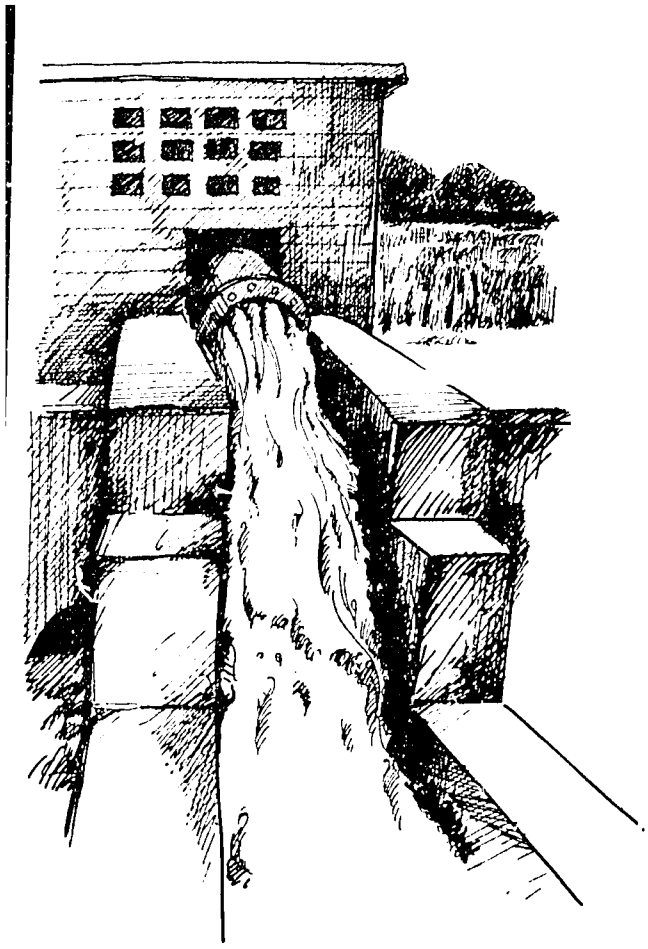
PN-ABH-019

PRIVATIZATION OF SCARP TUBEWELLS: SOME ECONOMIC CONSIDERATIONS

Special Report Series
No. 15



Pakistan Economic Analysis
Network (EAN) Project

PN-ABH-019
ISN 69663

PRIVATIZATION OF SCARP TUBEWELLS: SOME ECONOMIC CONSIDERATIONS

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No. 15

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Published by the Directorate of Agricultural Policy and Chemonics International Consulting Division for The Economic Analysis Network Project in collaboration with the Ministry of Food, Agriculture, and Cooperatives, Government of Pakistan, and the United States Agency for International Development under the provisions of USAID Contract 394-0491-C-00-5034

Islamabad
September 1989

DEFINITIONS AND ABBREVIATIONS

ACE	-	Associated Consulting Engineers, Ltd
AF	-	Acre foot
AVP	-	Average Value Product
CCA	-	Canal Command Area
Cusecs	-	Cubic Feet per Second
ERR	-	Economic Rate of Return
FC	-	Fixed Costs
FGW	-	Fresh Groundwater
FWIR	-	Farm Worker Income Ratio
GI	-	Gross Income
GOP	-	Government of Fakistan
Indus Basin	-	Pakistan's surface irrigation system encompassing Indus river and its tributaries, storage reservoirs, barrages, canals, and watercourses. This is the largest contiguous irrigation system in the world.
Irrigation efficiency	-	Ratio of water available at crop root zone to the water delivered at the watercourse head.
Kharif	-	Cropping season lasting from April to September.
KWH	-	Kilowatt per Hour
LIR	-	Land Income Ratio
MAF	-	Million Acre Feet
MVP	-	Marginal Value Product
NI	-	Net Income
O&M	-	Operation and Maintenance
PARC	-	Pakistan Agricultural Research Council
PID	-	Provincial Irrigation Department
Rabi	-	Cropping season lasting from October to March.
SCARP	-	Salinity Control and Reclamation Project
SGI	-	Specialists Group Incorporated
SGW	-	Saline Groundwater
USAID	-	United States Agency for International Development
Utilization rate	-	Ratio of tubewell's operation time to its maximum potential operation time.
VC	-	Variable Costs
WAPDA	-	Water and Power Development Authority
Warabandi	-	Water allocation system of Pakistan, where wara means turn and bandi means fixation. Under this system farmers take the full supply of water flowing in the watercourse for a period of time proportional to the size of their land holding, at a specific time once a week.
WUA	-	Water User Association

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EXECUTIVE SUMMARY

A comprehensive multi-decade large scale vertical drainage program called SCARP (Salinity Control and Reclamation Project) was started in the early 1960s to address the problems of waterlogging and salinity in Pakistan. Presently, some 12,500 tubewells (generally of 2-5 cusec capacity) installed under this program are serving an area of about 7.4 million acres, which is about 20 percent of the Indus Basin's cultivated area. More than 90 percent of SCARP capacity is located in fresh groundwater areas. The O&M of these tubewells is the responsibility of the Provincial Irrigation Departments (PIDs).

Aside from controlling waterlogging and salinity, SCARP tubewells have served as an important source of supplemental water supply. As a result, agricultural production has improved in the SCARP areas. However, in recent years these public tubewells have become increasingly expensive to operate. The pumping capacity has declined due to deficient maintenance which, in turn, is severely constrained by non-availability of funds.

To maximize social benefits from groundwater development, the government has decided to transfer the responsibility of groundwater extraction from the public sector to the private sector in fresh groundwater areas. This also includes transfer (or replacement) of SCARP tubewells to the farmers (or with farmer-owned tubewells).In this context, a pilot project was started in 1985-86 in SCARP I, but the government has expressed serious concerns about the high cost of transition approach being followed under this project.

The present study presents the analysis of three important policy issues. First, what is the value of water in SCARP areas? Second, what energy source should be used to operate the tubewells--diesel or electricity? Third, what is the economics of possible SCARP transition options? Analysis of these issues would not only help to fill the information void on some important decision parameters, but would hopefully provide broader bases for developing a practically oriented SCARP transition program.

The marginal value of water in the project area was estimated to be Rs 50 per acre inch under financial prices and Rs 149 per acre inch under economic prices. Comparison of the value of water relative to pumping costs indicates an extremely favorable return on investment. Net benefits attributable to water supplied by SCARP tubewells were estimated to be Rs 806 per acre. Accounting for drainage benefits would enhance the profitability of SCARP tubewells even further. Thus, the SCARP program does not appear to be overly expensive--given its high social rate of return in crop productivity and further if viewed as an insurance policy to prevent deterioration of an important irrigated land asset.

The financial cost of water pumped from electric and diesel-powered tubewells was estimated to be Rs 154 and Rs 225 per acre ft, respectively, which explains the users' current preference for electricity since it is subsidized. However, the economic cost structure indicates that electric tubewells are expensive to operate as compared to diesel tubewells. In addition, diesel tubewells can be regarded as a somewhat more reliable source of water, as they are not subject to the risks of intentional load shedding and frequent outages in the electrical system. The financial and economic variable costs of operating a SCARP tubewell

are relatively higher than those estimated to operate a small private electric tubewell.

In areas where SCARP tubewells are completely worn out, it seems appropriate to replace these tubewells with farmer-owned small tubewells. The success of this approach, however, depends upon the magnitude of economic incentives provided to the farmers to install tubewells. Since every farmer in the project area is unlikely to own a tubewell, benefits of groundwater development under this option would need to be shared mainly through the water markets. In practice, this option not only requires installation of a sufficient number of tubewells but also calls for proper locational distribution of these tubewells to ensure effective working of the water markets.

The management and operational functions of SCARP tubewells which are in operable condition may be transferred to private groups. In addition to having the political advantage of providing water equitably to all water users, this option would help in reducing government's O&M budget deficit. However, since Pakistan's experience in organizing private groups has not been very encouraging in the past, it is important to examine the practicability of various forms of private groups (such as individual farmers, farmers' groups like WUAs, and commercial firms) on a pilot basis. The operable SCARP tubewells should be kept operational unless they are replaced by equal alternative pumping capacity in the private sector to prevent waterlogging. As aging SCARP tubewells become inoperable, they should be allowed to die their natural death and farmers should be encouraged to replace these with smaller wells located in areas where needed.

To maximize social benefits from the groundwater management program, the public sector agricultural extension programs should educate farmers about various aspects of tubewell technology and efficient operation and maintenance procedures. Rural institutions should be strengthened to ensure efficient management of groundwater at the local level. Institutional rigidities implicit in the water allocation and distribution system should be removed, and frequent trading and marketing of water should be encouraged.

CHAPTER 1

SCARPS IN HISTORICAL PERSPECTIVE

1.1 Preliminaries

Irrigation has been practiced in the Indus Basin for at least two thousand years. The earliest efforts diverted flood water to lands near the major rivers. In the 19th century, the British developed the first large scale perennial systems. The objectives of these diversion programs were to insure against famine and to distribute the water widely so as to achieve equitable distribution as well as maximize the benefits of the scarce water resource. By the latter part of the 20th century, an area of over 33 million acres was under irrigation, said to be the world's largest contiguous irrigated area. Water is one of the most significant inputs to Pakistan's agriculture. Production function studies (Khan and Young, 1975; Hussain and Young, 1985) indicate irrigation water alone contributes some 30 percent of the total value of irrigated agricultural production.

The Indus Plain is underlain by a vast alluvial groundwater deposit (aquifer), which contains a supply of water measuring in billions of acre feet. The groundwater system was in hydrologic balance with the rivers prior to the introduction of large scale irrigation. However, the infiltration of irrigation water applied in excess of evapotranspiration needs and leakage from the canals and distributaries of the irrigation system added water to the aquifer more rapidly than the slow natural drainage on the flat Indus Plain moved it away. The result was a rising level of the aquifer.

When the water table approaches a few feet of the ground surface, crop productivity is threatened as soil aeration is lost and as dissolved salts, which always occur naturally in groundwater, are deposited in the upper soil zones. These problems, called "waterlogging" and "salinization" were identified in localized areas as early as a century ago. By the 1950s, the problem was so severe that over 5 million acres had been rendered unproductive and some 75 thousand additional acres were being lost annually[1]. Groundwater below the Indus Plain is, unfortunately, often highly saline. However, some two thirds of the Indus Plain is found to overlie waters of a quality suitable for irrigation.

Solutions to waterlogging and salinity problems calls for choices based on a combination of technological and institutional options. Technological choices are basically between "horizontal" and "vertical" drainage systems. The former system collects the excess sub-surface water and carries it away from the drained site, while sub-surface water is lifted through pumps to the surface for eventual disposal under the latter system. Horizontal systems are very capital-intensive, but generally speaking, are preferred when reclamation from soil salinization is a significant purpose of the effort and when the drainage water is highly saline. Open collector drains may be less expensive than buried tile, but use up valuable land. Vertical drainage, in general, is less capital intensive but a heavy user of energy. However, when the quality of the water pumped is satisfactory, low-lift pumping

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[1]. See S.H. Johnson,III, (1982) for a detailed historical review of the problem.

provides an inexpensive source in water deficient areas, and provides an important external benefit by helping maintain the water table at most suitable levels.

On the institutional side, drainage has properly been regarded as a collective problem. There are a few situations in which the individual farmer can economically collect and dispose of the effluent from waterlogged soils. A typical institutional arrangement in U.S. involves creation by a majority vote landowners of a drainage "district" with power to tax and to borrow. The district installs and operates the structural drainage system and pays off loans, if necessary, with tax revenues over a several year period. Properly planned surface irrigation projects should anticipate eventual drainage problems and give early consideration to facilities and land area required to alleviate them.

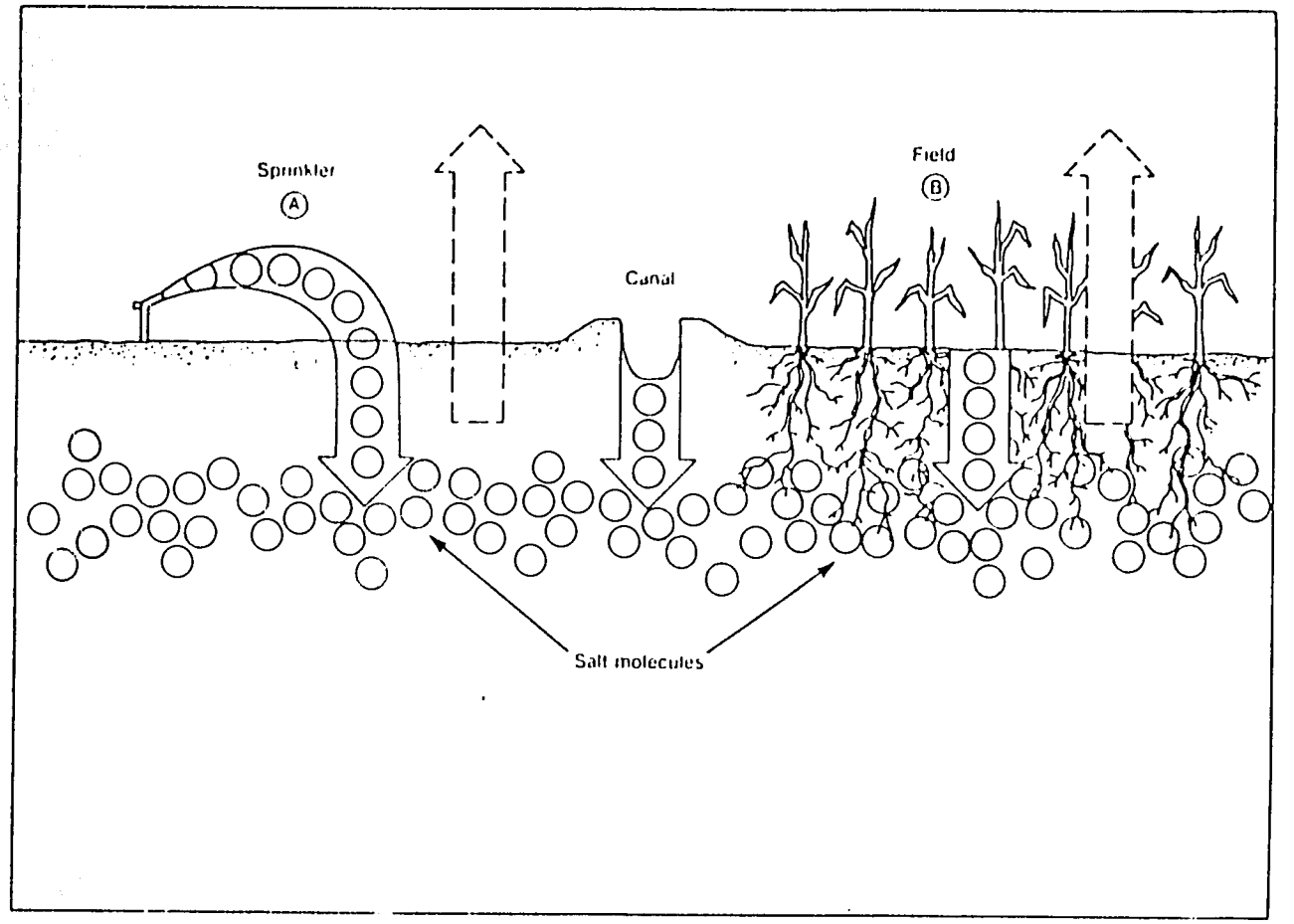
1.2 Process of Salinization and Waterlogging

Natural dissolution of rocks and soils mineralizes the surface and groundwater supplies. When this water is used to irrigate the crops, salts are carried into the soil and root zone. This process is illustrated in Figure 1.1; the small circles in the water pathway represent salts. The upward pointing arrows indicate the water that evaporates from the plants or from the soil surface. Since the quantity of minerals taken up into plants and subsequently removed with the harvest is negligible, the minerals generally remain in the soil. Rising mineral concentration in the soil can eventually reach levels detrimental to plant growth (Yaron, 1986). The effect is analogous to the stress effects of water shortage: salt in the soil water forces the plant to exert more energy to extract water from the soil and reduces its growth (Young and Horner, 1986).

To restore crop productivity, where water supplies permit, farmers apply the larger amount of irrigation water per unit of land. As the excess water drains below the root zone, it carries a portion of the soluble salts below the level at which the plant roots extract moisture, thus restoring crop productivity. However, this process leads to another problem called "waterlogging". Water drained below the root zone percolates down until it reaches an aquifer or an impermeable layer. Since the mineralized soil water is several times as saline as the irrigation water, it begins to fill the space below the root zone. Consequently, it contributes to a rising water table.

These are long term processes which eventually cause a two-way negative impact on crop production. First, when the water table rises into the root zone, it cuts off the oxygen, thus creating an adverse environment for crop production. Second, as the water evaporates into the atmosphere from the capillary fringe above the water table, it pulls more salts upward with the water. These salts remain in the upper soil layer as the water evaporates, after a time becoming concentrated enough to inhibit or even destroy the crop production potential.

Figure 1.1. Irrigated Field in Cross-Section Illustrating Pathways of Water and Deposition of Salts



Source: Young and Horner (1986). "Irrigated Agriculture and Mineralized Water" in Agriculture and the Environment, Resources for the Future, Washington, D.C.

1.3 Background of SCARP Tubewells

Extensive developments in the Indus irrigation system over the last century and lack of appropriate drainage facilities have caused severe waterlogging and salinity in large areas of Punjab and Sind provinces, where most of the country's food and fiber crops are produced. Public tubewells were first used in the 1940s to address waterlogging and salinity problems. These attempts were generally unsuccessful, mainly because they were not on a sufficiently widespread scale. The first large scale Salinity Control and Reclamation Project (SCARP), with one to five cusec (cubic feet per second) capacity tubewells, was started in 1959 and completed in 1963.

Realizing that vertical drainage can be used to control waterlogging problems as well as to supplement surface irrigation supplies with groundwater, a comprehensive multi-decade program was developed by the Water and Power Development Authority (WAPDA) for the whole of Pakistan in the early 1960s. Implementation of this program required commitment of huge financial resources. Since there were many different issues concerning technological options and the role of public and private sectors in developing groundwater resources, the plan was reviewed by several individual experts and consulting groups appointed by the Government of Pakistan (GOP) and the World Bank[2]. These reviews generally endorsed the SCARP concept as an appropriate drainage technology and the basis for subsequent SCARP investments (World Bank, 1986).

Since 1960, some 12,500 tubewells (generally of 2-5 cusec initial capacity) have been installed under 11 major and minor SCARPs in all the provinces. These tubewells serve an area of about 7.4 million acres, which is about 20 percent of the Indus Basin's cultivable area. A province-wise break down of completed and under construction SCARPs is shown in Table 1.1. Almost all of the completed projects are located in fresh groundwater (FGW) areas, though a third of the Indus Plain is underlain with saline groundwater (SGW). However, under the ongoing projects, 40 percent of the new tubewells are to be located in SGW areas. Estimated cost of completed and under-construction projects is US $ 5.5 and 1.2 billion at current prices (World Bank, 1986). Concentration of SCARP tubewells in FGW areas implies that provision of supplemental water has emerged as a primary objective of these tubewells in addition to meeting the drainage requirements.

1.4 Performance and Evaluation: An Overview

Over the last 20 years, a number of studies have been carried out to assess the performance and impact of SCARP tubewells on agricultural productivity. These evaluations typically focused on parameters such as: water supply from SCARPs, waterlogging and salinity control, impact on crop yields and cropping intensities, design and technology of tubewells (including their maintenance problems), and financial and economic impacts of tubewells.

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[2]. A list of various consulting groups appointed and reports prepared by them are reviewed in historical order in "Public and Private Tubewell Performance: Emerging Issues and Options", Pakistan Subsector Report, World Bank, 1983.

Table 1.1. Summary Inventory of SCARPs in FGW and SGW Areas as of 1986

Name of SCARP	a FGW Areas		b SGW Areas		TOTAL	
	c CCA e (M.Ac)	d TWs (No.)	CCA (M.Ac)	TWs (No.)	CCA (M.Ac)	TWs (No.)
I. COMPLETED						
PUNJAB						
1. SCARP I	1.14	2069	-	-	1.14	2069
2. SCARP II	1.50	2205	-	-	1.50	2205
3. SCARP II(FGW)	-	-	0.55	816	0.55	816
4. SCARP III	0.95	1635	-	-	0.95	1635
5. SCARP IV	0.55	935	-	-	0.55	935
6. Allahbad	0.20	623	-	-	0.20	623
7. Other SCARPs	0.44	1367	0.163	150	0.60	1517
Punjab Total	4.78	8834	0.713	966	5.49	9800
SIND						
1. Khairpur	0.13	175	0.25	365	0.38	540
2. North Rohri	0.69	1192	-	-	0.69	1192
3. Sukkur RB	0.13	400	-	-	0.13	400
4. Other SCARPs	0.03	129	-	-	0.03	129
Sind Total	0.98	1896	0.25	365	1.23	2261
NWFP						
1. Bannu	0.08	176	-	-	0.08	176
2. Others	0.213	263	-	-	0.213	263
NWFP Total	0.293	439	-	-	0.293	439
Pakistan Total (Completed)	6.04	11169	0.97	1331	7.00	12500
II. UNDER CONSTRUCTION						
PUNJAB						
1. SCARP VI	-	-	1.20	307	1.20	307
2. Drainage IV	-	-	0.20	f	0.20	f
3. Others	-	-	0.50	357	0.50	357
Punjab Total	-	-	1.90	664	1.90	664
SIND						
1. South Rohri	0.37	1530	-	-	0.37	1530
2. Ghotki	0.40	1350	-	-	0.40	1350
3. LBOD Stage 1	-	-	1.40	1400	1.40	950
4. Others	-	-	3.20	g	3.20	-
Sind Total	0.77	2880	4.60	1400	5.37	4180
NWFP						
1. Mardan SCARP	-	-	0.17	-	0.17	-
NWFP Total	-	-	0.17	-	0.17	-
Pakistan Total (Under construction)	0.77	2880	6.67	1964	7.44	4494
GRAND TOTAL: PAKISTAN	6.81	14049	7.63	3395	14.40	17444

a. Fresh Groundwater; b. Saline Groundwater; c. Canal Command Area; d. Tubewells;
e. Million acres; f. No tubewells since tile drainage is used; g. Surface drainage scheme only.
Source: Pakistan SCARP Transition Pilot Project, World Bank, 1986.

These evaluations are based on data up to 1977 and reviewed in detail in a World Bank study (1983). Major findings of these studies are discussed in this section and updated data for certain parameters are utilized to synthesize the main issues.

1.4.1 Water Supply

Available data show that pumpage in various SCARPs has been declining consistently over time. WAPDA (1979) estimated pumpage of only 7 MAF from approximately 10,200 public tubewells as against their designed capacity of about 23.1 MAF. Recent statistics (Table 1.2) show that in SCARPs I, II, III, and IV there has been 48, 32, 21 and 27 percent reduction in reported pumpage as compared to initial planned pumping capacity, respectively. The discharge capacity has declined at an average annual rate of about 3.7, 3.0, 5.7, and 6.7 percent in SCARPs I, II, III, and IV, respectively. The pumpage has declined in addition to normal expected depreciation design problems, high O&M costs, inadequate O&M, and less than optimum management practices.

1.4.2 Waterlogging and Salinity Control

The available data show that waterlogging and salinity problems have improved in the SCARP areas, but not to the extent anticipated in project plans. Shortfalls could be attributed to consistent decline in pumpage and pumping capacities. For the 0-5 ft interval, 24 percent of the SCARP commands are waterlogged, compared to about 30 percent of the Indus Basin as a whole. Table 1.3 shows the areas under different water table depths in SCARP I. The data do not exhibit any specific pattern, but clearly indicate that the area recently under critical range (0-5 ft) is significantly lower than the pre-project levels. However, the waterlogging relief provided by SCARP tubewells rapidly diminished in cases where tubewells were abandoned due to high salinity or mechanical breakdowns (Bokhari, 1980). In SCARP areas though the public tubewells have been successful in lowering the water table, only a small fraction of salt-effected soils has been effectively reclaimed (GOP, 1988).

1.4.3 Agricultural Production

The available information indicates improvements over pre-project conditions in terms of higher yields, higher cropping intensities, and some shifts toward more water responsive and higher value crops. However, the ambitious agricultural production targets set at the planning stage were not fully realized. Some unrealistic assumptions regarding availability and use of water and non-water inputs are reported to have restrained the achievement of planned targets. At the same time, improvements that occurred in SCARP areas cannot be attributed only to installation of public tubewells as significant growth in use of private

Table 1.2. Reduction of Pumpage in Selected SCARPs

Name of SCARP	Name of Scheme	Initial Planned Pumping Capacity (cfs)	Subsequent Pumping from initial level (cfs)	Percentage Reduction (%)	Period of Operation (Years)
SCARP I		6343	3329	48	13
SCARP II	Lalian	676	468	31	13
	Mona	456	322	29	11
	Khadar	988	637	35	9
SCARP III	Alipur	2362	1757	26	4
	Kot Adu	2391	2049	14	3
	Rangpur	2411	1856	23	4
SCARP IV		4483	3289	27	4
SCARP V	Khairpur	1248	1099	12	9
SCARP	North Rohri	3663	3029	17	7

Source: Control of Waterlogging and Salinity by WAPDA. Report of National Seminar on Waterlogging and Salinity, WAPDA, Lahore, 1986.

tubewells has taken place and production technology has improved as well[3].

1.4.4 Design and Technology

SCARP tubewells utilized imported turbine pumps ranging from 1 to 5 cusecs capacity. These tubewells pumped water into main watercourses, but no provisions were made for enlarging the size of watercourses to accommodate flow which at times was two to three

[3]. How much of the increase in crop yields is a function of new high yielding varieties and what percentage is a function of additional groundwater supplies is unknown (Johnson III, Sam,H. 1984). Moreover, how much of the agricultural improvements are due to increased water supply and what percentage is a function of waterlogging and salinity control is also unknown.

Table 1.3. Areas Under Different Water Table Depths in SCARP I, (Percent of Gross Area)

Period	Percent Areas With Depth Ranges		
	0-5 feet	5-10 feet	10-15 feet
Pre-project			
June 1961	13.5	61.2	25.3
June 1970	Nil	12.5	87.5
June 1971	Nil	8.1	91.9
June 1972	Nil	8.3	91.7
June 1973	0.4	9.2	90.4
June 1974	0.1	16.1	82.9
June 1975	1.0	15.6	83.4
June 1976	2.5	20.6	76.9
June 1977	2.2	30.4	67.4
June 1978	1.2	26.0	72.8
June 1979	3.2	37.5	59.3
June 1980	1.2	26.5	72.3
June 1981	4.1	45.1	50.8
June 1982	8.9	41.2	49.9
June 1983	5.3	38.7	56.0
June 1984	0.7	25.3	74.0
June 1985	0.1	21.5	78.4
June 1986	2.6	24.6	72.5
June 1987	2.2	24.8	73.0

Source: Assembled by senior author from office files of Scarp Monitoring Organization, WAPDA, Lahore.

times their designed flow. In some areas, a special diversion box was used to allocate public tubewell water to two or more watercourses. In actual practice, according to some reports (USAID, 1970), many of the diversion boxes are being illegally bypassed and the tubewell water is serving only one watercourse. Appropriate mixing ratios between canal and tubewell water were not achieved. Other sources (Harza, 1978; WAPDA, 1979) point out that inadequate design, construction, and maintenance of screens and gravel packs have resulted in low capacity utilization rates. Over time, improvements in tubewell design and construction have not been achieved due to inadequate feedback from field experience and absence of systematic research on various aspects of tubewell technology.

1.4.5 Operation and Maintenance

SCARPs were planned, designed and constructed by WAPDA. For the first one or two years, these were operated by WAPDA and then handed over to Provincial Irrigation Departments (PIDs) for operation. The tubewells need far greater and more frequent attention than do canals, but the tempo and style of field control and monitoring for tubewells is almost the same as for operating canals (Ali, *et al.*, 1981). Pumping schedules were never made compatible with estimated canal water supplies and crop water requirements. Tubewell operators are, of course, not willing to work for 24 hours a day. They remain frequently absent from tubewells and, alternatively, allow the farmers to operate tubewells. This practice has resulted in damaging of motors and other protective devices. Frequent electric breakdowns[4] further aggravate an already deficient operational schedule.

The pumping capacity of SCARP tubewells is reported to have declined due to deficient maintenance of screens and gravel packs. Various surveys have shown that, at any point in time, anywhere from 25-40 percent of the SCARP tubewells were not operating due to maintenance related defects. Maintenance is seriously constrained by the lack of availability of funds. The funds left for maintenance and repairs of a tubewell after meeting power costs come to Rs 38 per tubewell per month (Ali, *et al.*, 1981). Moreover, in cases when funds were available, a slow, cumbersome, and centralized decision making process caused unnecessary delay in fixing the problems.

This experience points out one of the inadequately recognized disadvantages of relatively large publically owned and managed tubewells. The wells are too valuable and too technically complex to be left alone for any length of time. The wells are typically not spaced close enough together to permit an operator to be responsible for more than one well. The operator, meanwhile, has little to do when the equipment is properly functioning. Therefore, the wage costs of full time attendants would be very large, and the PIDs have chosen to have, in effect, part-time operators and to assume the risks of breakdowns at the hands of farmers and the costs (of foregone productivity and waterlogging control) from frequent stoppages. In contrast, a privately owned, presumably smaller tubewell could be monitored as needed by its owner while he is performing other useful tasks related to irrigation and crop production. Further, the private owner would be expected to have a more personal interest in protecting the productive capacity of a well which he was paying for himself.

1.4.6 Financial Burden

Inadequate funding for tubewell replacement and O&M have hampered the performance of SCARP tubewells. The share of the O&M budget for SCARP tubewells in the total O&M budget is continuously increasing, though the operating efficiency of tubewells is

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[4]. SCARP power lines have frequently been over-loaded due to the grant of numerous private connections by WAPDA from these lines.

declining. Subsidies on SCARP tubewell water has been a source of major concern in recent years. For example, in 1985-86, subsidies were Rs 142 per acre served by SCARP wells in Punjab province (Chaudhry, 1986). Higher O&M allocations for SCARP tubewells translate into availability of less funds for O&M of the country's vast surface irrigation system, resulting in continuous deferred maintenance, which has a very high social cost (Chaudhry and Ali, 1989). Low water charges, deficient budgeting procedures, and overall tight budgetary constraints are the principal reasons for not allocating funds required for maintenance of the tubewells.

1.4.7 SCARPs Economics

Ex-post evaluations for selected SCARPs show that the economic rate of return (ERR) varies from marginal to unacceptable levels (World Bank, 1983). For example, an economic analysis of SCARP I indicated a rate of return of only 6 percent; with water pumpage, crop yields, and cropping intensities being less than in the adjoining areas with private tubewells (GOP, 1988)[5]. The economic viability of SCARPs has been reported to be adversely affected because the underlying assumptions were optimistic and have frequently proven to be incorrect. As it turned out, the planners underestimated the energy cost and O&M requirements for public tubewells and the rate of growth in private tubewells, but overestimated the agricultural production increases and the life of public tubewells. Also, management problems arose which often were not anticipated at the planning stage.

1.4.8 SCARP Transition Concept: Origins and Present Status

The above review suggests that SCARPs performance has fallen short of its targets due to a variety of economic, technical, financial, and management reasons. Most importantly, the public tubewells take up about 60 percent of the country's irrigation O&M budget, thus leaving very little for an already deteriorating canal irrigation system. On the other hand, SCARPs have undoubtedly contributed importantly to their primary role of controlling waterlogging and salinity. Benefits of conjunctive groundwater use demonstrated by SCARP tubewells induced tremendous growth in private tubewells which, in turn, also played an important role in increasing agricultural production by providing supplemental water and controlling waterlogging.

Success of private tubewells in fresh groundwater zones, serious O&M problems associated with public tubewells, severe budgetary constraints, and failure of SCARP tubewells to provide reliable supplemental irrigation at a sustainable cost have been the important factors in the emergence of the "SCARP transition concept". This concept suggests shifting the responsibility for groundwater development from government to farmers, mainly by using small capacity (1 cusec or less) tubewells in FGW areas. This idea was a major recommendation of the study completed by WAPDA (1979), and later on was declared as

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[5]. It is somehow not clear from the reports reviewed in this section that whether their evaluations were based on benefits attributable to supplemental irrigation water supply or drainage or both.

a policy objective in the Sixth Five Year Plan (1983-88).

During the first half of the 1980s, several feasibility studies were conducted to investigate issues relating to SCARP transition[6]. At GOP request, the World Bank agreed to serve as an executing agency. The feasibility reports were reviewed by the experts from the GOP and the World Bank, and it was decided to take up SCARP transition on a pilot basis within a selected area of SCARP I. Khanqah Dogran block was selected as a representative site for the pilot project. The World Bank appraisal of the pilot project was based on a feasibility study conducted by the local consultants, Associated Consulting Engineers (ACE) and Specialists Group Incorporated (SGI) in 1985 in the project area.

The pilot project cost of RS 380 million for the replacement of 213 tubewells appears to be unexpectedly high. The pilot study includes a high foreign exchange component which probably is unnecessary (GOP, 1988). At this cost, replacement of 7,500 usable groundwater SCARP tubewells would cost about Rs 13,500 million. Our discussions with the farmers in the pilot project area and project management revealed that the pilot project is falling short of its targets. For example, in the first year of the project (1986-87), 25 SCARP tubewells were scheduled for replacement with 239 small tubewells, comprising 50 diesel and 189 electric operated tubewells. In contrast, only 24 tubewells (19 diesel and 5 electric) were actually installed by the end of 1987. Once again, it seems that the validity of underlying assumptions is in question. For instance, agricultural credit has not been made available to farmers to buy tubewell machinery as anticipated, and the process of providing electric connections is extremely slow. As of November 1987 not a single public tubewell had been abandoned in the pilot project area which has caused problems for the farmers who have installed tubewells under the SCARP transition program[7].

1.5 Objectives and Scope of Study

The above review of the performance of SCARP tubewells tends to suggest that their functions be privatized. However, there are certain important issues which require more careful and indepth analysis before a large scale SCARP transition program could be conceived and implemented.

The overall objective of the present study is to identify and analyze issues which would contribute to further understanding of the economic aspects related to the SCARP tubewell privatization program. This includes estimation of financial (private) and economic (social)

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6. For details see: (1) SCARP Transition Project, Draft General Reconnaissance Report by Associate Consulting Engineers (ACE) Ltd. and Specialists Group Incorporated (SGI), 1983. (2) SCARP Transition and Improvement Project, Feasibility Report (Five Volumes) by ACE-SGI, 1984.

7. Some small farmers in the pilot project area told us that though they have installed tubewells under the SCARP transition program, they have not yet operated these because water supply from SCARP tubewell is sufficient to irrigate their crops. These farmers advocated that SCARP tubewells should be abandoned as promised by the GOP; so that they could make their investments profitable by pumping more water and selling it to the adjoining farmers. Contrarily, farmers who have not installed their own tubewells naturally favored the continuation of SCARP tubewells.

value of water in SCARP areas. Estimates with respect to value of water provide signals for investment in irrigation development, and serve as basis to determine farmers' ability to pay for the irrigation service. Also, financial and economic costs of pumping groundwater under different energy sources (electricity and diesel) are estimated to assess the implications of government's energy and fuel pricing policy. These estimates can be compared with the value of water to determine the economic feasibility of planned investments in groundwater. Finally, the economic aspects of various possible privatization options are analyzed to determine their profitability from the farmer's standpoint.

The analyses of issues outlined above are primarily based on irrigation benefits attributable to groundwater use. In other words, our analysis does not directly deal with waterlogging and salinity benefits and assumes that profitability of groundwater use serves as a lower bound on collective profitability. However, where necessary, waterlogging and salinity control implications of groundwater use are subjectively discussed. Since our analysis deals only with sweet water areas, it implicitly assumes that groundwater is just as productive as surface water. Before generalizing the results of this study, it is important to recognize its limitations. Results presented with respect to value of water (Chapter 2) and profitability of various transition options (Chapter 4) are based on the analysis that assumed micro (farmer) level perspective. Also, the partial equilibrium approach employed in this study prevented the derivation of general equilibrium price and production forecasts which would be possible from large-scale national models.

CHAPTER 2

FINANCIAL AND ECONOMIC VALUE OF WATER IN SCARP I AREA

2.1 Importance

Marglin (1967) defined the value of water as the amount that a perfectly rational and fully informed user of the water would be willing to pay for it. The value of water estimates provide a useful basis for determining the economic feasibility of various means for augmenting supplies. In a country like Pakistan, where simultaneous efforts[8] are being made to overcome water shortages, estimates of the value of water can be used to pre-test programs proposed to contribute to national economic development through increased water supplies. In the context of the present study, for example, it is useful to test the economic viability of technological options available for pumping groundwater. Such an analysis, in turn, would provide signals for designing macro level investment priorities in groundwater development. Also, these estimates could be used to examine the efficiency of resource use and to aid in formulating national and regional resource development policies (Hussain and Young, 1985).

The performance of SCARP tubewells in recent years has been criticized mainly because their O&M costs to public agencies have proven unsustainable. In fact, it was only the O&M cost issue that marked the beginning of the SCARP transition concept in the GOP policy portfolio. To date, however, there have been no studies that have compared these costs with the benefits of water provided by the SCARP tubewells. The present study will help to fill this information void and provide bases for evaluating both structural and non-structural methods of enhancing returns to the scarce resource.

The value of water estimates are often used as a measure to estimate the farmer's ability to pay for water. In general, water charges in Pakistan are inadequate to support an effective O&M program. On the other hand, recommendations with respect to water charges increases have often been denied on the grounds that such increases are beyond the farmer's payment capacity. Although the existing water charges in SCARP areas are double than those in non-SCARP areas in Punjab province, their comparison with the value of water would contribute to rationalization of water pricing policies.

2.2 Methods for Estimating Value of Water

Water in most cases is partly or wholly a non-marketed good. Thus, procedures for estimating water value can be interpreted as efforts to simulate market outcomes (Young and Gray, 1972). Before discussing the procedures that can be employed to simulate

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[8]. These efforts include programs such as: canal rehabilitation, watercourse improvement, and groundwater management in private sector, including subsidies to farmers for tubewell installation.

"shadow" or "accounting" prices of water, it is important to distinguish between two important concepts frequently used in water allocation or development decisions.

The first concept refers to the perspective of the assumed decision-maker and is known as "accounting stance". The distinction here is because the public planning context may differ from the private one due to government ceilings or supports on input and product prices (Howe, 1971). The monetary value of revenues versus input purchases are considered in accounting for profits from the private business viewpoint. In contrast, public agencies by their nature, should adopt a broader perspective.

The second concept calls for distinction between market prices and "accounting" or "shadow" prices. Market prices are those actually received for benefits or charged for inputs within a freely functioning exchange system. However, as a result of government interventions in pricing policies, market prices sometimes may not reflect the true value of the resource. Often there is a complete absence of markets for a good or service, which is usually the case for the water resource (Young, 1988). When the market prices are inadequate or absent, "accounting" or "shadow" prices are imputed by some analytic or synthetic method. Following Gittinger (1972), we use the term "economic" prices to identify.

Several techniques can be used to estimate the value of irrigation water[9]. The production function technique can be used to derive the marginal value product function of water by using data obtained from crop production experiments or farm management surveys. Though this technique can yield meaningful short-run private values, limitations are encountered in using it for estimating the long-run social value of water under alternative policy scenarios. Moreover, in the presence of price control programs, when prices received by farmers are used in valuing outputs, the social value of the water would be incorrectly estimated.

The value of water can also be estimated by using the residual imputation technique. This procedure allocates the total value of output among each of the resources used in the productive process. If appropriate prices can be assigned to all inputs but one, then the residual of the total value of product is imputed to the remaining resource (Heady, 1952). Euler's Theorem states that, under certain conditions, resources paid according to their marginal productivities will result in complete exhaustion of the total product.

Linear programming (LP) procedures have been frequently employed to derive two types of values of water. In the first case, shadow prices generated by the dual solution of the model are interpreted as marginal value of water. Water constraints representing different time periods can be incorporated in the model to obtain shadow prices of water for corresponding time periods. In another case, LP models can be used to generate total irrigation benefits under different levels of water supply; the marginal value productivity is the change in total benefits with respect to changes in water supply. A partial listing of previous LP models developed to estimate value productivity of resources in Pakistani

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[9]. For detailed discussion of these techniques, their merits and limitations, and specific conditions under which these techniques can be used, see "Economic Value of Water: Concepts and Empirical Estimates" by Young and Gray, 1972.

agriculture includes Revelle (1964), Eckert (1975), Gotsch *et al.*, (1975), and Chaudhry (1985).

Another common approach used to estimate the value of water is the residual budgeting method. This method defines returns to irrigation water as the residual after costs of all cash and non-cash inputs, other than water, have been subtracted from gross returns. To do so, enterprise/farm budgets are prepared so as to identify and value the inflow of resources and the outflow of products with a specified accounting period, usually one year.

In the present study, we have used both the residual budgeting method and developed a LP model to estimate values of irrigation water. These methods have the advantage of relative simplicity and ease of data collection, and they can be readily adapted for expected changes in technology and input and output prices (Bowen and Young, 1985). Water productivity for various crops grown in SCARP I is estimated using the residual budgeting method. Since a variety of crops compete for water and other fixed resources on the farm, an LP model was developed for a representative farm in the project area to estimate the average value of water.

2.3 Data Base and Methods of Analysis

2.3.1 The Data

The water productivity estimates presented here are primarily based on the analysis of the data collected and compiled by the local consultants (ACE-SGI) as part of the feasibility study on "Scarp Transition and Improvement Project" in 1984. The study was financed by the UNDP and supervised by the World Bank. The farm management survey conducted interviews with 493 farmers located on 67 public tubewells in SCARP I. For each selected public tubewell, eight farmers were chosen, so as to ensure that the sample should include at least one private tubewell owner, one tenant, and the balance in proportion with size of area and tenurial status. Results of the survey with respect to an input-output matrix of various crops grown in SCARP I are reported in Annex 15 of the feasibility report. The survey provided detailed information about cropping pattern, water use, seed rate, use of pesticides, fertilizer use, manual and bullock labor use, and crop yields, etc.

The results of the survey, particularly with respect to fertilizer use and crop yields, were updated in 1985 by ACE for a subsequent feasibility study on "SCARP Transition and Improvement Pilot Project". Revisions were stated to be based on the indications from the local agriculture extension agents, interviews with the farmers and data obtained from the crop cutting experiments of the agriculture department. To cross-check the validity of the input-output matrix developed on the basis of the above information, we also consulted local extension service agents, agronomists, and a few farmers.

The crop/farm budget analysis is based on 1986-87 prices of inputs and outputs. Since the public planning context differs from the private one, the value of water is estimated using financial and as well as economic prices. Prices of all inputs and outputs were adjusted to

farmgate. Financial and economic prices used in the analysis and the input-output matrix for various crops are shown in Tables A.1-A.3 of Annex A.

2.3.2 *Analytic Methods*

As discussed in Section 2.2 above, we have used the residual budgeting method to estimate the value of irrigation water for the important crops grown in SCARP I. This method requires construction of crop budgets. Study of individual crop budgets help to explain the internal structure of the farm and to show the relative contribution of each enterprise to the whole organization (Brown, 1979). Since there are no absolute conventions, many institutions and individuals around the world develop crop and farm budgets using different approaches. The choice for a particular approach depends upon the objective(s) to be addressed through the crop/farm budget analysis. For example, at the one extreme, "partial" budgets are prepared to account for the changes whose impacts minimally affect the total organization of farm resources. At the other extreme, "complete" budgets are required when a potential proposal is likely to have major, long term impacts on farm productivity (Young, 1988).

Crop/farm budgets are conventionally grouped into three parts: production costs, gross income and net income. The information about these elements can be compiled in tabular form, incorporating all the necessary assumptions regarding production technology and prices.

The model used in this study to estimate water productivity is structured to operate in three stages. At the first stage, per acre net income of selected crops is estimated by using equation [2.1].

$$NI_i = GI_i - VC_i - FC_i \qquad [2.1]$$

where:

NI_i = Per acre net income from crop i;
GI_i = Per acre gross income from crop i;
VC_i = Per acre variable costs in production of crop i; and
FC_i = Per acre fixed costs in production of crop i.

Gross income is comprised of income from both the main output and by-products. Variable production costs represent the cost of manual and bullock labor, seed, fertilizer, pesticides, farm manure, interest on working capital, and payments made to artisans[10]. Fixed costs include land rent and non water taxes such as land revenue and items relating to ownership

[10]. One can argue against the inclusion of items such as bullock labor, family labor and farm manure as variable costs, since these can be considered as fixed farm resources as well. In doing so, however, long-run returns to water would be overestimated. Therefore, our analysis considers a situation where all the factors of production were assumed to be hired and payments made for their use.

of machinery. The land rent prevailing in the area reflects the capital value of land which is significantly higher than that of the non-irrigated land, thus signifying the importance of assured irrigation supply to the area. In other words, in the absence of irrigation, the land rent would not be as high as it is now. Therefore, an opportunity cost of land calculated on the basis of returns to dryland wheat cultivation is charged in the model.

At the second stage, results regarding crop returns were used in conjunction with the crop water requirements data to estimate the value of water, using equation [2.2].

$$\text{Value of water in crop i} = \frac{\text{Net income of crop i}}{\text{Water req. of crop i}} \qquad [2.2]$$

At the third stage, an LP model of a representative farm in SCARP I was formulated to estimate the average value of water on the farm. This further step was necessary because crop-wise analysis does not adequately portray the overall financial structure of the farm. It is quite possible that the farm as a whole might be making good profit, but some of its enterprises might be doing rather badly. In contrast, the farm-level analysis captures the cost and income variations of all enterprises grown on the farm. The objective function of the model was designed so as to maximize net benefits to irrigation water subject to a series of technical, institutional, and resource constraints. Formulation of the model and its constraints are discussed in detail in Chapter 4. The model was also used to generate water productivity estimates by source of water supply. The study area (pilot project area) receives irrigation water supplies from canals, public tubewells, and private tubewells.

2.4 Value of Water Estimates

2.4.1 Value of Water for Individual Crops from Crop Budgets

Financial and economic estimates of water productivity by crops are shown in Table 2.1. Financial value of water ranges from a minimum of Rs 7.28 per acre inch in the production of Irri rice to a maximum of Rs 104.61 per acre inch in the production of pulses. The value of water in production of some of the management-intensive cash crops such as vegetables, pulses, oilseeds, and orchards was especially very high. The present cropping pattern statistics indicate that these crops, however, do not occupy a major share of the cultivated area. Instead, two important crops of the study area are basmati rice and wheat, since the pilot project area falls in the rice-wheat cropping zone. The value of water in production of these crops is Rs 20.60 and Rs 36.60 per acre inch, respectively.

It is evident from Table 2.1 that the economic value of water is significantly higher than the financial value of water in the production of basmati rice, wheat, and oilseed crops. The difference mainly stems from the fact that economic prices of these crops are relatively higher than their financial prices. In contrast, since the economic prices of sugarcane and cotton are lower than their financial prices, the economic value of water in the production of these crops turned out to be lower than its financial value.

Table 2.1. Estimated Financial and Economic Value of Irrigation Water by Crops in SCARP I, 1987

Crops	Irrigation[a] Requirement (Acre inches per Acre	Financial[b] Net Returns (Rs/Acre)	Economic[b] Net Returns (Rs/Acre)	Financial Value of Water --Rs per	Economic Value of Water Acre inch--
Cotton	31.77	260.84	-72.32	8.21	-2.28
Rice (Basm)	43.32	892.33	3907.10	20.60	90.19
Rice (Irri)	43.32	315.45	253.68	7.28	5.86
Kharif fodder	21.42	777.06	837.91	36.28	39.12
Kharif veg	39.07	2387.93	2380.70	61.12	60.93
Wheat	19.33	707.47	2147.39	36.60	111.09
Pulses	11.84	1238.57	1275.63	104.61	107.74
Oilseed	12.88	511.26	924.44	39.69	71.77
Rabi fodder	37.50	1997.37	2113.31	53.26	56.35
Rabi veg	23.96	2449.93	2442.70	102.25	101.95
Sugarcane	75.00	1453.66	-64.18	19.38	-0.86
Orchards	48.66	3531.70	3636.30	72.58	74.73
Weighted Avg:	31.33	1063.20	2306.86	33.94	73.63

Source:

a. ACE, Ltd. SCARP Transition Pilot Project, Table 1 of Annex C-3. Figures adjusted assuming application efficiency of 0.80.

b. Derived from Tables A.4 and A.5 of Annex A of this Report.

2.4.2 Value of Water from LP Models

To estimate the value of water supplied from different sources at the farm level, two separate runs of the LP model were made. The first run considered water supply from the public irrigation system (canals and SCARP tubewells), while the water supply in the second run was augmented using water supply from the private tubewells. Results with respect to water productivity, cropping intensity, and net benefits to irrigation are shown in Table 2.2. The average financial value of water in the pilot project area was Rs 77 per acre inch when the water supply to a farm was available from canals and SCARP tubewells. With the availability of additional water supply from private tubewells, the average value of water declined to Rs 73 per acre inch. Cropping intensity at the farm increased from 80 percent

Table 2.2. Linear Programming Model Estimates of Financial and Economic Value of Water Supplied From Different Sources in SCARP I

Model and Parameters	Sources of Water Supply[a]	
	Canal + SCARP tubewells	Canal + SCARP tubewells + Pvt tubewells
Financial Model		
1. Returns to Water (Rs per acre)	1005.91	1560.11
2. Average Value of Water (Rs/ac.inch)	77.36	72.68
3. Marginal Value[b] of Water (Rs/ac.inch)	NA	50.37
4. Cropping Intensity (%)	80.35	108.06
Economic Model		
1. Returns to Water (Rs per acre)	1958.49	3597.68
2. Average Value of Water (Rs/ac.inch)	152.62	179.65
3. Marginal Value of Water (Rs/ac.inch)	NA	149.00
4. Cropping Intensity (%)	80.18	105.80

NA: Not applicable

a. Annual water supply available to a representative farm was 63.62 acre inches from canal, 110.84 acre inches from SCARP tubewells and 110 acre inches from private tubewells.

b. Marginal return to per acre inch of water = $\frac{\text{Change in net farm income from water supply scenario (a) to (b)}}{\text{Change in water supply from water supply scenario (a) to (b)}}$

where water supply under scenario (a) comes from the public irrigation system i.e., canals and SCARP tubewells; while scenario (b) considers water supply from canals, SCARP tubewells, and private tubewells.

under the initial water supply scenario to 108 percent when the water supply was augmented with water from private tubewells[11].

Net benefits to irrigation water increased from Rs 1006 per acre under the initial water supply scenario to Rs 1560 per acre when supplemental water from private tubewells was supplied to the farm. The difference between the net benefits under the two water supply situations (Rs 556 per acre) can be defined as incremental net benefits to irrigation water in the study area. If the water supply from SCARP tubewells is terminated, the net benefits would reduce from Rs 1560 per acre to Rs 754 per acre. In other words, water supply from SCARP tubewells adds about Rs 806 per acre in total net benefits. Based on area irrigated by SCARP tubewells and financial outlays earmarked for O&M of these tubewells, per acre O&M costs were estimated to be Rs 260 for 1986-87 in the Punjab province. Treating capital costs as sunk, the benefit-cost ratio comes to 3:1. This clearly suggests that SCARP tubewells are still playing an important role in increasing agricultural production. We may emphasize that the benefits estimated above are attributable only to the supplemental irrigation water provided by SCARP tubewells. In other words, if drainage benefits of SCARP tubewells are also taken into account, the magnitude of total net benefits would be even greater.

The financial marginal value of water was estimated to be Rs 50 per acre inch. The average value product of water was Rs 77 per acre inch when water was supplied from the public irrigation system. When water supply to the farm was augmented with private sources, the average value of water declined to Rs 73 per acre inch.

An important question is: if SCARP tubewells are as beneficial as argued above, then why does the government not levy higher water charges to recover O&M costs? Historically, water charges in Pakistan have been very low and most of the efforts made to make water charges compatible with cost recovery targets were defeated on political grounds. In other words, farmers have become accustomed to entitlement to an inexpensive resource. Therefore, proposals calling for an increase in water charges face strong resistance from the farmers. In addition, farmers view water supplies from the public irrigation system just as "water" regardless of the source or cost of supply. Since the supply of inexpensive surface water to SCARP areas has been intentionally set lower than that to non-SCARP areas, significant differentiation in water charges with respect to source of supply or across different regions becomes increasingly difficult[12].

The average economic value of water in the pilot project area was Rs 153 per acre inch when water was assumed to be available from the public irrigation system. However, with the addition of water from private sources, the average economic value of water increased

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[11]. The cropping pattern and cropping intensity predicted by the model under full water supply closely approximated the observed situation, indicating that the predictions of the model were quite reliable. The model's validation is discussed in detail in Chapter 4.

[12]. Average annual per acre canal water supply to the pilot project area is about 11 acre inches. In contrast, for example, the Pakpattan area which falls in mixed cropping zone receives 25 acre inches per acre annually from canals (WAPDA, 1983). To compensate the shortfalls in canal water supply in the pilot project area, supplemental water is provided from SCARP tubewells which is more expensive than the canal water.

to Rs 180 per acre inch. The marginal economic value of water was estimated to be Rs 172 per acre inch in the study area. Cropping intensity generated by the economic model was a little lower than that predicted by the financial model. However, net benefits to irrigation in the economic model were about 2.3 times higher as compared to those generated by the financial model. The economic net benefits were higher because the economic prices of crops which dominated the solution (wheat and rice basmati) were higher as compared to their financial prices. Moreover, a shift in production from lower to higher return crops was also observed in the economic model.

We believe the SCARP program is not overly expensive given its high social rate of return in crop productivity, and further viewed as an insurance policy to prevent deterioration of an important irrigated land asset. Moreover, since the government is extracting a much larger sum from agricultural producers of the project area through underpricing of wheat and basmati rice, the size of the SCARP O&M budget should not cause undue concern. This is, however, not to say that the effectiveness of SCARP should (could) not be improved.

In addition, review of capital costs associated with alternative water saving and waterlogging reduction modes suggest that canal improvement and perhaps even watercourse improvement are the much more expensive means of saving (generating) water than those possible with either SCARP or private tubewells. For example, per ac.ft capital cost of water saved or generated under alternative water supply modes as shown in WAPDA (1979), and expressed in 1987 prices, was Rs 244 for canal remodelling; Rs 667 for canal lining; Rs 273 for watercourse lining; Rs 166 for public electric tubewells; Rs 98 for private diesel tubewells; and Rs 214 for private electric tubewells. The WAPDA study has also shown an approximate rate of return of 12-15 percent for canal remodelling, 6-8 percent for 100 percent watercourse lining, 10-13 percent for 75 percent watercourse lining, 9-12 percent for public tubewells, and 25 percent or more for private tubewells.

CHAPTER 3

TECHNOLOGY AND COST OF PUMPING WATER

3.1 Technological Considerations

A GOP policy goal for the SCARP program is to transfer the responsibility of groundwater extraction from the public sector to the private sector in fresh groundwater areas. Under this program, large capacity SCARP tubewells would be gradually replaced by farmer-owned small capacity tubewells. As such, the economics of SCARP transition concept would primarily depend upon the technology adopted for installation of private tubewells in the project area.

During the last two decades, Pakistan has made considerable progress in the development and adoption of tubewell technology. However, the advanced technology has been adopted mostly in the public sector while the private sector continues to follow the technology in its simplest concepts, mainly because of high cost differentials (ACE, 1985). Though we have assumed an average tubewell technology for the pilot project area consisting of centrifugal pumps and low cost coir wound strainers, the source of energy would be an important factor in determining the ultimate cost of pumping water.

The two most common sources of energy presently being used in operating private tubewells are electricity and diesel fuel. Conventional wisdom holds that electric-powered tubewells are preferred to diesel. But, in view of the fact that electricity is subsidized and diesel is taxed in Pakistan, estimates with respect to financial and economic costs of pumping water would help to determine the social profitability of planned investments in tubewells. Moreover, the existing energy crisis and slow rate of electric tubewell installation in the pilot project area underscore the need to evaluate the profitability of diesel-operated tubewells.

3.2 Cost of Pumping Water

3.2.1 Assumptions and Data

Estimates with respect to financial and economic costs of pumping water are developed using both energy sources for one cusec capacity privately owned tubewells. Pump efficiencies of 50 percent for electric tubewells and 60 percent for diesel tubewells are assumed in the calculations. Required lift (water table + drawdown + outlet height) of 30 feet is assumed in both the cases. Energy use of 4.86 KWH/hr for electric tubewell and 2.10 liters/hr for diesel tubewells is assumed. Other common operating assumptions are an annual working time of 1750 hours and an annual output of 145.83 acre feet. These assumptions are based on our discussions with subject specialists and on data given in SCARP transition feasibility reports.

Pumping costs are categorized into capital costs and variable costs. Capital costs represent costs of the well, including casing and strainer, motor, pump and related accessories, and shelter. For electric operated tubewells, the cost of electrical connections is also accounted for in the capital cost. Annualized costs are estimated assuming a 15 year life period and an interest rate of 14 percent. While calculating annualized capital costs, salvage values of different machinery and building components was taken into account after adjusting for their economic life. The capital cost data were compiled from information provided on this subject in Seckler et.al.,(1987), World Bank (1986) and ACE (1985). The estimated cost of various items was also confirmed from quotes by equipment suppliers.

Variable costs are classified into energy costs, repair and maintenance costs, and cost of operator labor. For electric tubewells, energy costs consist of energy charge, fuel surcharge, and duty. We have used the rates set by WAPDA for these items. Energy costs for diesel tubewells include cost of diesel oil and cost of lubricating oil. Our calculations are based on market rates of these items. The data with respect to repair and maintenance costs and cost of operator were taken from the same sources as mentioned for capital costs.

A spreadsheet model was developed to generate the pumping cost budget which allows us to capture the effects of alternative prices and operating assumptions on per unit pumping cost of water. The procedure used to calculate cost of pumping water, various operating assumptions, and variable and fixed costs of machinery and non machinery items for both electric and diesel tubewells are shown in Tables B1-B4 of Annex B.

3.2.2 Financial and Economic Costs of Energy

Financial costs of pumping water represent those costs which a farmer would have to incur to install and operate the tubewell. Market prices prevailing in 1987 were used to estimate these costs. In contrast, economic costs are net of estimated subsidies provided to farmers or taxes levied by the government on various items relating to tubewell installation or operation.

In the case of electric tubewells used for irrigation, farmers receive two types of subsidy. First, electrical connections are subsidized to induce farmers to install more tubewells. Second, the electricity charges are set lower as compared to those set for other consumers. While estimating the economic cost of pumping water, subsidies on electrical connections (about Rs 25,000) were added to the capital cost. No standard or reliable estimates regarding the economic price of electricity were available. World Bank (1986) assumed economic price of energy as Rs 1.15/KWH, while GOP in its project planning process assumed the economic price of energy as twice its financial price which comes about Rs 1.30/KWH. Based on our discussions with a number of energy experts and officials of the GOP, we have assumed Rs 1.40/KWH as the economic price of electricity in our calculations.

The financial price of diesel (sale price at the gas station) was about Rs 3.98 per liter which included items such as ex-refinery price, customs excise duty, distribution margin, dealer commission, inland freight margin, and development surcharge. The economic price

of diesel (Rs 2.66 per liter) was arrived at by subtracting the customs excise duty and development surcharge from the financial price of diesel.

3.2.3 Pumping Cost Estimates

The financial and economic costs of pumping water from electric and diesel operated tubewells are shown in Table 3.1. The financial cost of water pumped from electric and diesel powered tubewells was estimated to be Rs 154 and Rs 225 per acre ft, respectively. The share of variable costs in total pumping costs estimated for electric and diesel tubewell was 42 percent and 77 percent respectively.

In the case of electric tubewells, the estimated total economic pumping costs were Rs 216 per acre ft, 48 percent being variable costs and 52 percent fixed costs. The economic cost of water pumped from diesel tubewells was estimated to be Rs 192 per acre.ft, variable costs accounting for about 72 percent of the total costs.

The economic cost of water pumped from electric tubewells was estimated to be about 40 percent higher than its financial cost. In contrast, in the case of diesel tubewells, financial costs turned out to be about 17 percent higher than economic cost. Alternatively stated, the financial cost structure indicates that the diesel tubewells are more expensive to operate, while the electric-operated tubewells are expensive under the economic price structure. This essentially explains the user's preference for electric-operated tubewells. The diesel tubewells, however, have a reliablity advantage over the electric-operated tubewells as they are not subject to the risk of load shedding. Nevertheless, this advantage may hold true only if the supply and quality of diesel fuel is ensured.

Financial costs of pumping water from a rehabilitated (or replaced) SCARP tubewell were estimated to be Rs 108 per acre foot, 66 percent being variable costs and 34 percent fixed costs. The estimated economic pumping costs were about 80 percent higher than the financial pumping costs. Per acre foot total financial costs of water pumped from SCARP tubewell were about 30 percent less than the total cost of water estimated for privately owned one cusec electric-operated tubewells. This difference reduced to about 10 percent under the economic cost structure. However, the variable cost of water pumped from SCARP tubewells was about 13 percent and 53 percent higher than the water pumped from small electric-operated tubewells under the financial and economic models, respectively. On the other hand, fixed costs were low for SCARP tubewell water because of higher annual output.

3.2.4 Parametric Analysis

Pumping cost depends upon many factors such as rated discharge, pump efficiency, working time, and annual output. The first two variables are generally assumed as given, while the latter two variables bear an exact relationship with each other. The pumping cost is inversely related with the utilization factor or operating time, assuming fixed annual depreciation. A tubewell's operating time is mainly determined by on-farm irrigation needs

Table 3.1. Estimated Financial and Economic Costs of Pumping Water From One Cusec Capacity Electric and Diesel Powered Tubewells, and Replacement of 3 Cusecs SCARP Tubewell

Type of Cost	Electric Tubewell	Diesel Tubewell	SCARP Tubewell	Electric Tubewell	Diesel Tubewell	SCARP Tubewell
Financial	(Rs per hour)			(Rs per ac.ft)		
Variable costs	5.33	14.34	17.88	63.88	172.06	71.57
Annual fixed costs	7.50	4.40	9.09	90.02	52.84	36.34
Total costs	12.83	18.74	26.98	153.90	224.90	107.91
Economic						
Variable costs	8.59	11.57	39.52	103.18	138.79	158.00
Annual fixed costs	9.42	4.40	9.09	113.03	52.84	36.34
Total costs	18.01	15.97	48.61	216.21	191.63	194.42

Source: Tables B1-B6 of Annex B.

Table 3.2. Estimated Per Unit Cost of Pumping Water for Alternative Annual Operating Hours

Operating Hours	Electric (Rs per hour)	Diesel (Rs per hour)	Electric (Rs per ac.ft)	Diesel (Rs per ac.ft)
	Financial Costs			
500	33.67	29.75	403.97	356.99
800	22.72	23.97	272.69	287.64
1100	17.75	21.34	213.01	256.12
1400	14.91	19.84	178.91	238.10
1700	13.07	18.87	156.84	226.45
2000	11.78	18.19	141.40	218.29
	Economic Costs			
500	41.65	26.98	499.80	323.72
800	29.24	21.20	350.91	254.37
1100	23.60	18.57	283.24	222.85
1400	20.38	17.07	244.56	204.84
1700	18.30	16.10	219.54	193.18
2000	16.84	15.42	202.03	185.03

Source: Tables B1-B4 of Annex B.

and quantity of water that could be sold to other farmers. The impact of alternative annual operating time assumptions on cost of pumping water is shown in Table 3.2.

The pumping costs showed a declining trend in response to an increase in operating hours. For very low utilization rates (500 hours or below), the financial cost of pumping water from an electric tubewell even exceeded the cost of water pumped from the diesel tubewell. However, as the operating hours were assumed to increase, the electric tubewell became more cost efficient relative to the diesel tubewell. The economic cost of pumping water from an electric tubewell was higher than the cost of water pumped from the diesel tubewell over the entire range of operating hours assumed in the analysis.

3.3 Returns to Private Tubewell Investment

The estimated financial marginal value of water in the pilot project area is about Rs 50 per acre inch while the estimated cost of pumping water from a diesel tubewell is about Rs 19 per acre inch, indicating an extremely favorable return on investment. In the absence of SCARP water supplies the potential returns are even higher. Benefit-cost ratios for private tubewell development on large farms are from 3 to 4. However, for farms not large enough to profitably utilize the well, a profitable investment depends on the ability to market the surplus water to downstream neighbors. On the other hand, farms without sufficient resources to invest in a tubewell may be able to purchase tubewell water, but it will be relatively expensive, and they must find a properly located willing seller. Tubewell development by formal or informal cooperative groups is possible, but has been slow to take off.

CHAPTER 4

EVALUATION OF ALTERNATIVE SCARP TRANSITION OPTIONS

4.1 Introduction

A GOP policy objective for the SCARP program is to transfer the responsibility of groundwater development to the private sector in fresh groundwater areas. In this context, GOP is also seeking to transfer most of the SCARP tubewells to the private sector. The economic rationale behind this policy objective is to maximize social benefits from conjunctive groundwater use and to relieve government from ever increasing O&M budget deficits. These deficits have grown at an alarming rate during the 1980s, primarily due to increased O&M funding requirements of public tubewells and very low water charges. In the last two decades, the commendable role played by private tubewells in controlling the water table and providing supplemental water for irrigation had lent further support to the idea of privatization of the groundwater resource. At the same time, consistently increasing public sector inefficiencies in managing SCARP tubewells have reinforced the GOP thinking about transferring these tubewells to the private sector.

Against this background, the GOP initiated a SCARP Transition Project in Khanqah Dogran unit of SCARP I in 1986. In the absence of prior experience, it was not known exactly how the farmers and institutions would participate in or respond to this concept or what would be the impact of this transition on farmers' income or how this transition would affect the water table etc. Therefore, the project was designed on a pilot basis to assess its replicability in other SCARP areas having fresh groundwater supplies. The World Bank is providing financial and technical assistance for this project. The project aims to replace 213 SCARP tubewells with 1050 small capacity, farmer-owned tubewells in the project area. The project is described in detail in World Bank (1986), and its first year performance is briefly reviewed earlier in Chapter 1.

The GOP has expressed serious concerns about the high cost of the SCARP transition approach being followed in the pilot project area (GOP, 1988). Replicability of this approach to other areas is highly doubtful because of higher costs, underscoring the need to examine alternative privatization options. Efficiency and equity aspects of these options would determine their prospects for implementation over a vastly expanded area.

This chapter explores the allocative efficiency and equity implications of alternative transition options at the farm level. Micro level analysis is important as it would generate information about the farmer's response to altered water supplies available under any given transition option. This information, in turn, can be utilized to rationalize a more practically oriented transition strategy. Analysis of the macro level impact of these options is equally important, particularly with respect to environmental (water table) concerns. However, farmers are unlikely to respond to this "common" problem in the very short run. Farmers would be motivated to take measures to cope with this "common" problem only after they have realized the impact of waterlogging on land and crop production. In other words, for

a given transition option, there will be a transitional period of inadequate pumping and a rising water table. This is hoped to be followed by a process of natural adjustment, and more farmers will be motivated to take measures to address this "common" problem.

The allocative efficiency objective of a particular transition option calls for the maximization of agricultural net income of the farm subject to the technical constraints of the production function and input-output prices faced by the farmer. The equity objective of any transition strategy will be to distribute the benefits of groundwater more equitably among different farm categories. Evaluation of equity concerns is particularly important because: (a) farm distribution by size and tenure in the project area is relatively skewed more in favor of farms having low resource endowments and little access to institutional facilities[13]; and (b) equity in groundwater distribution is in principle guaranteed to all farm categories with SCARP tubewells.

The rest of this chapter is organized as follows. Structure and parameters of the analytical model developed to simulate farmers' response to alternative SCARP transition options are discussed in Section 2. Various transition options evaluated in this study are described in Section 3. The next section describes the allocative efficiency and equity criteria used to analyze the effectiveness of various transition options. Results of the analysis are discussed in the final section.

4.2 SCARP Transition Model

Various transition options discussed above would lead to different institutional arrangements with respect to groundwater pumpage and distribution. The price, quantity, and timing of water supplied to the farmer under each arrangement would determine the micro level feasibility of these options. A long tradition of economists has been to deal with water allocation in largely conceptual terms, usually concluding that exchangeable property rights would improve economic welfare. Ciriacy-Wantrup (1967), Johnson, *et al.*, (1981) and Young (1986) are representative examples. Anderson and Maass (1971) were, to our knowledge, the first to formulate an analytic optimizing model for the purpose of evaluating irrigation system operating rules. Young and Bredehoeft (1972) adapted the standard LP format to a conjunctive ground and surface water management problem.

The linear programming formulation was selected for this study because the technique is widely understood, and could readily incorporate alternative water sources with differing costs and (or) timing of availability. The productivity and profitability of a wide range of water shortage patterns could also be readily reflected. Institutional incentives and (or) penalties were represented as price changes in water purchase activities, while altered water

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[13]. About 76 percent of the farms in the project area are small farms (< 12.5 acres) cultivating 42 percent of the total farm area. Large farms (> 25 acres) constitute only 7 percent of the total farms but occupy 30 percent of the total farm area. As regards tenurial arrangements, 45 percent of the farms in the project area are owner-operated farms while 30 percent of the farms are operated by the tenants. Small farms have less land, low water availability, and little access to credit facility. Similarly, available evidence suggest that amount of institutional credit available to owner operated farms is 2.7 times higher than the amount available to tenant operated farms (Sharif et.al., 1986).

supply constraints could represent quotas or other quantity controls.

4.2.1 Structure of the Model

The LP model developed to simulate farmer response to alternative transition options represents the Khanqah Dogran unit of the SCARP I area. A standard form of the model is:

$$\text{Max (or Min) } Z = C X' \qquad [4.1]$$

$$\text{subject to} \quad A X' \leq B$$

$$\text{and} \quad X \geq 0$$

The four basic elements of the model are: objective function (CX'); activities (X); constraints (B); and the matrix of technical coefficients (A). The schematic presentation of the model developed for the project area is given in Table 4.1. The objective function is designed to maximize returns to irrigation water subject the technical constraints of the production function, the level of resource availability, and prices of products and inputs including water.

The model considers four types of activities: production, sales, feeding, and purchasing. The production activities include the production of 11 crops and 5 types of livestock. For all crops, 7 production activities each representing different level of water stress are represented. For some major crops, production activities representing different planting dates and possibilities of substitution between fertilizer and water are also considered. Sales activities cover the disposition of output from primary crops and livestock. Inclusion of these activities can facilitate price policy analysis. Intermediate activities represent the feeding of fodder and residue of primary crops to the livestock. Purchasing activities in the model are incorporated for those inputs where pricing is an issue.

The constraints faced by the present maximization model can be categorized into fixed resource constraints (land, canal water, family and bullock labor); resource augmenting constraints which limit the amount of purchased inputs to pre-specified level; and special constraints which restrict the range of feasible cropping patterns. Land and water are basic constraints and they are both expressed on a monthly basis. The present model represents a farm size of 10 acres, which is the average farm size in the project area. The model assumes that water supply (including pumping capacity) in each month is fixed and it cannot be transferred among months. Labor is valued at prevailing market rates and this constraint is expressed on seasonal (rabi and kharif) basis.

The model contains a special set of constraints that restrict the range of feasible solutions. The acreage of certain perishable, high risk and therefore high net return crops (vegetables, orchard, and pulses) has been restricted in order to avoid their domination in the solution. The opportunity to sell such crops is often constrained by distance to markets or processing

Table 4.1. Schematic Representation of Linear Programming Model

Row Identification[a]		Unit	Activities and Column Identification: Crop Production (90)	Livestock Production (4)	Sales or Final Consumption (11)	Livestock Feeding (5)	Input Purchases (4)	Water purchase (12)	Right-hand side
			Acre	Animal	Kg	Kg	Nutrient-kg or Man-hour	Acre inches	
			X_{ik}	X_j	X_j	X_j	X_j	X_j	
Objective function	(2)	Rs	$-C_{jk}$	C_j	C_j	0	$-C_j$	$-C_j$	Max
Crop outputs	(11)	Kg	$-A_{jk}$		0,1	0,1			= 0
Livestock outputs	(4)	Animal		0,1					= 0
Livestock inputs	(5)	TDN		A_{ij}		$-A_{ij}$			= 0
Monthly land	(12)	Acre	0,1						$\leq B_i$
Fertilizer	(3)	Nutrient (kg)	A_{ijk}				-1		= 0
Seasonal labor	(2)	Man-hour	A_{ijk}				-1		$\leq B_i$
Monthly water	(12)	Acre inches	A_{ijk}						$\leq B_i$
Monthly pumping[b]	(12)	Acre inches						-1	$\leq B_i$
Production limits	(4)	Acre	A_{ijk}						$>< B_i$

[a] Number of activities (columns) and constraints (rows) given in parentheses. i indexes inputs; j indexes products; k indexes water stress levels.

[b] Maximum water available from public or private tubewells. Separate constraints for these sources are added because water from private tubewells has a price tag attached to it.

facilities. The upper limit corresponds to observed cropping pattern in the project area and it is 0.10 acres for pulses, 0.05 acres for orchards, and 0.14 acres for vegetables. The number of livestock on the farm is restricted to the typical existing holding of a pair of bullocks, two sheep, and one each of buffalo, cow, and donkey. Explicit constraints on acreage under fodder were not placed. The model provides the required amount of TDN and DP to these animals via production of seasonal fodder, wheat straw, sugarcane tops and rice straw.

The technical coefficient matrix of the model is comprised of two basic types of technical coefficients. The first category represent the quantities of resources required to produce an acre of crop or a unit of livestock. The values for these coefficients reside in their respective resource constraint rows. These resource constraint coefficients are monthly for land and water, seasonal for labor, and annual for fertilizer. Labor requirements for stressed water supply production activities were adjusted since these activities would require less labor[14]. The other major category of the coefficients is found in transfer rows and converts per acre activities into outputs. These transfer rows allow the outputs to be either sold, consumed on farm,or used as intermediate goods for input into production activities. Table 4.1 displays the partial LP tableau which illustrates how the model was formulated.

4.2.2 *Yield Response to Water*

The benefits of added flexibility in irrigation water can be captured by both direct and indirect ways. According to the direct approach, higher crop-yields are introduced in the model exogenously on the assumption that application of the required amount of water at the right time will allow the farmer to obtain higher per acre yields. This approach results in a preconceived solution. The indirect approach adopted here assumes that change in water availability will not only change per acre yield but it may also alter the whole spectrum of farmer decision making on crops and inputs. This specification allows the model to select crop production activities having no stress, or which are least stressed, according to net profitability for a given water supply. Accordingly, a curve has been developed for each crop, expressing the specific water-yield relationship. This allows the model to simulate flexibility in decision making, particularly when the farmer has to allocate water under shortages.

Whenever actual evapotranspiration is less than maximum transpiration, the evapotranspiration deficit causes the actual yield to fall below the maximum potential yield. According to FAO (1979), the effect of water stress can be quantified by deriving the relationship between relative yield decrease and relative evapotranspiration deficit given by the empirically derived yield response factor (k_y), or:

$$ky = [1 - Y_a / Y_m] / [1 - ET_a / ET_m]. \qquad [4.2]$$

[14]. Labor use would decrease when an irrigation turn is completely or partially missed. Because of reduction in yield, labor requirements at the harvesting time would also decrease.

where:

Y_a = actual harvested yield;
Y_m = maximum harvested yield;
ET_a = actual evapotranspiration; and
ET_m = maximum evapotranspiration.

The yield response factor for various crops, estimation of actual yield in response to evapotranspiration deficits, water-use coefficients and labor requirements for stressed production activities can be found in Annex C.

4.2.3 Data Base

Most of the data used in the model were taken from the feasibility reports of the SCARP Transition Pilot Project (see Section 2.3.1 for details). The data with respect to important parameters were validated after discussion with a panel of experts and local extension agents. Data about input-output coefficients and prices are shown in Tables A1 to A3 of Annex A. Data concerning availability of fixed resources at the farm, water-use coefficients, stressed production activities, and adjusted labor requirements are shown in Tables C1 to C4 of Annex C.

4.3 Alternative Transition Options

Various transition options evaluated in this study are discussed in this section. Each option differs from the other both in terms of water availability to the farm and institutional arrangements needed to enforce the transition option. Cost sharing arrangements between the government and the farmers for each option further differentiate various transition options from each other. Macro level implications of each transition option are also briefly outlined, though we have not quantified the possible effects of these implications on farmer income or the government treasury. Instead, we have simulated the farmer's response to these options within the context of efficiency and equity objectives considering the altered water supply that would be available under these options. Table 4.2 summarizes the key assumptions underlying each transition option and outlines macro level possible outcomes which may follow as a result of implementing these options.

4.3.1 Continuation of Existing SCARP Program (Continuation)

This option assumes that SCARP tubewells would continue to operate. Further, no change in existing institutional arrangements is assumed. Farmers would continue to receive water from SCARP tubewells, in addition to the canals and private tubewells already installed in the project area. The government would bear the cost of supplying water from public tubewells and canals. Farmers would bear the cost of private tubewell water, whether pumping or purchasing. As a result of this option, not only would O&M subsidies continue, but the canal system would be undermaintained since a higher proportion of the total O&M budget would be diverted towards the maintenance of the public tubewells. In the longer-

run, large public sector investments would be needed to replace the wells and pumps as they depreciated.

4.3.2 Complete Termination of SCARP Program (Termination)

This option assumes that all SCARP tubewells are immediately terminated or abandoned. In this case, the farmer would receive water only from canals and private tubewells existing at the time of termination. No other change is assumed in the existing institutions. Under this option, crop production and farmer income would be affected adversely due to less water availability. On the other hand, the financial burden on the government treasury would be relaxed. This option is likely to make more funds available for O&M of the canal system. As a result of decline in groundwater pumpage, the water table would be expected to rise, which in turn will cause damage to land and crop production. We have analyzed two cases under this option. Case 1 assumes no change in the existing utilization rate of the private tubewells (12 percent). Case 2 assumes that in the absence of SCARP tubewells, demand for supplemental water would increase, encouraging the tubewell owners to increase the pumpage. It is assumed that annual utilization rate of private tubewells would increase from 12 percent to 15 percent.

4.3.3 Transfer to Private Ownership (Transfer)

Under this option, management and operation functions with respect to SCARP tubewells are assumed to be transferred to private groups. Private groups can take the form of an individual farmer, farmer groups such as water user associations, a village level cooperative, or a commercial firm. Practically, it is very unlikely that an individual farmer would choose to own a SCARP tubewell because of its large capacity and usually inconvenient location. However, it could become a beneficial venture if a group of farmers located on the same watercourse takes it up for operation. Nevertheless, Pakistan's experience in organizing such farmer groups has not been very encouraging. This is not to say that such groups cannot be formed to function successfully on a long-term basis. As a matter of fact, such groups have proven to be successful in various parts of the world having similar irrigation system and other socio-economic factors. More serious research efforts are needed to study the causes restricting cooperation among the farmers and to devise policies which can bring them together for their common cause. Also, commercial firms have not participated in the development of the irrigation water industry in the manner they have participated in the development of other farm inputs industries. However, this would not occur unless some kind of government support and assistance is provided to private investors[15].

Whatever is the structure or form of the group, efficiency of public tubewells is expected to increase for two inter-linked reasons: (a) the profit motive would guide the private sector

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[15]. To start with, farmers may not respond positively to private firms as they would perhaps view these investors as an outsiders working against the interests of the farming community. However, with government support, farmers can be convinced about the role these investors can play in the supply and distribution of an input which is scarce and highly valuable to the farmers.

to pump and sell more water to the needy farmers; and (b) there will be much less deferred maintenance or undue break-downs due to non availability of funds. In addition, the SCARP tubewells provide water equitably to all water users. New institutions would emerge in the form of private groups. Presently, the average annual utilization rate of SCARP tubewells is very low (around 30 percent). With the private sector taking up the management and operation functions of SCARP tube-wells, one can definitely expect an increase in the annual utilization rate. We have assumed an average annual utilization rate of 50 percent, restricting it to the maximum of 60 percent in a particular month. We have analyzed two cases under this option. Case 1 assumes that government would fix (rehabilitate or replace) the deteriorated tubewells and then transfer these to private groups for regular operation, management, and maintenance. In this case, water will be priced on the basis of O&M costs of the tubewell. Case 2 assumes that SCARP tubewells are transferred to private groups in their present form. Private groups would rehabilitate the tubewells and operate them. The price of water in this case would include O&M costs and annualized capital costs. Cost estimates of pumping water from SCARP tubewell are shown in Table B5 of Annex B.

As a result of increased groundwater pumpage, the water table will be lowered. Agricultural production is expected to increase due to less waterlogging and to the availability of more supplemental water. The government would be relieved of heavy financial strains implying that more funds would be available for O&M of the canal system.

4.3.4 Replacement With Smaller Private Wells (Replacement)

This option assumes that SCARP tubewells are terminated and replaced by small farmer-owned tubewells. This option is similar to the SCARP transition approach presently being followed in the pilot project area. Benefits demonstrated by SCARP and private tubewells are expected to motivate the farmers to install their own small tubewells. Moreover, water shortages caused by the termination of SCARP tubewells would induce the farmers to invest in small tubewells. In order to speed up the implementation process, government will have to make strenuous efforts to provide credit and electrification facilities to the farmers. As has been evidenced in the pilot project area, project implementation will be slow to take off in the absence of these facilities. In turn, this will cause the water table to rise, which may do serious damage to land and crop production.

As the SCARP tubewells are replaced with small farmer-owned tubewells, new water markets are expected to emerge. Since every farmer in the project area is not expected to own or have a share in a tubewell, these markets would bring together the sellers and the buyers through the pricing mechanism. Typically, the pricing mechanism can take either one or a combination of the following forms: cash payment, share of the crop, or trading of the canal water rights. This option would result in availability of timely water to the farmer who owns the tubewell. In the very short-run, the water table may rise as a result of inadequate pumping. Because of the termination of SCARP tubewells, more funds would be available for O&M of the canal system. Demand for energy (diesel or electricity) would rise under this option.

Three possible cases are analyzed under this option. The first case considers a situation where the farmer owns a tubewell of one cusec capacity. However, he is assumed to operate the tubewell only to meet his own farm needs. The second case assumes that the farmer can sell the surplus water to other neighboring farmers. In this case, the average annual utilization rate of the tubewell is assumed to be 20 percent as against the current rate of 12 percent in the project area. With the termination of SCARP tubewells, one can expect this much increase in utilization rate of the private tubewells. The sale rate of the supplemental water in the project area is about Rs 17 per hour or acre inch, which is 15 to 20 percent higher than the variable pumping costs. The third case considers a situation where the farmer does not own a tubewell, but purchases the water at the market rate. In this case, necessary adjustments in irrigation delivery efficiency assumptions were made to reflect the distance of the farm from the tubewell.

4.3.5 Improved Management of SCARP Tubewells (Improvement)

This option assumes management and operational improvements in various components of the public irrigation system. We have analyzed three cases under this option. The first case assumes improvements in the management and operation of SCARP tubewells. These improvements can be realized by providing better economic incentives to the field staff (particularly tubewell operators) of the irrigation department; more careful and intensive monitoring; and developing procedures for quick repair and maintenance of the tubewells. However, some of these improvements may not be possible without some additional cost. In the absence of prior information on this issue, we have assumed a 10 percent increase in water pumped from SCARP tubewells with similar increases in the cost of water.

The second case considers improvements in the delivery efficiency of the watercourse. The process of waterlogging and salinization is slowed by any reduction in seepage losses such as those that occur as a result of watercourse improvements (USAID, 1982). Therefore, in recent years, most of the irrigation development programs in Pakistan have focused their attention on avoiding water losses from the irrigation system. The watercourse improvement program has been one of the most successful programs implemented in this context, perhaps the only program that received great appreciation from the farmers. Clyma and Corey (1974) estimated average water losses from watercourses located in SCARP areas to be around 40 percent, approximately 15 percent due to seepage and 25 percent due to spills. About 75 percent of spillage losses can be controlled with simple routine maintenance of earthen watercourse main channel and major branches at the cost of Rs 9.82 per acre (Eckert, et.al 1975). We have used the same assumptions in our analysis, expressing the cost estimates at 1987 prices (Rs 25.48 per acre).

The third case is a combination of both management and operational improvements considered in cases 1 and 2. Under this transition option, agricultural production is expected to increase due to increased availability of water. As a result of the watercourse improvement program and increased pumpage from SCARP tubewells, one expects the water table to decline. There will be a little change in the existing institutions. Higher O&M subsidies are likely to continue under this transition option.

Table 4.2: Water Supply and Institutional Assumptions Used in the Analysis of Various Transition Options

Transition Option	Source of Water Supply[a]	Annual Water Availability (Acre inches)	Cost Bearing Agency (Government or Farmers or Private Groups)	Possible Changes in Institutional Arrangements	Probable Impacts on		
					Water-table	Agric. Output	Govt's O&M Budget Deficit
Continuation	CN, GT, PT	284.47	Government for CN and GT; and farmers for PT.	No change in existing institutions.	b	b	Increase
Termination							
Case 1	CN, PT	173.63	Government for CN; and farmers for PT.	No change in existing institutions.	Rise	Decrease	Decrease
Case 2	CN, PT	201.06	Government for CN; and farmers for PT.	No change in existing institutions.	Rise	Decrease	Decrease
Transfer							
Case 1	CN, GT, PT	346.43	Government for CN and rehabilitation of GT; private groups for O&M of GT; and farmers for PT.	Local level groups are formed to take up O&M functions of GT.	Drop	Increase	Decrease
Case 2	CN, GT, PT	346.43	Government for CN; farmers for PT; and private groups for rehabilitation and O&M of GT.	Local level groups are formed to take up rehabilitation and O&M functions of GT.	Drop	Increase	Decrease
Replacement							
Case 1	CN, PT	449.72	Government for CN; and farmers for PT.	No change in existing institutions.	Drop	Increase	Decrease
Case 2	CN, PT	1357.72	Government for CN; and farmers for PT.	Water markets would develop permitting frequent sale and purchase of groundwater in study area.	Drop	Increase	Decrease

Continued on next page

Table 4.2. Continued

Transition Option	Source of Water Supply[a]	Annual Water Availability (Acre inches)	Cost Bearing Agency (Government or Farmers or Private Groups)	Possible Changes in Institutional Arrangements	Probable Impacts on		
					Water-table	Agric. Output	Govt's O&M Budget Deficit
Case 3	CN, PT	447.33	Government for CN; and farmers for PT.	Water markets would develop permitting frequent sale and purchase of ground-water in study area.	Drop	Increase	Decrease
Improvement							
Case 1	CN, GT, PT	295.54	Government for CN and GT; and farmers for PT.	Management improvements in O&M of GT through better economic incentives to PID staff.	Rise	Increase	Increase
Case 2	CN, GT, PT	320.69	Government for CN and GT; and farmers for PT.	Physical improvements in water delivery system.	Rise	Increase	Increase
Case 3	CN, GT, PT	334.18	Government for CN and GT; and farmers for PT.	Management improvements in O&M of GT through better economic incentives to PID staff; and physical improvements in water delivery system.	Rise	Increase	Increase

a. CN = Canal, GT = Government Tubewell, PT = Private Tubewell. b. Existing situation

4.4 Results and Discussion

For each transition option, the model uses the estimates of available water supply for the farm and selects the cropping pattern (intensity) which will yield the highest expected financial net benefits. It means allocating available water to high-valued crops under the given set of physical and technical constraints, and input-output prices faced by the farmer.

Comparison of allocative efficiency and equity measures of various transition options with the existing case would reflect the impact of altered water supply and institutional changes induced as a result of a particular transition option. This comparison would also help to determine the trade-off possibilities between allocative efficiency and equity objectives across different transition options.

4.4.1 Evaluation of Performance

The allocative efficiency measure used in this study to evaluate the performance of various transition options is net benefits. The most economically efficient option is the one that would yield the highest net benefits to irrigation. Cropping intensity, while not a major criterion, is of interest, and is also displayed.

Under the existing case, net irrigation benefits were estimated to be Rs 1560 per acre with a cropping intensity of 108 percent. The average and marginal values of water under this case were Rs 73 and Rs 50 per acre inch, respectively. Predictions of the model with respect to cropping pattern and intensity saisfactorily approximated the actual observed farm behavior (see Table 4.3). The predicted cropping intensity was almost the same as shown by the records of the irrigation department. Rice dominated the cropping pattern in the kharif season, while wheat occupied the major share of cropped area in the rabi season.

The comparative net benefits of various transition options are examined in Table 4.4. Among all the options, the cases considered under the replacement option yielded the highest net benefits and cropping intensity. Although the cropping intensity was the same (193.5 percent) for each of the cases considered under the replacement option, the net benefits were different. The net benefits were highest under case 2 which was followed by cases 1 and 3. The net benefits of case 2 were higher than the net benefits of case 1 because the farmer had the opportunity to sell surplus supplemental water in the former case. On the other hand, the net benefits of case 3 (purchaser) were lower than the net benefits of case 1 (owner) because the price of supplemental water was higher in the former case. In case 1, variable pumping costs were used as the price of supplemental water, while the market rate for supplemental water (which was 15 to 20 percent higher than the variable pumping costs) was considered in case 3.

The transfer option was ranked as the next best option. The net benefits under case 1 were about 10 percent higher as compared to case 2, although the cropping intensity was same under both the cases. The efficiency differences can be attributed to different cost sharing arrangements assumed in these cases. Case 1 of the transfer option assumed that public tubewells would be repaired by the government and operated by the private groups; while

Table 4.3. Comparison of Results of LP Model Regarding Cropping Pattern and Cropping Intensity With Observed Situation in the Project Area.

(Percent of Cultivated Area)

Crops	Observed Cropping Pattern[a]	Survey Results[b]	Model Results
Cotton	1.30	0.50	0.00
Rice	21.80	31.20	26.98
Kh.fodder	7.70	11.60	6.24
Kh.vegetables	0.80	0.40	0.80
Wheat	42.70	50.60	46.99
Pulses	1.00	1.50	1.00
Oilseeds	1.10	0.20	4.13
Rb.fodder	17.90	15.00	11.70
Rb.vegetable	1.40	2.10	0.00
Sugarcane	2.80	6.30	4.61
Orchard	0.45	0.70	0.50
Others	5.80	1.30	0.00
Cropping Intensity:	108.00	128.40	108.06

Source:

a. Data from Irrigation Department , SCARP Transition and Improvement Pilot Project Report, pp 3-13. The data applicable to only pilot project area.

b. Data based on survey of 493 farms in SCARP I area. SCARP Transition and Improvement Project, Vol III, pp 4-Annex 7. The data represent overall situation in whole SCARP I area.

both fixing and O&M of public tubewells were assumed to be the responsibility of private groups in the second case.

Case 3 of the improvement option yielded almost the same net benefits as case 2 of the transfer option, but the cropping intensity was lower in the former case. This discrepancy was again due to different cost sharing arrangements assumed in the analysis. The farmer was assumed to pay only for the incremental costs required to pump supplemental water from the public tubewells under the improvement case, while water was priced to recover total O&M costs under case 2 of the transfer option. However, the first two cases of the improvement option performed poorly as compared to the cases considered under the transfer option.

Table 4.4. Comparison of Various SCARP Transition Options Using Different Performance Measures

Transition Option	Water Supply (Ac.inches)	Net Benefits (Rs per Acre)	Cropping Intensity (Percent)
1. Continuation	284.5	1560.1	108.0
2. Termination			
Case 1	173.6	754.5 (-52)	73.0 (-32)
Case 2	201.1	982.1 (-37)	74.0 (-32)
3. Transfer			
Case 1	346.4	1973.7 (27)	143.0 (32)
Case 2	346.4	1798.2 (15)	143.0 (32)
4. Replacement			
Case 1	449.7	2451.0 (57)	193.5 (79)
Case 2	1357.7	2692.5 (73)	193.5 (79)
Case 3	447.3	2252.3 (44)	193.5 (79)
5. Improvement			
Case 1	295.5	1606.8 (03)	113.4 (05)
Case 2	320.7	1753.1 (12)	124.2 (15)
Case 3	334.2	1815.9 (16)	130.7 (21)

Note: Figures in parantheses indicate the percentage difference from the continuation case.

Among the cases considered under the improvement option, physical improvements in the delivery system (case 2) generated more net benefits and cropping intensity than could have been possible with the management improvements assumed in case 1. Case 3 was ranked superior to other two cases because it reflected the cumulative effect of both physical and management improvements.

The termination option performed poorest among all the options. The net benefits reduced considerably under this option. As a result of the termination of SCARP tubewells, one can expect the water table to rise at a faster rate causing severe damage to land and agricultural production.

4.4.2 Evaluation of Equity Concerns

To explore the equity aspects of various transition options, farmers of the project area are classified by size (small vs large) and tenancy (owner vs tenant) categories. This approach can assume that both types of farms under each category have identical production functions except for the differences in size of the farm, their accessibility to agricultural credit, availability of labor, and number of livestock heads maintained at the farm[16]. The basic model was first adjusted so as to reflect the impact of these institutional constraints on net farm income. The model was then used to capture the income distribution effects of various transition options on different farm categories.

The equity of various transition options is examined by using two measures. The first measure--Land Income Ratio (LIR)--explains the difference in per acre net income of various farm categories. It is defined as ratio of the per acre net income of small (or tenant) farmer to the per acre net income of large (or owner) farmer. The second measure--Farm Worker Income Ratio (FWIR)--explains the difference in income per farm worker on each farm category. It is defined as ratio of the income per farm worker on small (or tenant) farms to the income per farm worker on large (or owner) farms. In the case of perfect equality, the ratio equals one and decreases as inequality increases, under both the measures.

The ratios representing equity levels attained under different transition options are presented in Table 4.5. In general, the income distribution was found to be relatively more unequal among farms having different tenurial arrangements as compared to the farms which differ by size. The ranking of various transition options stayed almost the same under both equity measures for a particular farm group. However, for a given equity measure, the ranking was different across different farm groups.

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[16]. The average size of small and large farms in the project area is reported as 5.5 and 43 acres respectively (ACE, 1985). The average farm size of tenant and owner operated farms in the rice zone is reported as 9.39 and 10.63 acres, respectively (Sharif, et.al, 1986). We have, however, assumed a farm size of 10 acres for both the owners and the tenants. The study done by Sharif, et.al (1986) reported that annual per acre agricultural credit availability was Rs 356 for the small farmer, Rs 404 for the large farmer, Rs 466 for the owner, and Rs 170 for the tenant. Labor and livestock information corresponding to each farm category was also reported in this study.

Table 4.5. Comparison of Various SCARP Transition Options Using Different Equity Measures

Transition Options	LIR[a]		FWIR[b]	
	Small vs Large	Tenant vs Owner	Small vs Large	Tenant vs Owner
1. Continuation	0.78 (7)	0.58 (3)	0.33 (4)	0.52 (4)
2. Termination				
Case 1	0.37 (9)	0.61 (1)	0.16 (6)	0.54 (2)
Case 2	0.54 (8)	0.61 (1)	0.23 (5)	0.55 (1)
3. Transfer				
Case 1	0.86 (2)	0.56 (4)	0.36 (2)	0.50 (5)
Case 2	0.85 (3)	0.59 (2)	0.36 (2)	0.53 (3)
4. Replacement				
Case 1	0.86 (2)	0.51 (6)	0.36 (2)	0.46 (7)
Case 2	0.92 (1)	0.46 (7)	0.49 (1)	0.41 (8)
Case 3	0.86 (2)	0.53 (5)	0.36 (2)	0.47 (6)
5. Improvement				
Case 1	0.79 (6)	0.58 (3)	0.33 (4)	0.52 (4)
Case 2	0.81 (5)	0.58 (3)	0.35 (3)	0.52 (4)
Case 3	0.83 (4)	0.58 (3)	0.35 (3)	0.52 (4)

a. LIR (Land Income Ratio) is defined as ratio of the per acre net income of small (or tenant) farmer to the per acre net income of large (or owner) farmer.

b. FWIR (Farm Worker Income Ratio) is defined as the ratio of the income per farm worker on small (or tenant) farms to the income per farm worker on large (or owner) farms.

Rank is given in parentheses.

Results with respect to small versus large farms indicated that case 2 of the replacement option performed best while case 1 of the termination option was ranked lowest under both equity measures. The LIR ranged between 0.78 to 0.86 for most of the cases, except for the cases considered under the termination option. The FWIR for these farm categories ranged from a minimum of 0.16 to the maximum of 0.49. For the existing option, the LIR was 0.78 and FWIR was 0.33.

According to both equity measures, various transition options showed very modest improvements in the income of small farmer relative to the income of large farmer from the existing level, except for the two extreme cases. In this later situation, however, the differences in income were more pronounced. Alternatively stated, termination of SCARP tubewells would further aggravate the income distribution gap between small and large farmers, while case 2 of the replacement option would significantly narrow the income distribution gap between these farm categories.

Ranking of various transition options changed when equity implications of these options were analyzed for farmers with different tenurial status. According to both equity measures, the termination option was ranked best while case 2 of the replacement option performed poorest. The LIR ranged from 0.46 to 0.61 for various transition options, with a ratio of 0.58 for the existing case. The FWIR for the existing option was 0.52, and ranged between 0.41 to 0.55 for various transition options.

The income distribution gap between owner and tenant operated farms under the termination option would reduce due to two reasons. First, the tenant would share only part of the losses as compared to the owner (self cultivating farmer) who would bear all of the losses caused by the termination of SCARP water supplies. Second, the impact of water shortages on productivity of resources such as agricultural credit would be more severe on owner operated farms. On the other hand, assumptions with respect to tubewell ownership caused the income distribution gap to grow between owner and tenant operated farms as reflected under case 2 of the replacement option[17]

4.4.3 Evaluation of Policy Options

Various transition options were evaluated in the context of allocative efficiency and equity objectives in the preceding two sections. The next important question is: which of these options is to be preferred? The answer largely depends upon the mechanical and operating condition of the SCARP tubewells selected for privatization in the project area. For instance, some of the tubewells are completely worn out and cannot be operated to supply water at a reasonable cost. On the other hand, there are tubewells which still have some economic life and which can be fixed and operated if management efficiency is improved.

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[17]. Since tenants are not expected to install tubewells on rented land, the owner of the farm is assumed to own the tubewell. The pumping costs of water needed at the farm would be shared jointly by the owner of the tubewell/farm and the tenant. However, the proceeds earned through the sale of surplus water would boost the owner's income resulting in higher income distribution gap between owner and tenant operated farms.

In areas where SCARP tubewells are completely worn out, the replacement option appears to be the best choice. This approach yielded the highest net income and cropping intensity and turned out to be relatively more equitable for the farmers who differ by farm size. However, benefits of this option were skewed relatively more in favor of owners as compared to tenants. Differences in initial resource endowments and assumptions with respect to tubewell ownership could have been the possible factors responsible for making tenants relatively worse off under this option. Moreover, in the economic efficiency context, it would be socially profitable to replace SCARP tubewells because the incremental costs of SCARP water exceeds the incremental cost of water from new wells.

The benefits of groundwater development under this option would be shared mainly through water markets, since every farmer in the project area is not expected to own a tubewell. Water market conditions are portrayed by cases 2 and 3 of this option. Both the owner of a tubewell and purchaser of the tubewell water are estimated to have the same cropping intensity, but the net income of the tubewell owner was estimated to be about 20 percent higher than the net income of the farmer who has to purchase the water. The difference in income mainly stems from the cost of water[18]

This option, however, assumes that the water markets would perform their functions satisfactorily i.e., farmers not having their own tubewells would be able to buy as much water as required for their crops at the prevailing market price. In practice, this condition not only requires installation of the sufficient number of tubewells but also calls for proper locational distribution of these tubewells to ensure effective working of the water markets[19]. The former requirement would not be difficult to meet because, with the termination of SCARP tubewells, the demand for supplemental water would definitely induce the farmers to install their own tubewells. Meeting the later requirement, however, will be more critical since rigidity of the warabandi system greatly affects the economics of private tubewell installation because of a fewer number of potential users and purchasers of tubewell water.

During the replacement process, emphasis should be more on diesel powered tubewells rather than electric tubewells for a number of reasons. First, our economic analysis with respect to cost of water in Chapter 3 suggested that water from diesel tubewells is probably a little less costly from the social perspective than electric tubewells. Second, diesel engines are somewhat more reliable, although diesel fuel is not free from the risk of quality variation due to adulteration, as they are not subject to the risk of load-shedding and outage frequent in the electrical system. Third, current electrical power shortages not only hamper the overall magnitude of pumpage but also pose severe threats to the required rate of

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[18]. The reported rental rate of water in the project area is about 15 to 20 percent higher than the variable pumping cost of water. Moreover, cost of water at the root zone would be higher for the farmer who has to purchase water as compared to the farmer who owns the tubewell because of the differences in delivery efficiency, since delivery efficiency decreases with distance of the farm from the source of water.

[19]. The present warabandi system of water allocation does not allow the farmers to supplement canal water supplies with tubewell water unless either they have uninterrupted right to the total discharge and flow in the watercourse or when the main watercourse length between their nakka location and the tubewell location is unused or empty of water (Renfro, 1982).

installation of private tubewells. Fourth, clustering is relatively more common in the case of electric tubewells because these have to follow transmission lines, eventually leading to short term drawdown interference effects. Finally, since the government is now rationalizing crop prices to bring them closer to world market prices, it should no longer be necessary to subsidize inputs.

The transfer option appears to be the best choice in areas where SCARP tubewells still have some economic life. The cases evaluated under this option turned out to be relatively more efficient. Moreover, since SCARP tubewells provide water equitably to all water users, it is an important political advantage by itself. Under this option, either the government or the farmers can fix the tubewells; but O&M of the tubewells will be the responsibility of the farmers in any case. As SCARP tubewells become inoperable, they should be allowed to die a natural death and farmers should be encouraged to replace them with smaller wells located where they are needed.

With the change in management, these tubewells can still play an important role in controlling the water table and increasing agricultural productivity. In this context, the practicability of different transfer models should be tested on a pilot basis, for instance, transfer to individual farmers, to farmers' groups, and to commercial firms. If the tubewells cannot be sold, these can be gifted to groups such as water users' associations (WUAs). The transfer of SCARP tubewells would mean a shift in the burden of costs since the new private owners would pay the electricity bills and meet maintenance expenses. This would be consistent with the growing worldwide trend to transfer production costs to the private sector.

The implementation of the transition program, whether it considers replacement of the worn out tubewells or transfer of the operable SCARP tubewells, should proceed cautiously. If farmers do not invest enough in installing new, smaller tubewells (replacement option), or take up the management of SCARP tubewells (transfer option), the waterlogging problem may worsen. Under this situation, it would be desirable to keep SCARP tubewells operational. In other words, SCARP tubewells should be shut down only as they are replaced by equal, alternative pumping facilities. Although it is problematic to continue the SCARP program in its present form, terminating it abruptly is also not necessarily desirable. Termination of the program would reduce water availability, produce a negative impact on crop production, and give rise to serious problems of waterlogging.

Finally, the public sector agricultural extension programs should educate farmers about various technical and financial aspects of groundwater management. More particularly, these programs should include installation and maintenance procedures which may help to reduce the cost of supplemental water at the farm level. Also, the costs and returns of pumping water should be regularly developed as it would help the farmers to make rational investment decisions in groundwater extraction. In addition to structural and engineering emphasis for water management, the rural institutions should be strengthened to ensure successful implementation of the groundwater privatization program. Water allocation and distribution policies should be tailored so as to encourage exchanges and marketing of water.

CHAPTER 5

SUMMARY AND CONCLUSIONS

5.1 History and Performance

Extensive developments in the Indus irrigation system and lack of drainage facilities have resulted in severe waterlogging and soil salinization in large areas of the Punjab and Sind provinces. This problem was addressed through a vertical drainage program called SCARP. Presently, about 12,500 SCARP tubewells are serving about 7.4 million acres (20 percent of the Indus Basin's cultivable area). More than 90 percent of the SCARP capacity is located in FGW areas. The O&M of these tubewells is the responsibility of the Provincial Irrigation Department (PID).

It is recognized that these tubewells have played a critical role in controlling waterlogging and salinity over vast areas. Agricultural production has also improved in the project area, though part of this can be attributed to the increasing number of private tubewells, and to chemical inputs and varietal improvements. However, in recent years these public tubewells have become increasingly expensive to operate. The pumping capacity has declined due to deficient maintenance which, in turn, is severely constrained by non-availability of funds. Low water charges, deficient budgeting procedures, and overall tight budgetary constraints are the principal reasons for non-availability of funds required for O&M of these tubewells in particular, and the irrigation system in general. The economic viability of SCARPs has been adversely affected because the underlying assumptions regarding operational potential were optimistic and have proven incorrect.

Success of private tubewells in FGW areas, serious O&M problems associated with public tubewells, severe budgetary constraints, and failure of SCARP tubewells to provide reliable water supplies at sustainable cost have been the important factors in the emergence of the SCARP transition concept. A pilot project was started in 1986-86 in SCARP I. Under this project, 213 SCARP tubewells are to be replaced by privately owned small tubewells at the cost of Rs 380 million. The project has, however, been slow to take off. For instance, disbursement of agricultural credit and provision of electric connections to farmers was reported to be very slow.

5.2 Issues Examined

The present study presents the analysis of three important policy issues. First, what is the value of water in SCARP areas? This issue is important because most of the recent studies on the subject have not given adequate recognition to the contribution of water supplied by SCARP tubewells. In contrast, these studies have criticized the performance of SCARP tubewells on the grounds that O&M costs of these tubewells have proven unsustainable to the public agencies. Second, what is the cost of pumping water under different energy sources (diesel and electricity)? In view of the current energy crisis, and the fact that

electricity is subsidized and diesel is taxed, the source of energy would essentially determine the economic viability of a particular transition strategy. Third, what are the possible SCARP transition options? The GOP has expressed serious concerns about the high cost of the SCARP transition approach presently being followed in the project area. Replicability of this approach over wider areas is being questioned because of the high costs. Analysis of these issues would not only help to fill the information void on some important decision parameters, but also provide broader bases for developing a practically oriented SCARP transition program.

5.3 Value of Water

The financial value of water ranges from a minimum of Rs 7.28 per acre inch in the production of Irri rice to a maximum of Rs 104.61 per acre inch in the production of pulses. The economic value of water is higher than its financial value for crops (wheat, rice basmati, and oilseed) having higher economic prices relative to their financial prices. The average financial and economic value of water in the project area was Rs 77 and Rs 152 per acre inch, respectively. The marginal value of water was rs 50 per acre inch under the financial prices and Rs 149 per acre inch under the economic prices.

The financial net benefits to SCARP water were Rs 806 per acre. Comparing these benefits with the incremental costs of pumping (measured by existing O&M costs) gives a benefit-cost ratio of 3:1. This clearly suggests that SCARP tubewells are still playing an important role in increasing agricultural productivity. Accounting for drainage benefits would make the cost-benefit ratio even better. This role, however, has been underated so far.

From this perspective, the SCARP program does not appear to be overly expensive particularly when the government is extracting a large portion of potential producer surplus via underpricing of some of the agricultural outputs. It should be viewed as an insurance policy to prevent deterioration of the important irrigated land asset. However, this conclusion should not be interpreted to mean that the efficiency of SCARP tubewells should (could) not be improved.

5.4 Pumping Cost of Water and Potential Returns

Energy pricing and tax policy appear to favor uses of electricity. The financial cost of water pumped from electric and diesel-powered tubewells was estimated to be Rs 154 and Rs 225 per acre ft, respectively, which explains the users' current preference for electricity. The share of variable costs in total pumping costs estimated for electric and diesel tubewell was 42 and 77 percent, respectively. However, the economic cost of water pumped from electric tubewells was estimated to be about 40 percent higher than its financial cost. In contrast, in the case of diesel tubewells, our estimate of the economic cost turned out to be about 17 percent lower than its financial cost. The total average cost of water pumped from SCARP tubewell was lower than the cost of water pumped from small private tubewells, but the variable cost was estimated to be higher for SCARP water. The diesel tubewells, in general, can be regarded as the somewhat more reliable source of water, as they are not

subject to the risks of intentional load shedding and frequent outages in the electrical system.

Comparison of the value of water relative to pumping costs indicates an extremely favorable return on investment; the more so in the absence of SCARP water supplies. Large farms clearly have the advantage of utilizing tubewells efficiently because of greater on-farm water requirements. However, for farms not large enough to profitably utilize the well, a profitable investment depends on the ability to market the surplus water to downstream neighbors.

5.5 Transition Options

The GOP has expressed serious concerns about the high cost of the present transition approach. Aside from the cost issue, some of the underlying assumptions appear to warrant reconsideration. The assumptions with respect to disbursement of agricultural credit, provision of electric connections, and tubewell owner's inability to market surplus water have especially proven somewhat wide of the mark. Also, some of the small farmers in the project area have in good faith invested in private tubewells with the expectation that SCARP tubewells would be terminated as promised and, as a result, they would be able to sell the surplus water. This has, however, not happened.

We have explored the efficiency and equity implications of five transition options at the farm level. These transition options are named as: continuation, termination, transfer, replacement, and improvement. Each transition option differs from the other both in terms of water availability to the farm and cost sharing arrangements between the government and the farmer. A linear programming model was developed to simulate farmer response to these options considering the altered water supply available under each option.

In areas where SCARP tubewells are completely worn out, the replacement option appears to be the best choice. This option calls for installation of farmer-owned small tubewells. The success of this approach really depends upon the magnitude of economic incentives provided to the farmers to install tubewells. Since every farmer in the project area is unlikely to own a tubewell, benefits of groundwater development under this option would need to be shared mainly through the water markets. In practice, this option not only requires installation of the sufficient number of tubewells but also calls for proper locational distribution of these tubewells to ensure effective working of the water markets. The emphasis should be on diesel tubewells during the replacement process because these are less costly and more reliable to operate. The government incentives should be tailored to encourage installation of tubewells under joint ownership. This arrangement would not only ensure participation from large numbers of farmers, but would help to avoid over-capitalization in private tubewells. At the same time, the public sector agricultural extension programs should educate farmers about efficient installation and maintenance procedures which may help to reduce the cost of supplemental water. The costs and returns of pumping water should be regularly developed as it would help the farmers to make rational investment decisions in groundwater extraction.

In areas where SCARP tubewells are in operable condition, the management and operational responsibilities of these tubewells are proposed to be transferred to private groups. Pakistan's experience in organizing such groups, however, has not been very encouraging in the past. Therefore, it is important that practicability of various forms of private groups (such as individual farmers, farmers' groups like WUAs, and commercial firms) should be tested on a pilot basis. With the transfer of management functions to the private sector, these tubewells can still play an important role in increasing agricultural productivity and controlling waterlogging. Since O&M costs are proposed to be borne by the private groups under this option, the government's O&M budget deficit would reduce remarkably. As aging SCARP tubewells become inoperable, they should be allowed to die their natural death and farmers should be encouraged to replace these with smaller wells located in areas where needed.

If the rate of private investment in new small tubewells (replacement option) is exceptionally low or farmer groups are not willing to take up the management functions of operable SCARP tubewells (transfer option), the SCARP tubewells should be kept operational against a need to prevent a possible return to waterlogging. These tubewells should be shut down only if they are replaced by equal, alternative pumping facilities. Finally, the transition program should proceed but with emphasis on diesel tubewells over electric tubewells. It is important to organize local level groups to ensure successful implementation of a particular transition approach. Water allocation and distribution policies should be tailored so as to encourage exchanges and marketing of water.

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ANNEX A

FARM ENTERPRISE BUDGETS

Table A1. Per Acre Input-Output Matrix of Various Crops in SCARP I Area of Punjab Province

INPUTS	UNITS	Cotton	Rice Basm	Rice Irri	Kh.Fodder	Kh.Veg	Wheat	Pulses	Oilseed	Rb.fodder	Rb.Veg	Scane	Orchards
Manual labor	Hours	176	176	176	96	152	112	48	64	160	152	336	288
Bullock labor	Hours	84	60	60	24	48	48	32	24	36	48	84	48
Seed	Kgs	12	5	5.5	15	110(a)	40	9	5	7	110(a)	1200	110(a)
Fertilizer													
Nitrogen	N.Kgs	18	25	25	9	32	23	3	9	3	32	32	23
Phosphorus	N.Kgs	6	16	16	4	23	11	6	5	5	23	16	18
Potash	N.Kgs			4		4	4				4	6	4
Pesticides	Rs	100	50	50		100			50		100	100	300
Farm manure	Cart load	1	1	1	1	1	1	0.5	0.5	2	1	3	2
Interest rate (b)	Rs												
Artisans (c)	Rs												
Non water taxes	Rs	24	35	35	32	125	29	41	20	74	63	93	104
Land rent (d)	RS	144	144	144	144	144	144	144	144	144	144	288	288
Main Product	Kgs	340	920	1200	12000	4000(a)	900	360	320	20000	4000(a)	14930	6000(a)
By-Product	Kgs	1360	920	1200			900					1493	

Source: (1) Feasibility Report on "SCARP Transition Project", Vol 5, Annex 15; (2) Feasibility Report on "SCARP Transition Pilot Project" Vol 1 & & 2; and (3) Personal interviews with local extension agents, farmers, and subject specialists.

(a). Expressed in value terms.

(b). 14 percent on cash inputs. For each crop adjusted according to the length of crop season.

(c). one percent of gross income.

(d). Opportunity cost of land calculated on the basis of dryland wheat.

Table A2. Financial Prices of Inputs and Outputs (Rs per Kg) for the Year 1987

INPUTS	PRICE (Rs/Unit)	Cotton	Rice Basm	Rice Irri	Kh.Fodder	Kh.Veg	Wheat	Pulses	Oilseed	Rb.fodder	Rb.Veg	Scane	Orchards
Manual labor	3.30												
Bullock labor	4.65												
Seed		4.27	4.60	2.80	3.75	110(a)	3.03	5.70	4.70	14.71	110(a)	0.32	110(a)
Fertilizer													
Nitrogen	5.62												
Phosphorus	5.07												
Potash	1.60												
Pesticides	1.00												
Farm manure	22.50												
Interest rate													
Artisans													
Non water taxes	1.00												
Land rent	1.00												
Main Product		4.83	2.42	1.35	0.13	1.00	1.90	5.19	3.70	0.16	1.00	0.29	1.00
By-Product		0.08	0.08	0.08			0.16					0.10	

Source:
1. Manual and bullock labor: World Bank Scarp Transition Report and interview with farmers and extension agents of the project area.
2. Fertilizer: Pakistan Economic Survey, 1987.
3. Seed: Punjab Seed Corporation (for major crops) and market rates (for minor crops).
4. Output prices: Government fixed prices published in Pakistan Economic Survey, 1987 (for major crops) and market rates (for minor crops).

(a). Expressed in value terms--Rs per acre.

All prices have been adjusted to farm gate.

Table A3. Economic Prices of Inputs and Outputs (Rs per Kg) for the Year 1987

INPUTS	PRICE (Rs/Unit)	Cotton	Rice Basm	Rice Irri	Kh.Fodder	Kh.Veg	Wheat	Pulses	Oilseed	Rb.fodder	Rb.Veg	Scane	Orchards
Manual labor	2.70												
Bullock labor	3.31												
Seed		2.90	10.78	2.56	3.75	110(a)	5.74	5.70	6.10	14.71	110(a)	0.21	110(a)
Fertilizer													
Nitrogen	6.47												
Phosphorus	10.10												
Potash	4.20												
Pesticides	1.00												
Farm manure	22.50												
Interest rate													
Artisans													
Non water taxes	1.00												
Land rent	1.00												
Main Product		3.28	5.68	1.24	0.13	1.00	3.60	5.19	4.93	0.16	1.00	0.16	1.00
By-Product		0.08	0.08	0.08			0.16					0.10	

Source:

1. Manual labor: Economic price is 0.82 times the financial price, World Bank SCARP Transition Report.
2. Bullock labor: Economic price is 0.91 times the financial price, World Bank SCARP Transition Report.
3. Economic prices of wheat, basmati rice, irri rice, sugarcane, and fertilizer are taken from the price projections (1987-1995) made in SCARP Transition Report. Economic price of cotton is taken from the Report of the National Commission on Agriculture.
4. Ratio of financial seed prices to financial output prices is applied to economic output prices to arrive at economic seed prices.

(a). Expressed in value terms--Rs per acre.

All prices have been adjusted to farm gate.

Table A4. Financial Costs and Returns of Various Crops in SCARP I, 1987, (Rs per Acre)

INPUTS	UNITS	Cotton	Rice Basm	Rice Irri	Kh.Fodder	Kh.Veg	Wheat	Pulses	Oilseed	Rb.fodder	Rb.Veg	Scane	Orchards
PRODUCTION COST													
Manual labor	Rupees	580.80	580.80	580.80	316.80	501.60	369.60	158.40	211.20	528.00	501.60	1108.80	950.40
Bullock labor	Rupees	390.60	279.00	279.00	111.60	223.20	223.20	148.80	111.60	167.40	223.20	390.60	223.20
Seed	Rupees	51.24	23.00	15.40	56.25	110.00	121.20	51.30	23.50	102.97	110.00	384.00	110.00
Fertilizer	Rupees												
Nitrogen	Rupees	101.16	140.50	140.50	50.58	179.84	129.26	16.86	50.58	16.86	179.84	179.84	129.26
Phosphorus	Rupees	30.42	81.12	81.12	20.28	116.61	55.77	30.42	25.35	25.35	116.61	81.12	91.26
Potash	Rupees	0.00	0.00	6.40	0.00	6.40	6.40	0.00	0.00	0.00	6.40	9.60	6.40
Pesticides	Rupees	100.00	50.00	50.00	0.00	100.00	0.00	0.00	50.00	0.00	100.00	100.00	300.00
Farm Manure	Rupees	22.50	22.50	22.50	22.50	22.50	22.50	11.25	11.25	45.00	22.50	135.00	90.00
Interest rate	Rupees	27.93	28.75	28.67	13.33	42.92	27.06	9.12	13.42	17.55	42.92	136.68	115.78
Artisans	Rupees	17.51	23.00	17.16	15.60	40.00	18.54	18.68	11.84	31.50	40.00	44.04	60.00
Non water taxes	Rupees	24.00	35.00	35.00	32.00	125.00	29.00	41.00	20.00	74.00	63.00	93.00	104.00
Land rent	Rupees	144.00	144.00	144.00	144.00	144.00	144.00	144.00	144.00	144.00	144.00	288.00	288.00
TOTAL COST	Rupees	1490.16	1407.67	1400.55	782.94	1612.07	1146.53	629.83	672.74	1152.63	1550.07	2950.69	2468.30
INCOME													
(a) Main product	Rupees	1642.20	2226.40	1620.00	1560.00	4000.00	1710.00	1868.40	1184.00	3150.00	4000.00	4255.05	6000.00
(b) By-product	Rupees	108.80	73.60	96.00	0.00	0.00	144.00	0.00	0.00	0.00	0.00	149.30	0.00
(c) Gross income	Rupees	1751.00	2300.00	1716.00	1560.00	4000.00	1854.00	1868.40	1184.00	3150.00	4000.00	4404.35	6000.00
NET INCOME	Rupees	260.84	892.33	315.45	777.06	2387.93	707.47	1238.57	511.26	1997.37	2449.93	1453.66	3531.70
Water requirements	Inches	31.77	43.32	43.32	21.42	39.07	19.33	11.84	12.88	37.50	23.96	75.00	48.66
Value of water	Rs/Acre inch	8.21	20.60	7.28	36.28	61.12	36.60	104.61	39.69	53.26	102.25	19.38	72.58

Table A5. Economic Costs and Returns of Various Crops in SCARP I, 1987, (Rs per Acre)

INPUTS	UNITS	Cotton	Rice Basm	Rice Irri	Kh.Fodder	Kh.Veg	Wheat	Pulses	Oilseed	Rb.fodder	Rb.Veg	Scane	Orchards
PRODUCTION COST													
Manual labor	Rupees	475.20	475.20	475.20	259.20	410.40	302.40	129.60	172.80	432.00	410.40	907.20	777.60
Bullock labor	Rupees	278.04	198.60	198.60	79.44	158.88	158.88	105.92	79.44	119.16	158.88	278.04	158.88
Seed	Rupees	34.80	53.90	14.08	56.25	110.00	229.60	51.30	30.50	102.97	110.00	252.00	110.00
Fertilizer	Rupees												
Nitrogen	Rupees	116.46	161.75	161.75	58.23	207.04	148.81	19.41	58.23	19.41	207.04	207.04	148.81
Phosphorus	Rupees	60.60	161.60	161.60	40.40	232.30	111.10	60.60	50.50	50.50	232.30	161.60	181.80
Potash	Rupees	0.00	0.00	16.80	0.00	16.80	16.80	0.00	0.00	0.00	16.80	25.20	16.80
Pesticides	Rupees	100.00	50.00	50.00	0.00	100.00	0.00	0.00	50.00	0.00	100.00	100.00	300.00
Farm Manure	Rupees	22.50	22.50	22.50	22.50	22.50	22.50	11.25	11.25	45.00	22.50	135.00	90.00
Interest rate	Rupees	28.48	36.56	34.95	14.47	52.38	39.68	11.01	15.67	18.15	52.38	129.82	127.81
Artisans	Rupees	12.24	52.99	15.84	15.60	40.00	33.84	18.68	15.78	31.50	40.00	25.38	60.00
Non water taxes	Rupees	24.00	35.00	35.00	32.00	125.00	29.00	41.00	20.00	74.00	63.00	93.00	104.00
Land rent	Rupees	144.00	144.00	144.00	144.00	144.00	144.00	144.00	144.00	144.00	144.00	288.00	288.00
TOTAL COST	Rupees	1296.32	1392.10	1330.32	722.09	1619.30	1236.61	592.77	648.16	1036.69	1557.30	2602.28	2363.70
INCOME													
(a) Main product	Rupees	1115.20	5225.60	1488.00	1560.00	4000.00	3240.00	1868.40	1577.60	3150.00	4000.00	2388.80	6000.00
(b) By-product	Rupees	108.80	73.60	96.00	0.00	0.00	144.00	0.00	0.00	0.00	0.00	149.30	0.00
(c) Gross income	Rupees	1224.00	5299.20	1584.00	1560.00	4000.00	3384.00	1868.40	1577.60	3150.00	4000.00	2538.10	6000.00
NET INCOME	Rupees	-72.32	3907.10	253.68	837.91	2380.70	2147.39	1275.63	929.44	2113.31	2442.70	-64.18	3636.30
Water requirements	Inches	31.77	43.32	43.32	21.42	39.07	19.33	11.84	12.88	37.50	23.96	75.00	48.66
Value of water	Rs/Acre inch	-2.28	90.19	5.86	39.12	60.93	111.09	107.74	72.16	56.35	101.95	-0.86	74.73

ANNEX B

FINANCIAL AND ECONOMIC COST OF PUMPING WATER WITH ELECTRIC AND DIESEL TUBEWELLS, PUNJAB PROVINCE, (1987 Prices)

Table B1. Estimated Financial Cost of Pumping Groundwater With Diesel Engine (1987 Prices)

Col #	C1	C2	C3	C4	C5
Row #	Description	Definition of unit	# of units or Price/unit	Cost (Rs)	Calculation formulas
R1	Operating Assumptions				
R2	Rated discharge	Cusecs (cfs)	1.00		One cusec/hr = 1 acre inch
R3	Required lift	Feet	30.00		Lift = Water table + drawdown + outlet height
R4	Pump efficiency	Percent	60.00		
R5	Fuel used	Liters/hr	2.10		R5C3 = R3C3*.07
R6	Working time	Hours	1750.00		
R7	Annual output	Acre feet	145.83		R7C3=R2C3*R6C3/12
R8	A. Variable Costs				
R9	1.Energy costs				
R10	a.Light diesel oil	Rs/liter	3.98	14626.50	R10C4=R6C3*R5C3*R10C3
R11	b.Lubricating oil	Rs/liter	12.00	7350.00	R11C4=R6C3*0.35*R11C3
R12	c.Others	Rs	0.00	0.00	
R13	2.Repair & maintenance costs				
R14	a.Motor	Rs/Hour	0.43	752.50	R14C4=R6C3*R14C3
R15	b.Pump	Rs/Hour	0.10	175.00	R15C4=R6C3*R15C3
R16	c.Other	Rs/Hour	0.11	192.50	R16C4=R6C3*R16C3
R17	3.Cost of operato	Rs/Hour	1.14	1995.00	R17C4=R6C3*R17C3
R18	Total variable costs	Rs		25091.50	R18C4=SUM [R10C4....R17C4]
R19	B. Fixed Costs				
R20	1.Components				
R21	a.Well,casing and strainer	Rs		18500.00	
R22	b.Motor	Rs		15000.00	
R23	c.Pump & accessories	Rs		8500.00	
R24	d.Building	Rs		8640.00	
R25	e.Other misc. costs	Rs		2000.00	
R26	Total investment costs	Rs		52640.00	R26C4=SUM [R21C4...R25C4]
R27	2.Annual capital costs	Life (Years) =	15.00		
R28		Sal.value (Rs)=	3414.00		R28C3=[R26C4-R21C4]/10
R29	a.Depreciation			3781.73	R29C4=[R26C4+.5*R22C4-R28C3]/R27C3
R30	b.Interest charges	Rate (%) =	0.14	3923.78	R30C4=[[R26C4+R28C3]/2]*R30C3
R31	Annualized costs	Rs		7705.51	R31C4=R29C4+R30C4
R32	C. Per Unit Costs				
R33	1.Variable costs	Rs per hour		14.34	R33C4=R18C4/R6C3
R34	2.Annual fixed costs	Rs per hour		4.40	R34C4=R31C4/R6C3
R35	Total pumping costs	Rs per hour		18.74	R35C4=R33C4+R34C4
R36	1.Variable costs	Rs per Ac.ft		172.06	R36C4=R18C4/R7C3
R37	2.Annual fixed costs	Rs per Ac.ft		52.84	R37C4=R31C4/R7C3
R38	Total pumping costs	Rs per Ac.ft		224.89	R38C4=R36C4+R37C4

Table B2. Estimated Economic Cost of Pumping Groundwater With Diesel Engine (1987 Prices)

Col #	C1	C2	C3	C4	C5
Row #	Description	Definition of unit	# of units or Price/unit	Cost (Rs)	Calculation formulas
R1	Operating Assumptions				
R2	Rated discharge	Cusecs (cfs)	1.00		One cusec/hr = 1 acre inch
R3	Required lift	Feet	30.00		Lift = Water table + drawdown + outlet height
R4	Pump efficiency	Percent	60.00		
R5	Fuel used	Liters/hr	2.10		R5C3 = R3C3*.07
R6	Working time	Hours	1750.00		
R7	Annual output	Acre feet	145.83		R7C3=R2C3*R6C3/12
R8	A. Variable Costs				
R9	1.Energy costs				
R10	a.Light diesel oil	Rs/liter	2.66	9775.50	R10C4=R6C3*R5C3*R10C3
R11	b.Lubricating oil	Rs/liter	12.00	7350.00	R11C4=R6C3*0.35*R11C3
R12	c.Others	Rs	0.00	0.00	
R13	2.Repair & maintenance costs				
R14	a.Motor	Rs/Hour	0.43	752.50	R14C4=R6C3*R14C3
R15	b.Pump	Rs/Hour	0.10	175.00	R15C4=R6C3*R15C3
R16	c.Other	Rs/Hour	0.11	192.50	R16C4=R6C3*R16C3
R17	3.Cost of operato	Rs/Hour	1.14	1995.00	R17C4=R6C3*R17C3
R18	Total variable costs	Rs		20240.50	R18C4=SUM [R10C4....R17C4]
R19	B. Fixed Costs				
R20	1.Components				
R21	a.Well,casing and strainer	Rs		18500.00	
R22	b.Motor	Rs		15000.00	
R23	c.Pump & accessories	Rs		8500.00	
R24	d.Building	Rs		8640.00	
R25	e.Other misc. costs	Rs		2000.00	
R26	Total investment costs	Rs		52640.00	R26C4=SUM [R21C4...R25C4]
R27	2.Annual capital costs	Life (Years) =	15.00		
R28		Sal.value (Rs)=	3414.00		R28C3=[R26C4-R21C4]/10
R29	a.Depreciation			3781.73	R29C4=[R26C4+.5*R22C4-R28C3]/R27C3
R30	b.Interest charges	Rate (%) =	0.14	3923.78	R30C4=[[R26C4+R28C3]/2]*R30C3
R31	Annualized costs	Rs		7705.51	R31C4=R29C4+R30C4
R32	C. Per Unit Costs				
R33	1.Variable costs	Rs per hour		11.57	R33C4=R18C4/R6C3
R34	2.Annual fixed costs	Rs per hour		4.40	R34C4=R31C4/R6C3
R35	Total pumping costs	Rs per hour		15.97	R35C4=R33C4+R34C4
R36	1.Variable costs	Rs per Ac.ft		138.79	R36C4=R18C4/R7C3
R37	2.Annual fixed costs	Rs per Ac.ft		52.84	R37C4=R31C4/R7C3
R38	Total pumping costs	Rs per Ac.ft		191.63	R38C4=R36C4+R37C4

Table B3. Estimated Financial Cost of Pumping Groundwater With Electric Motor (1987 Prices)

COL #	C1	C2	C3	C4	C5
Row #	Description	Definition of unit	# of units or Price/unit	Cost (Rs	Calculation formulas
R1	Operating Assumptions				
R2	Rated discharge	Cusecs (cfs)	1.00		One cusec/hr = 1 acre inch
R3	Required lift	Feet	30.00		Lift = Water table + drawdown +
R4	Pump efficiency	Percent	50.00		outlet height
R5	Energy use	KWH/hr	4.86		KWH/hr = [R2C3*.081*R3C3]*100/R4C
R6	Working time	Hours	1750.00		
R7	Annual output	Acre feet	145.83		R7C3=R2C3*R6C3/12
R8	A. Variable Costs				
R9	1.Energy costs				
R10	a.Energy charge	Rs/Kwh	0.29	2466.45	R10C4=R6C3*R5C3*R10C3
R11	b.Fuel surcharge	Rs/Kwh	0.26	2211.30	R11C4=R6C3*R5C3*R11C3
R12	c.Duty	% of A.1.b	0.04	98.60	R12C4=R10C4*R12C3
R13	2.Repair & maintenance costs				
R14	a.Motor	Rs/Hour	0.30	525.00	R14C4=R6C3*R14C3
R15	b.Pump	Rs/Hour	0.21	367.50	R15C4=R6C3*R15C3
R16	c.Others	Rs/Hour	0.11	192.50	R16C4=R6C3*R16C3
R17	3.Cost of operator	Rs/Hour	1.14	1995.00	R17C4=R6C3*R17C3
R18	Total var. costs	Rs		7856.41	R18C4=SUM [R10C4....R17C4]
R19	B. Semi-Variable Costs				
R20	1.Flat energy charges	Rs/Kw/Month	24.00	1399.68	R20C4=R20C3*R5C3*12
R21	2.Meter rent	Rs/Month	5.00	60.00	R21C4=R21C3*12
R22	Total semi-var. costs	Rs		1459.68	R22C4=R20C4+R21C4
R23	C.Fixed Costs				
R24	1.Components				
R25	a.Well,casing and strainer	Rs		18500.00	
R26	b.Motor	Rs		0.00	0 implies that cost is
R27	c.Pump & accessories	Rs		17700.00	included in R27c4
R28	d.Building	Rs		8640.00	
R29	e.Elec. connections	Rs		50000.00	
R30	f.Other misc. costs	Rs		2000.00	
R31	Total investment costs	Rs		96840.00	R31C4=SUM [R25C4..R30C4]
R32	2.Annual capital costs	Life (Years) =	15.00		
R33		Sal.value (Rs)=	7834.00		R33C3=[R31C4-R25C4]/10
R34	a.Depreciation			5933.73	R34C4=[R31C4-R33C3]/R32C3
R35	b.Interest charges	Rate (%) =	0.14	7194.16	R35C4=([R31C4+R34C4]/2)*R35C3
R36	Annualized costs	Rs		13127.89	R36C4=R34C4+R35C4
R37	D.Per Unit Costs				
R38	1.Variable costs	Rs per hour		4.49	R38C4=R18C4/R6C3
R39	2.Semi-variable cost	Rs per hour		0.83	R39C4=R22C4/R6C3
R40	3.Annual fixed costs	Rs per hour		7.50	R40C4=R36C4/R6C3
R41	Total pumping costs	Rs per hour		12.83	R41C4=R38C4+R39C4+R40C4
R42	1.Variable costs	Rs per Ac.ft		53.87	R42C4=R18C4/R7C3
R43	2.Semi-variable costs	Rs per Ac.ft		10.91	R43C4=R22C4/R7C3
R44	3.Annual fixed costs	Rs per Ac.ft		90.02	R44C4=R36C4/R7C3
R45	Total pumping costs	Rs per Ac.ft		153.90	R45C4=R42C4+R43C4+R44C4

Table B4. Estimated Economic Cost of Pumping Groundwater With Electric Motor (1987 Prices)

COL #	C1	C2	C3	C4	C5
Row #	Description	Definition of unit	# of units or Price/unit	Cost (Rs	Calculation formulas
R1	Operating Assumptions				
R2	Rated discharge	Cusecs (cfs)	1.00		One cusec/hr = 1 acre inch
R3	Required lift	Feet	30.00		Lift = Water table + drawdown +
R4	Pump efficiency	Percent	50.00		outlet height
R5	Energy use	KWH/hr	4.86		KWH/hr = [R2C3*.081*R3C3]*100/R4C3
R6	Working time	Hours	1750.00		
R7	Annual output	Acre feet	145.83		R7C3=R2C3*R6C3/12
R8	A. Variable Costs				
R9	1.Energy costs				
R10	a.Energy charge	Rs/Kwh	1.40	11907.00	R10C4=R6C3*R5C3*R10C3
R11	b.Fuel surcharge	Rs/Kwh	0.00	0.00	R11C4=R6C3*R5C3*R11C3
R12	c.Duty	% of A.1.b	0.00	0.00	R12C4=R10C4*R12C3
R13	2.Repair & maintenance costs				
R14	a.Motor	Rs/Hour	0.30	525.00	R14C4=R6C3*R14C3
R15	b.Pump	Rs/Hour	0.21	367.50	R15C4=R6C3*R15C3
R16	c.Others	Rs/Hour	0.11	192.50	R16C4=R6C3*R16C3
R17	3.Cost of operator	Rs/Hour	1.14	1995.00	R17C4=R6C3*R17C3
R18	Total var. costs	Rs		14987.00	R18C4=SUM [R10C4....R17C4]
R19	B. Semi-Variable Costs				
R20	1.Flat energy charges	Rs/KW/Month	0.00	0.00	R20C4=R20C3*R5C3*12
R21	2.Meter rent	Rs/Month	5.00	60.00	R21C4=R21C3*12
R22	Total semi-var. costs	Rs		60.00	R22C4=R20C4+R21C4
R23	C.Fixed Costs				
R24	1.Components				
R25	a.Well,casing and strainer	Rs		18500.00	
R26	b.Motor	Rs		0.00	0 implies that cost is
R27	c.Pump & accessories	Rs		17700.00	included in R27c4
R28	d.Building	Rs		8640.00	
R29	e.Elec. connections	Rs		75000.00	
R30	f.Other misc. costs	Rs		2000.00	
R31	Total investment costs	Rs		121840.0	R31C4=SUM [R25C4..R30C4]
R32	2.Annual capital costs	Life (Years) =	15.00		
R33		Sal.value (Rs)=	10334.00		R33C3=[R31C4-R25C4]/10
R34	a.Depreciation			7433.73	R34C4=[R31C4-R33C3]/R32C3
R35	b.Interest charges	Rate (%) =	0.14	9049.16	R35C4=([R31C4+R34C4]/2)*R35C3
R36	Annualized costs	Rs		16482.89	R36C4=R34C4+R35C4
R37	D.Per Unit Costs				
R38	1.Variable costs	Rs per hour		8.56	R38C4=R18C4/R6C3
R39	2.Semi-variable cost	Rs per hour		0.03	R39C4=R22C4/R6C3
R40	3.Annual fixed costs	Rs per hour		9.42	R40C4=R36C4/R6C3
R41	Total pumping costs	Rs per hour		18.02	R41C4=R38C4+R39C4+R40C4
R42	1.Variable costs	Rs per Ac.ft		102.77	R42C4=R18C4/R7C3
R43	2.Semi-variable costs	Rs per Ac.ft		0.41	R43C4=R22C4/R7C3
R44	3.Annual fixed costs	Rs per Ac.ft		113.03	R44C4=R36C4/R7C3
R45	Total pumping costs	Rs per Ac.ft		216.20	R45C4=R42C4+R43C4+R44C4

Table B5. Estimated Financial Cost of Replacing SCARP Tubewell (1987 Prices)

COL #	C1	C2	C3	C4	C5
Row #	Description	Definition of unit	# of units or Price/unit	Cost (Rs)	Calculation formulas
R1	Operating Assumptions				
R2	Rated discharge	Cusecs (cfs)	3.00		One cusec/hr = 1 acre inch
R3	Required lift	Feet	40.00		Lift = Water table + drawdown + outlet height
R4	Pump efficiency	Percent	40.00		
R5	Energy use	KWH/hr	24.30		KWH/hr = [R2C3*.081*R3C3]*100/R4C3
R6	Working time	Hours	4320.00		
R7	Annual output	Acre feet	1080.00		R7C3=R2C3*R6C3/12
R8	A. Variable Costs				
R9	1.Energy costs				
R10	a.Energy charge	Rs/Kwh	0.51	53537.76	R10C4=R6C3*R5C3*R10C3
R11	b.Fuel surcharge	Rs/Kwh	0.00	0.00	R11C4=R6C3*R5C3*R11C3
R12	c.Duty	% of A.1.b	0.00	0.00	R12C4=R10C4*R12C3
R13	2.Repair & maintenance costs				
R14	a.Motor	Rs/Hour	1.50	6480.00	R14C4=R6C3*R14C3
R15	b.Pump	Rs/Hour	1.00	4320.00	R15C4=R6C3*R15C3
R16	c.Other	Rs/Hour	0.00	0.00	R16C4=R6C3*R16C3
R17	3.Cost of operator	Rs/Hour	3.00	12960.00	R17C4=R6C3*R17C3
R18	Total var. costs	Rs		77297.76	R18C4=SUM [R10C4....R17C4]
R19	B. Semi-Variable Costs				
R20	1.Flat energy charges	Rs/Kw/Month	0.00	0.00	R20C4=R20C3*R5C3*12
R21	2.Meter rent	Rs/Month	0.00	0.00	R21C4=R21C3*12
R22	Total semi-var. costs	Rs		0.00	R22C4=R20C4+R21C4
R23	C.Fixed Costs				
R24	1.Components				
R25	a.Well, casing and strainer	Rs		170400.00	
R26	b.Motor	Rs		35000.00	
R27	c.Pump & accessories	Rs		45000.00	
R28	d.Building	Rs		16000.00	
R29	e.Elec. connections	Rs		15000.00	
R30	f.Other misc. costs	Rs		2000.00	
R31	Total investment cost	Rs		283400.00	R31C4=SUM [R25C4..R30C4]
R32	2.Annual capital costs	Life (Years) =	15.00		
R33		Sal.value (Rs)=	11300.00		R33C3=[R31C4-R25C4]/10
R34	a.Depreciation			18140.00	R34C4=[R31C4-R33C3]/R32C3
R35	b.Interest charges	Rate (%) =	0.14	21107.80	R35C4=([R31C4+R34C4]/2)*R35C3
R36	Annualized costs	Rs		39247.80	R36C4=R34C4+R35C4
R37	D.Per Unit Costs				
R38	1.Variable costs	Rs per hour		17.89	R38C4=R18C4/R6C3
R39	2.Semi-variable costs	Rs per hour		0.00	R39C4=R22C4/R6C3
R40	3.Annual fixed costs	Rs per hour		9.09	R40C4=R36C4/R6C3
R41	Total pumping costs	Rs per hour		26.98	R41C4=R38C4+R39C4+R40C4
R42	1.Variable costs	Rs per Ac.ft		71.57	R42C4=R18C4/R7C3
R43	2.Semi-variable costs	Rs per Ac.ft		0.00	R43C4=R22C4/R7C3
R44	3.Annual fixed costs	Rs per Ac.ft		36.34	R44C4=R36C4/R7C3
R45	Total pumping costs	Rs per Ac.ft		107.91	R45C4=R42C4+R43C4+R44C4

Table B6. Estimated Economic Cost of Replacing SCARP Tubewell (1987 Prices)

COL #	C1	C2	C3	C4	C5
Row #	Description	Definition of unit	# of units or Price/unit	Cost (Rs)	Calculation formulas
R1	Operating Assumptions				
R2	Rated discharge	Cusecs (cfs)	3.00		One cusec/hr = 1 acre inch
R3	Required lift	Feet	40.00		Lift = Water table + drawdown +
R4	Pump efficiency	Percent	40.00		outlet height
R5	Energy use	KWH/hr	24.30		KWH/hr = [R2C3*.081*R3C3]*100/R4C3
R6	Working time	Hours	4320.00		
R7	Annual output	Acre feet	1080.00		R7C3=R2C3*R6C3/12
R8	A. Variable Costs				
R9	1.Energy costs				
R10	a.Energy charge	Rs/Kwh	1.40	53537.76	R10C4=R6C3*R5C3*R10C3
R11	b.Fuel surcharge	Rs/Kwh	0.00	0.00	R11C4=R6C3*R5C3*R11C3
R12	c.Duty	% of A.1.b	0.00	0.00	R12C4=R10C4*R12C3
R13	2.Repair & maintenance costs				
R14	a.Motor	Rs/Hour	1.50	6480.00	R14C4=R6C3*R14C3
R15	b.Pump	Rs/Hour	1.00	4320.00	R15C4=R6C3*R15C3
R16	c.Other	Rs/Hour	0.00	0.00	R16C4=R6C3*R16C3
R17	3.Cost of operator	Rs/Hour	3.00	12960.00	R17C4=R6C3*R17C3
R18	Total var. costs	Rs		77297.76	R18C4=SUM [R10C4....R17C4]
R19	B. Semi-Variable Costs				
R20	1.Flat energy charges	Rs/Kw/Month	0.00	0.00	R20C4=R20C3*R5C3*12
R21	2.Meter rent	Rs/Month	0.00	0.00	R21C4=R21C3*12
R22	Total semi-var. costs	Rs		0.00	R22C4=R20C4+R21C4
R23	C.Fixed Costs				
R24	1.Components				
R25	a.Well, casing and strainer	Rs		170400.00	
R26	b.Motor	Rs		35000.00	
R27	c.Pump & accessories	Rs		45000.00	
R28	d.Building	Rs		16000.00	
R29	e.Elec. connections	Rs		15000.00	
R30	f.Other misc. costs	Rs		2000.00	
R31	Total investment cost	Rs		283400.00	R31C4=SUM [R25C4..R30C4]
R32	2.Annual capital costs	Life (Years) =	15.00		
R33		Sal.value (Rs)=	11300.00		R33C3=[R31C4-R25C4]/10
R34	a.Depreciation			18140.00	R34C4=[R31C4-R33C3]/R32C3
R35	b.Interest charges	Rate (%) =	0.14	21107.80	R35C4=([R31C4+R34C4]/2)*R35C3
R36	Annualized costs	Rs		39247.80	R36C4=R34C4+R35C4
R37	D.Per Unit Costs				
R38	1.Variable costs	Rs per hour		39.52	R38C4=R18C4/R6C3
R39	2.Semi-variable costs	Rs per hour		0.00	R39C4=R22C4/R6C3
R40	3.Annual fixed costs	Rs per hour		9.09	R40C4=R36C4/R6C3
R41	Total pumping costs	Rs per hour		48.61	R41C4=R38C4+R39C4+R40C4
R42	1.Variable costs	Rs per Ac.ft		158.08	R42C4=R18C4/R7C3
R43	2.Semi-variable costs	Rs per Ac.ft		0.00	R43C4=R22C4/R7C3
R44	3.Annual fixed costs	Rs per Ac.ft		36.34	R44C4=R36C4/R7C3
R45	Total pumping costs	Rs per Ac.ft		194.42	R45C4=R42C4+R43C4+R44C4

ANNEX C

FARM RESOURCES, CROP WATER REQUIREMENTS, YIELD RESPONSE FACTORS, AND STRESSED PRODUCTION ACTIVITIES

Table C1. Fixed Resources Assumed Available on Representative 10-Acre Farm in SCARP I Area

Months	Land (Acres)	Canal[a] Water	Public[a] Tubewell Water	Family[b] Labor (Hours)	Bullock[b] Labor (Hours)
		--(Acre inches)--			
January	10	2.11	6.49	281	182
February	10	2.03	7.59	281	182
March	10	4.00	6.98	281	182
April	10	5.07	9.30	281	182
May	10	6.62	9.58	281	182
June	10	6.23	9.19	281	182
July	10	4.39	10.49	281	182
August	10	5.07	11.74	281	182
September	10	6.29	11.94	281	182
October	10	7.39	12.11	281	182
November	10	7.39	8.32	281	182
December	10	7.03	7.11	281	182

Source:

a. Feasibility Report of "SCARP Transition and Pilot Project", ACE Ltd, 1985.

b. "Constraints Facing Small Farmers in Punjab", Publication No. 224, Punjab Economic Research Institute, Lahore, 1986.

Table C2. **Monthly Water Requirements (Unstressed Water Supply) for Different Crops in SCARP I Area of the Punjab Province**

(Figures in acre inches)

Month	Cotton[a]	Rice	Kharif Fodder	Kharif[a] Veg	Wheat	Rabi Pulses	Rabi Oilseed	Rabi Fodder	Rabi[a] veg	Scane	Orchard
January					2.45	1.37	0.38	2.80	3.96	0.91	0.66
February					4.25	0.49		4.50	2.38	1.45	1.38
March			0.46	3.70	1.71			5.07	1.00	2.72	2.34
April			1.73	2.50				1.70		6.15	4.16
May	3.00		3.18	4.34						9.47	5.52
June	4.50	5.44	4.99	5.86						9.77	5.17
July	4.50	10.99	2.20	6.65						5.98	2.78
August	4.50	7.71	1.17	6.40			0.36	0.55		4.71	2.85
September	4.50	8.11	1.49	1.81		1.58	2.45	3.61	1.98	6.85	5.62
October	4.50	2.41	0.38		2.71	2.78	3.15	4.70	3.50	6.26	4.97
November	1.50				2.78	1.60	2.48	4.00	2.88	3.79	2.40
December					1.56	1.65	1.48	3.07	3.47	1.94	1.08
Total	27.00	34.66	15.60	31.26	15.46	9.47	10.30	30.00	19.17	60.00	38.93

Source: Feasibility Report of "SCARP Transition and Improvement Pilot Project",Annex C3,Vol.II,1985.
a. Based on the information obtained from Punjab Agricultural Research Institute, Faislabad, and Chaudhry (1985).

Table C3. Yield Response Factors, Water Requirements Per Acre for Stressed Production Activities, and Corresponding Yields and Labor Requirements by Crops

Crop Production Activities	Water Use[a] (Ac.inches)	Labor Use[b] (Hours)	Yield[c] (Kgs)	Crop Production Activities	Water Use[a] (Ac.inches)	Labor Use[b] (Hours)	Yield[c] (Kgs)
COTTON (Kharif): Ky = 0.85				PULSES (Rabi): Ky = 1.0			
C1	27.00	176.00	340.00	RP1	9.47	48.00	360.00
C2	24.30	172.26	311.10	RP2	8.52	47.04	324.00
C3	21.60	168.52	282.20	RP3	7.58	46.08	288.00
C4	18.90	164.78	253.30	RP4	6.63	45.12	252.00
C5	16.20	161.04	224.40	RP5	5.68	44.16	216.00
C6	13.50	157.30	195.50	RP6	4.74	43.20	180.00
RICE BASMATI (Kharif): Ky = 1.2				OILSEED (Rabi): Ky = 0.9			
RB1	34.66	176.00	920.00	RO1	10.30	64.00	320.00
RB2	31.19	171.78	809.60	RO2	9.27	62.85	291.20
RB3	27.73	167.55	699.20	RO3	8.24	61.70	262.40
RB4	24.26	163.33	588.80	RO4	7.21	60.54	233.60
RB5	20.80	159.10	478.40	RO5	6.18	59.39	204.80
RB6	17.33	154.88	368.00	RO6	5.15	58.24	176.00
RICE COARSE (Kharif): Ky = 1.2				FODDER (Rabi): Ky = 0.7			
RC1	34.66	176.00	1200.00	RF1	30.00	160.00	20000
RC2	31.19	171.78	1056.00	RF2	27.00	155.52	18600
RC3	27.73	167.55	912.00	RF3	24.00	151.04	17200
RC4	24.26	163.33	768.00	RF4	21.00	146.56	15800
RC5	20.80	159.10	624.00	RF5	18.00	142.08	14400
RC6	17.33	154.88	480.00	RF6	15.00	137.60	13000
FODDER (Kharif): Ky = 0.9				VEGETABLES (Rabi): Ky = 1.1			
KF1	15.60	96.00	12000	RV1	19.17	152.00	1600.00
KF2	14.04	92.98	10920	RV2	17.25	146.15	1424.00
KF3	12.64	89.95	9840	RV3	15.34	140.30	1248.00
KF4	11.37	86.93	8760	RV4	13.42	134.44	1072.00
KF5	10.24	83.90	7680	RV5	11.50	128.59	896.00
KF6	9.21	80.88	6600	RV6	9.59	122.74	720.00
VEGETABLES (Kharif): Ky = 1.1				SUGARCANE (FULL YEAR): Ky = 1.2			
KV1	31.26	152.00	1600.00	SC1	60.00	336.00	14930
KV2	28.13	146.15	1424.00	SC2	54.00	321.89	13138
KV3	25.01	140.30	1248.00	SC3	48.00	307.78	11347
KV4	21.88	134.44	1072.00	SC4	42.00	293.66	9555
KV5	18.76	128.59	896.00	SC5	36.00	279.55	7764
KV6	15.63	122.74	720.00	SC6	30.00	265.44	5972
WHEAT (Rabi): Ky = 1.0				ORCHARD (FULL YEAR): Ky = 0.95			
W1	15.46	112.00	900.00	OD1	38.93	288.00	2000.00
W2	13.91	109.76	810.00	OD2	35.04	278.42	1810.00
W3	12.37	107.52	720.00	OD3	31.14	268.85	1620.00
W4	10.82	105.28	630.00	OD4	27.25	259.27	1430.00
W5	9.28	103.04	540.00	OD5	23.36	249.70	1240.00
W6	7.73	100.80	450.00	OD6	19.47	240.12	1050.00

a. Water requirements for stressed production activities were estimated assuming uniform reductions @ 10 % in the monthly water-use coefficients shown in Table C2.

b. Labor requirements are adjusted to reflect the impact of missed irrigation turns & low output on labor use.

c. Estimated by using yield response factors (Ky) given in FAO, 1977.

Table C4. Response of Wheat Yield to Different Moisture and Fertility Levels in Punjab.

Treatments[a]	Water used[b] (Ac.inch)	Grain Yield (Kg/ha) of Varieties		
		Chenab.79	V.1287	Sandal
M1 F1	21.62	2908	2849	2476
M1 F2	21.62	3400	3715	2382
M2 F1	19.59	2405	2574	2204
M2 F2	19.59	3378	3394	2813
M3 F1	17.78	2177	2314	1914
M3 F2	17.78	2975	3675	2470

Source: Consumptive Use of Water For Crops in Pakistan, PARC, 1982.

a. M represents the moisture level while F indicates the fertility level. These levels are defined as follows:
M1 = 1 bar tension at 13.1 % soil moisture contents.
M2 = 4 bar tension at 8.4 % soil moisture contents.
M3 = 7 bar tension at 6.0 % soil moisture contents.
F1 = 56-28-0 (NPK) kg/ha.
F2 = 168-64-0 (NPK) kg/ha.

b. Month wise water use can be found in the source cited above.

EAN PROJECT PUBLICATIONS

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1988	Nilofer Hashmi, *Style Manual of Technical Writing*
1989	Nilofer Hashmi, *Style Manual of Technical Writing*, Second Edition, Revised

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