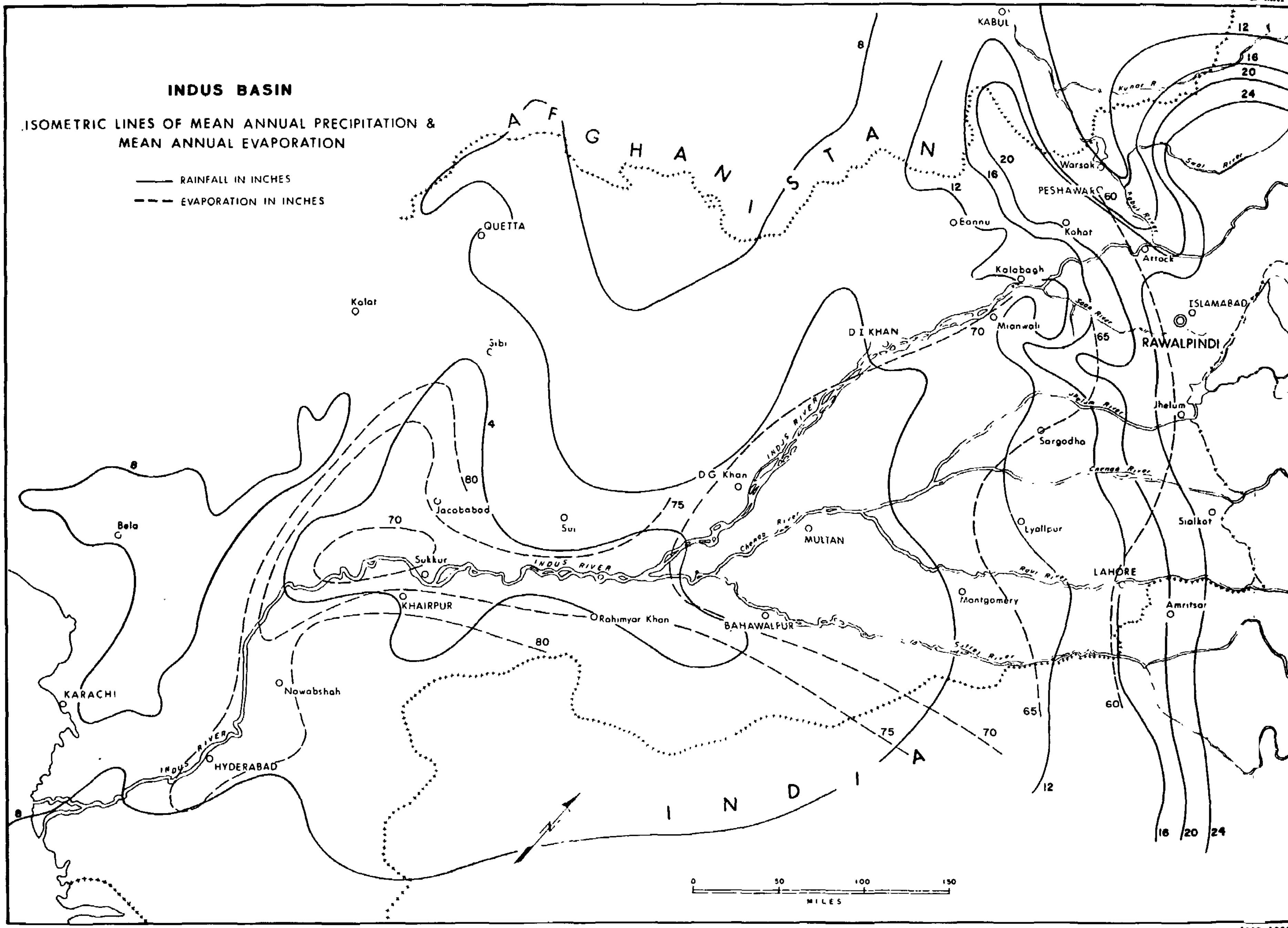
Similarly, an increase in e_0 of 9 percent from 0.55 to 0.60 would be:

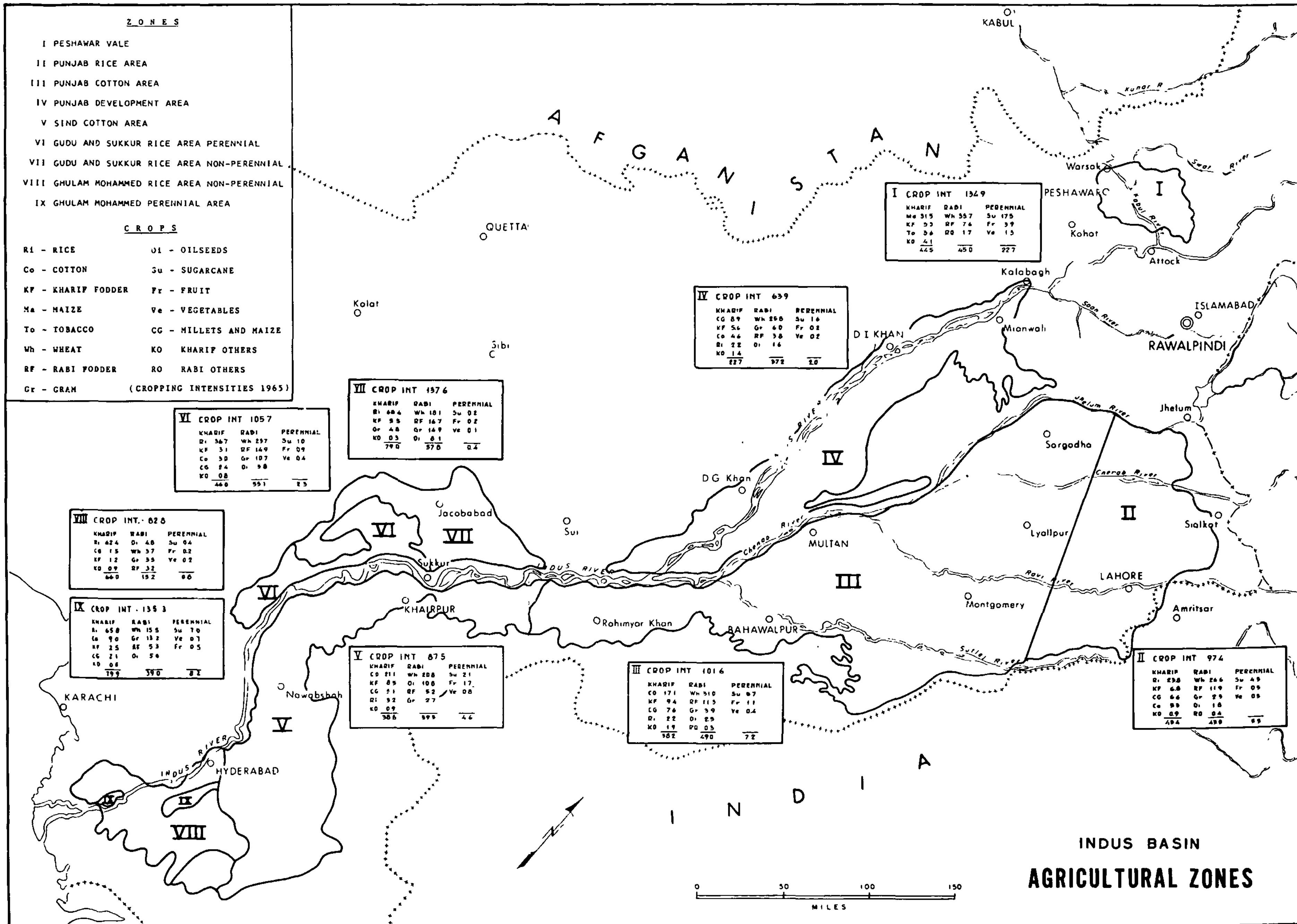
$$Y_1/125 - 1 = (2.3026)(0.60) \log 465/400$$

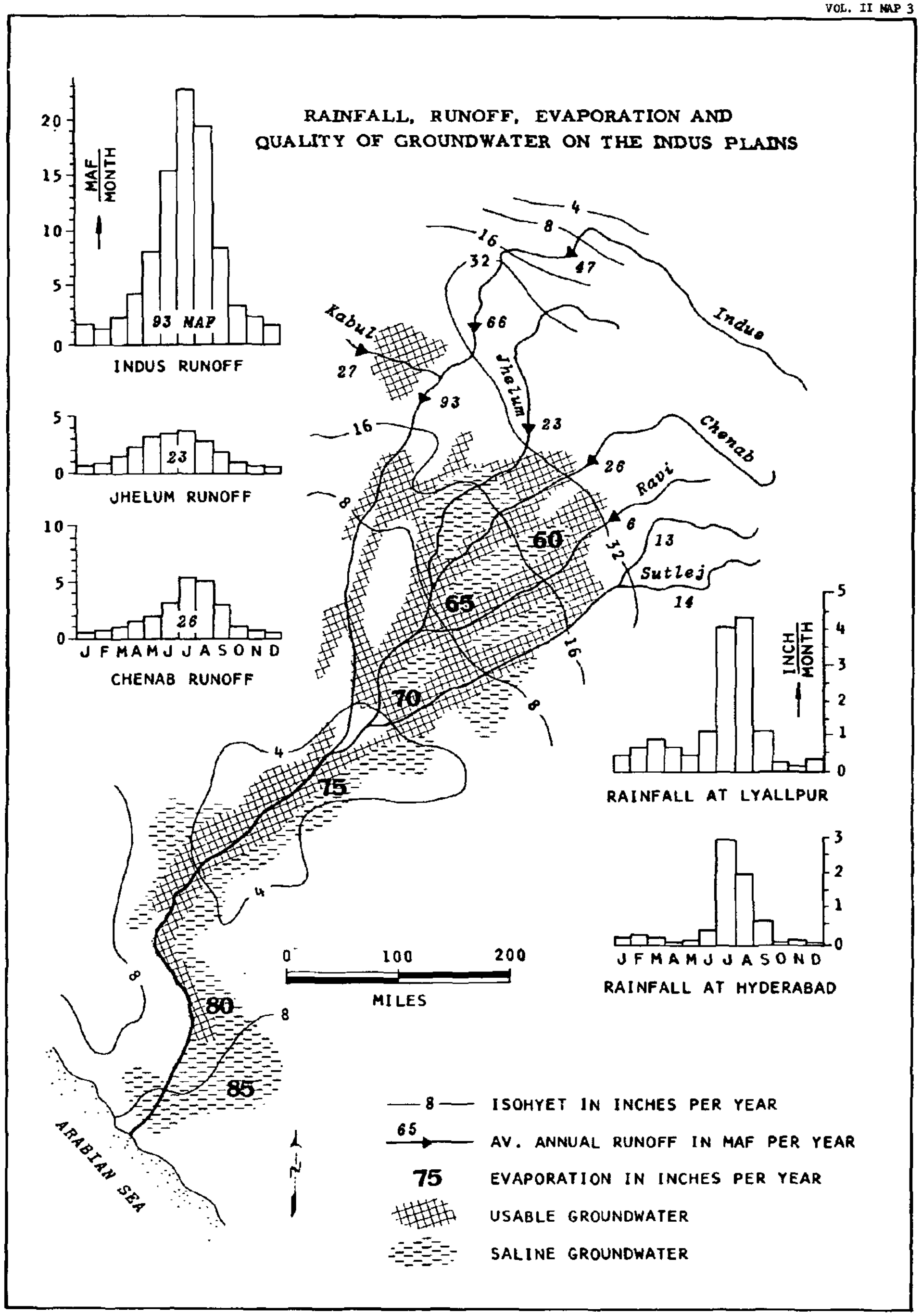
or

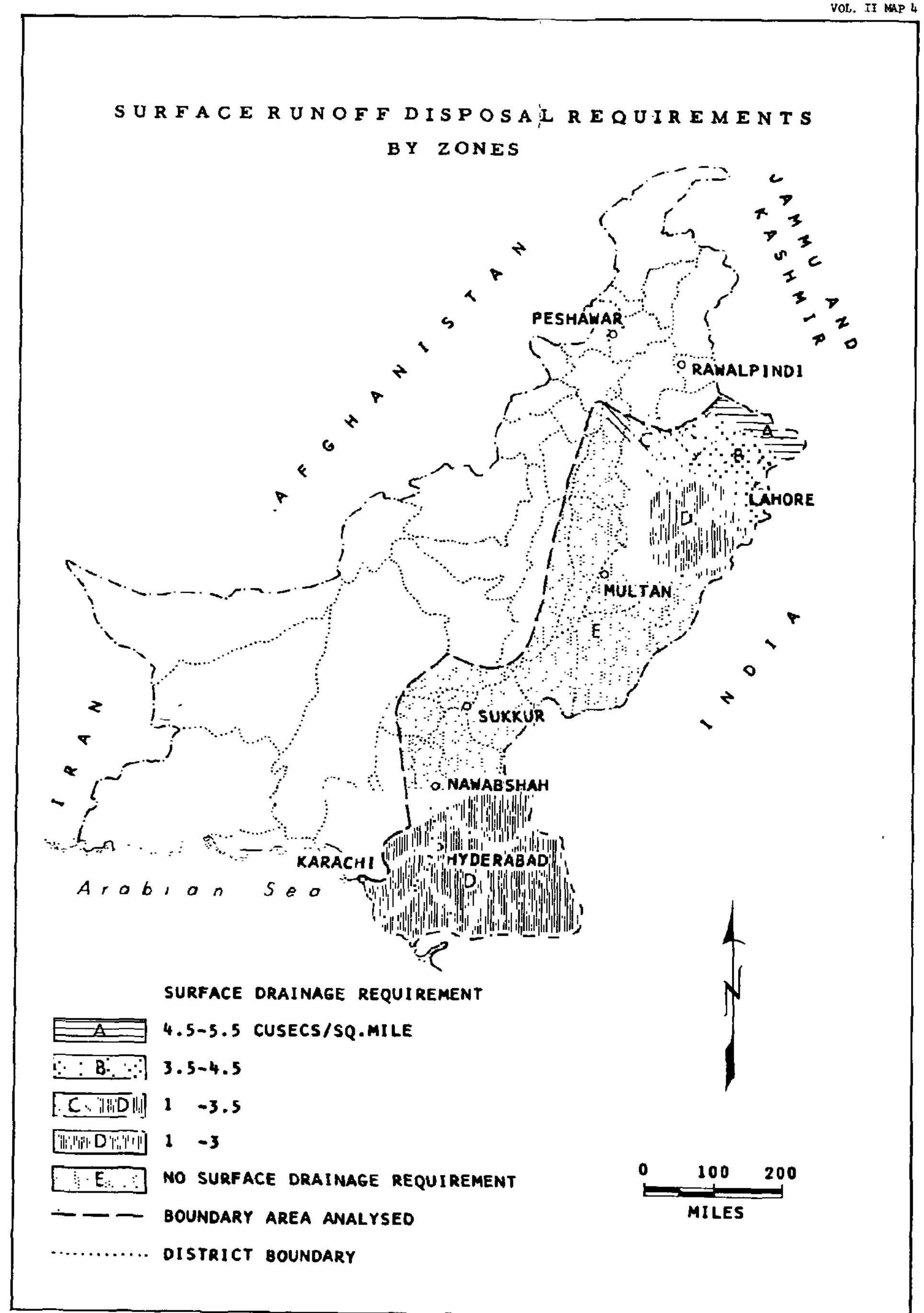
$$Y_1 = (125)(1.09035)$$
$$= \underline{\underline{136 \text{ kg.}}}$$

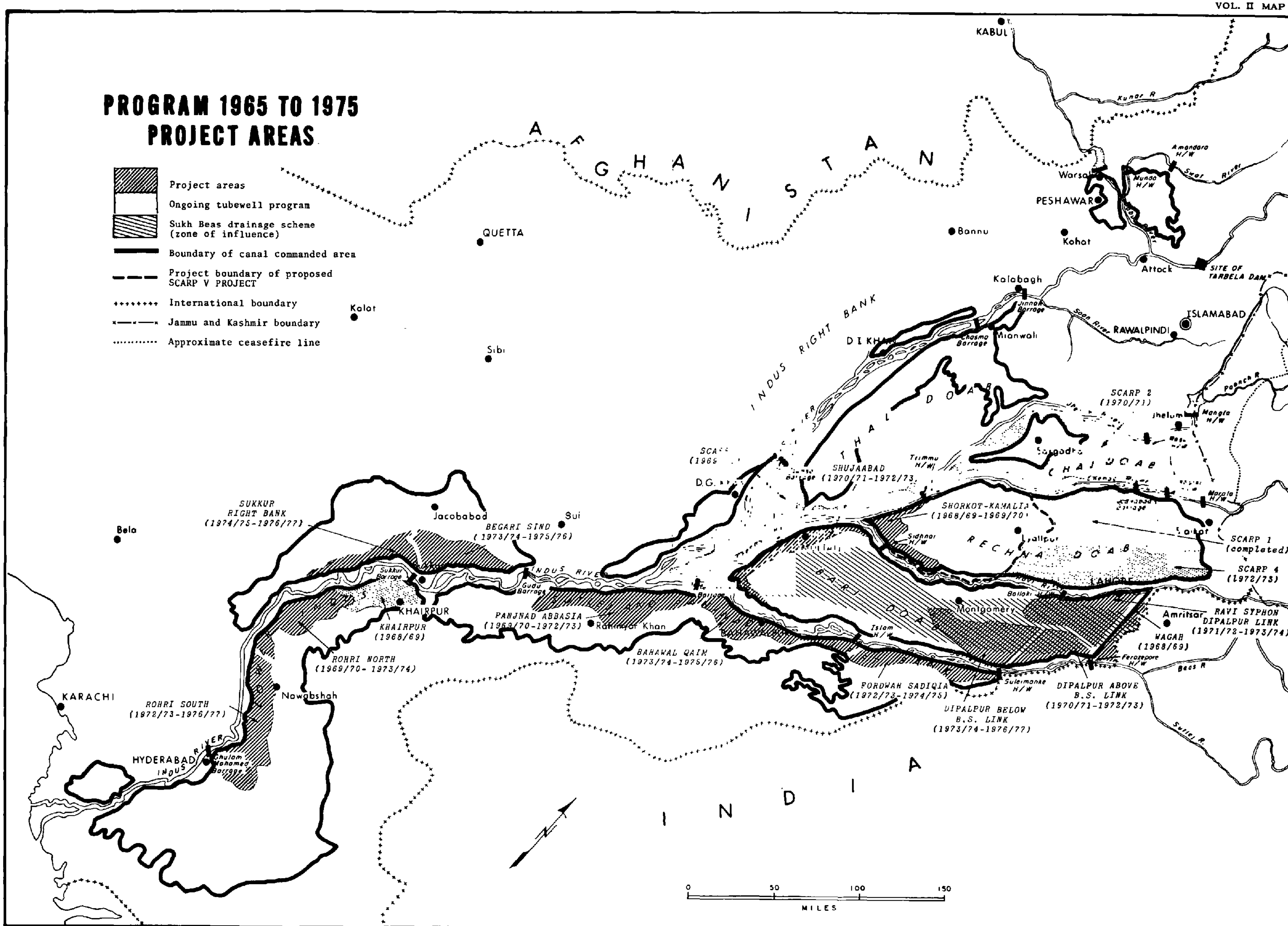
The changes in per capita consumption resulting from these adjustments in the coefficients are less than 1 percent. This level of relationship would vary with the size of the coefficients and the per capita expenditures concerned, but in general there should be only moderate changes in consumption as a result of fairly sizeable adjustments in a coefficient.


INDUS BASIN
ISOMETRIC LINES OF MEAN ANNUAL PRECIPITATION &
MEAN ANNUAL EVAPORATION
RAINFALL IN INCHES
EVAPORATION IN INCHES
AFGHANISTAN
INDIA
KABUL
QUETTA
Kalat
Sibi
Bela
KARACHI
Jacobabad
Sui
Sukkur
KHAIRPUR
Nowabshah
HYDERABAD
Rahimyar Khan
BAHAWALPUR
D G Khan
D I KHAN
MULTAN
Montgomery
Lyallpur
Sargodha
Mianwali
Kalabagh
Bannu
Kohat
PESHAWAR
Warsak
Attock
ISLAMABAD
RAWALPINDI
Jhelum
Sialkot
LAHORE
Amritsar
INDUS RIVER
Jhelum River
Chenab River
Ravi River
Sutlej River
Soan River
Kabul River
Kunar R
Swat River
N
0 50 100 150
MILES


ZONES
I PESHAWAR VALE
II PUNJAB RICE AREA
III PUNJAB COTTON AREA
IV PUNJAB DEVELOPMENT AREA
V SIND COTTON AREA
VI GUDU AND SUKKUR RICE AREA PERENNIAL
VII GUDU AND SUKKUR RICE AREA NON-PERENNIAL
VIII GHULAM MOHAMMED RICE AREA NON-PERENNIAL
IX GHULAM MOHAMMED PERENNIAL AREA
CROPS
Ri - RICE
Co - COTTON
KF - KHARIF FODDER
Ma - MAIZE
To - TOBACCO
Wh - WHEAT
RF - RABI FODDER
Gr - GRAM
Oi - OILSEEDS
Su - SUGARCANE
Fr - FRUIT
Ve - VEGETABLES
CG - MILLETS AND MAIZE
KO KHARIF OTHERS
RO RABI OTHERS
(CROPPING INTENSITIES 1965)
I CROP INT 1349
KHARIF RABI PERENNIAL
Ma 315 Wh 357 Su 175
KF 53 RF 76 Fr 39
To 36 RO 17 Ve 15
KO 41
445 450 227
IV CROP INT 639
KHARIF RABI PERENNIAL
CG 89 Wh 256 Su 16
KF 56 Gr 60 Fr 02
Co 46 RF 38 Ve 02
Ri 22 Oi 16
KO 14
227 372 20
VII CROP INT 1376
KHARIF RABI PERENNIAL
Ri 684 Wh 181 Su 02
KF 55 RF 167 Fr 02
Gr 48 Gr 149 Ve 01
KO 03 Oi 81
790 578 04
VI CROP INT 1057
KHARIF RABI PERENNIAL
Ri 367 Wh 237 Su 10
KF 31 RF 149 Fr 09
Co 30 Gr 107 Ve 04
CG 24 Oi 58
KO 08
460 551 23
VIII CROP INT.- 628
KHARIF RABI PERENNIAL
Ri 424 Oi 48 Su 04
CG 15 Wh 37 Fr 0.2
KF 12 Gr 35 Ve 02
KO 09 RF 32
460 152 06
IX CROP INT. 1353
KHARIF RABI PERENNIAL
Ri 658 Wh 155 Su 70
Co 90 Gr 132 Ve 07
KF 25 RF 53 Fr 05
CG 21 Oi 50
KO 05
799 390 82
V CROP INT 875
KHARIF RABI PERENNIAL
CO 211 Wh 208 Su 21
KF 85 Oi 108 Fr 17
CG 51 RF 52 Ve 08
RI 32 Gr 27
KO 09
386 395 46
III CROP INT 1016
KHARIF RABI PERENNIAL
CO 171 Wh 310 Su 57
KF 94 RF 113 Fr 11
CG 76 Gr 39 Ve 0.4
Ri 22 Oi 29
KO 19 RO 03
382 490 72
II CROP INT 974
KHARIF RABI PERENNIAL
Ri 238 Wh 266 Su 49
KF 6.8 RF 119 Fr 09
CG 66 Gr 29 Ve 05
Co 53 Oi 18
KO 0.9 RO 04
494 438 55
AFGANISTAN
INDIA
KABUL
Kunar R
Swat River
Warsak
PESHAWAR
Kabul River
Kohat
Attock
Kalabagh
Soan River
ISLAMABAD
RAWALPINDI
Mianwali
D I KHAN
QUETTA
Kolat
Sibi
Jhelum
Jhelum River
Sargodha
Chenab River
DG Khan
Jacobabad
Sui
MULTAN
Lyallpur
Sialkot
Sukkur
INDUS RIVER
Ravi River
LAHORE
KHAIRPUR
Rahimyar Khan
BAHAWALPUR
Montgomery
Amritsar
Sutlej River
KARACHI
Nawabshah
HYDERABAD
INDUS RIVER
I II III IV V VI VII VIII IX
N
0 50 100 150
MILES
INDUS BASIN
AGRICULTURAL ZONES

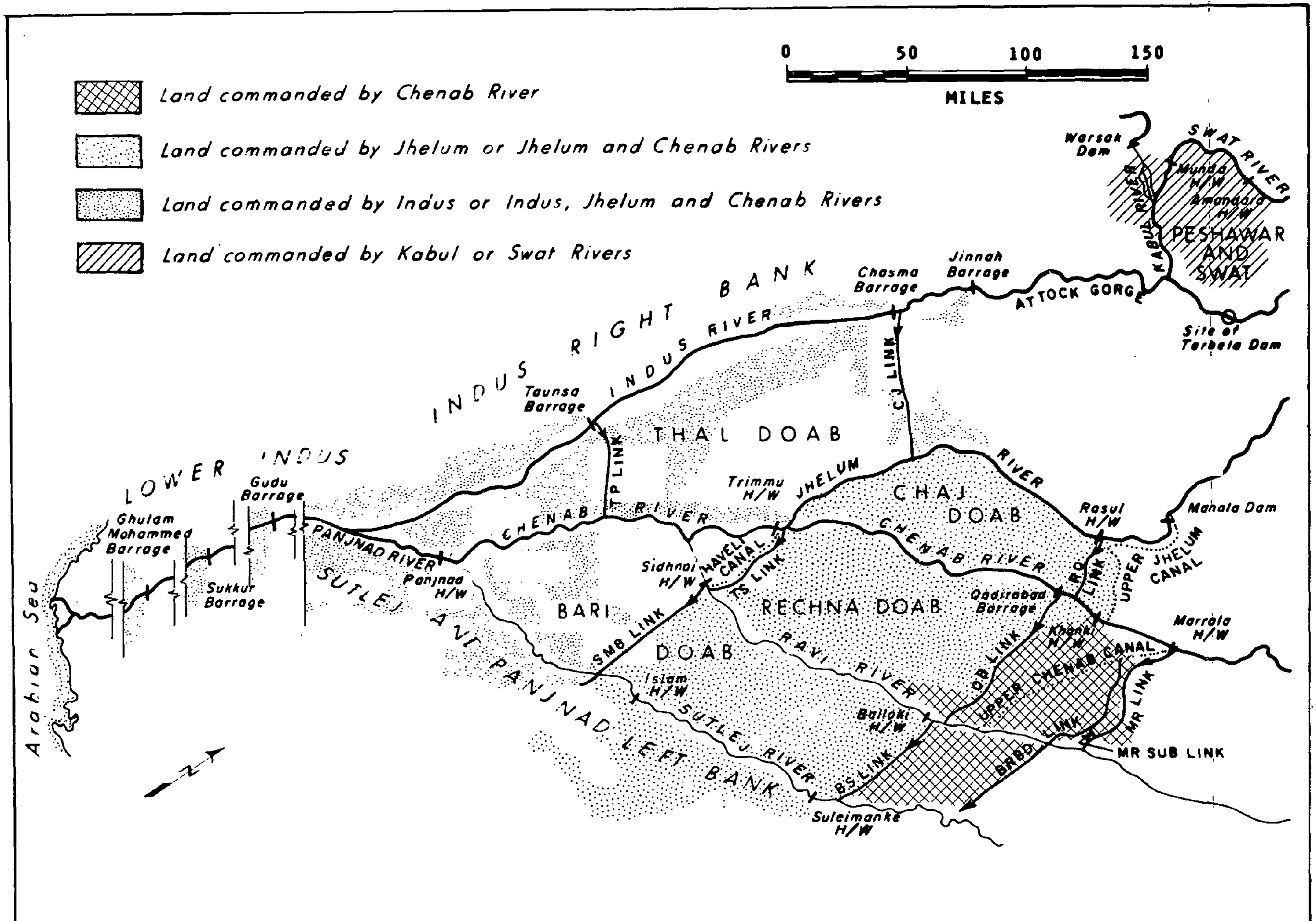

RAINFALL, RUNOFF, EVAPORATION AND
QUALITY OF GROUNDWATER ON THE INDUS PLAINS
MAF / MONTH
93 MAF
INDUS RUNOFF
23
JHELUM RUNOFF
26
J F M A M J J A S O N D
CHENAB RUNOFF
Kabul
Indus
Jhelum
Chenab
Ravi
Sutlej
INCH / MONTH
RAINFALL AT LYALLPUR
J F M A M J J A S O N D
RAINFALL AT HYDERABAD
0 100 200
MILES
ARABIAN SEA
60
65
70
75
80
85
8 ISOHYET IN INCHES PER YEAR
65 AV. ANNUAL RUNOFF IN MAF PER YEAR
75 EVAPORATION IN INCHES PER YEAR
USABLE GROUNDWATER
SALINE GROUNDWATER


SURFACE RUNOFF DISPOSAL REQUIREMENTS
BY ZONES
AFGHANISTAN
JAMMU AND KASHMIR
PESHAWAR
RAWALPINDI
LAHORE
MULTAN
SUKKUR
NAWABSHAH
KARACHI
HYDERABAD
IRAN
INDIA
Arabian Sea
SURFACE DRAINAGE REQUIREMENT
A 4.5-5.5 CUSECS/SQ.MILE
B 3.5-4.5
C D 1 -3.5
D 1 -3
E NO SURFACE DRAINAGE REQUIREMENT
BOUNDARY AREA ANALYSED
DISTRICT BOUNDARY
0 100 200
MILES



JULY 1967

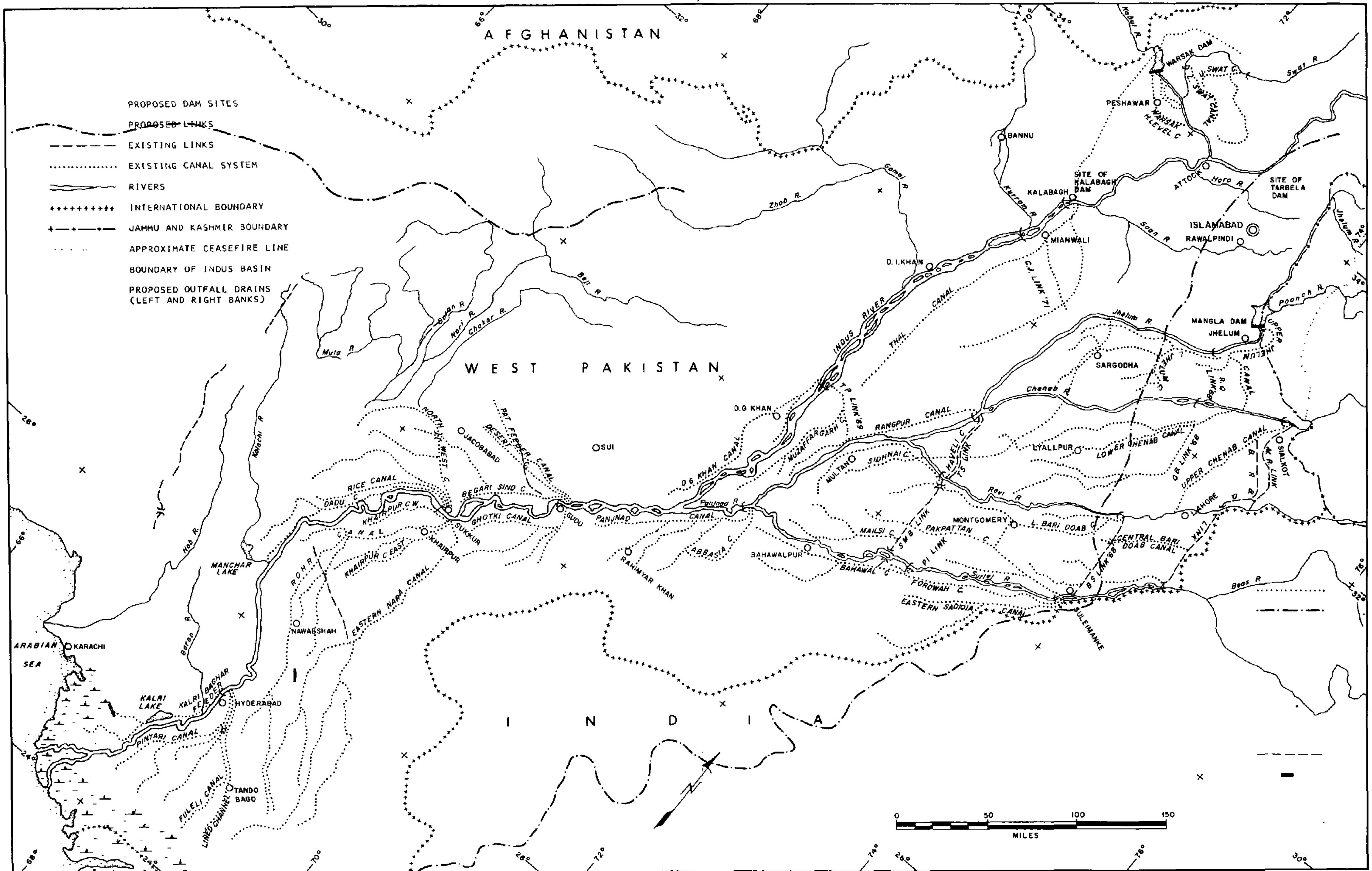
IBRD-1945R



RIVER AND LINK CANAL DISTRIBUTION SYSTEM

1971 Situation (including I B P Links)

INDUS BASIN - LOCATION OF CANALS AND LINKS



IBRD-1931R

The three volumes together represent core of the complete report made by Bank to the Government of Pakistan. Th present not only the Study Group's conc sions and recommendations but also invaluable record of the manner in whi the problems encountered were confront and solved, and how the Bank's consulta went about their work.

Volume I is a condensed, integrated versi of the analysis and results of the ent study, including an evaluation of the hu Tarbela project, the problems of agricultu development, the interaction of agricultu with other sectors of the economy, the d mand for power and means of meeting t demand, and areas of critical concern, su as the need for electrical interconnecti within West Pakistan.

Volume II gives a detailed discussion irrigation and agriculture, including the u of improved seeds, fertilizers, new croppi patterns, and modern techniques of hu bandry, in addition to the development water resources.

Volume III contains papers on the bac ground and methodology of the study, pa ticularly the macroeconomic framework, linear program of irrigated agriculture in th Indus Basin, and a computer simulation the power system.

PIETER LIEFTINCK, former Finance Ministe of the Netherlands, is an Executive Directo of the World Bank.

A. ROBERT SADOVE is Economic Adviser c the Bank's Projects Department.

THOMAS C. CREYKE is Adviser on Agricul tural Development, Agriculture Division c the Projects Department.

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