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SUBSECTOR REPORT

PUBLIC AND PRIVATE TUBEWELL PERFORMANCE: EMERGING ISSUES AND OPTIONS

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South Asia Projects Department
Irrigation I Division

PAKISTAN

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This report, dated June 27, 1983, was prepared by R. Anson of Irrigation I Division. Colleagues in the Division have contributed their operational experience. A. Youssef, Irrigation Engineer in the World Bank's Resident Mission, also contributed. Several Annexes were prepared on the basis of materials provided by W. Barber, Consultant Hydrologist. An earlier version of this report was discussed with concerned officials from Pakistan's Federal and Provincial Governments and Water and Power Development Authority (WAPDA). Their comments and views are appreciated.

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DEFINITIONS

ACE/SGI	Associated Computing Engineers and Specialists Group Inc.
CCA	Cultivable Command Ara
ERR	Economic Rate of Return
GOP	Government of Pakistan
IACA	Irrigation and Agriculture Consultants' Association
ISS	Indus Special Study
LBOD	Left Bank Outfall Drain [Project]
M	Million
MAF	Million acre feet
NDB	Nondevelopment Budget
ODA	Overseas Development Ministry (U.K.)
O&M	Operation and Maintenance
PID	Provincial Irrigation Department
PIDE	Pakistan Institute of Development Economics
PVC	Polyvinyl Chloride
RAP	Revised Action Programme
SAL	Structural Adjustment Loan
SCARP	Salinity Control and Reclamation Project
UNDP	United Nations Development Programme
WAPDA	Water and Power Development Authority of Pakistan

SUMMARY AND CONCLUSIONS

Background

i. Pakistan's Salinity Control and Reclamation Projects (SCARPs) have become the world's most extensive and costly vertical tubewell drainage program. SCARPs originally were designed primarily to alleviate the country's severe waterlogging and related salinity problems, and only secondarily to provide supplemental irrigation supplies. At the planning stages, there were extensive discussions regarding the role of public and private sectors in implementing the proposed program. The Government of Pakistan (GOP) opted for public control of an extensive groundwater pumpage program based on the rationale that this arrangement would enable the Government to meet multiple groundwater objectives in an efficient and equitable manner.

Government Policy

ii. The uneven performance of the SCARP tubewells, the unexpected growth in private tubewells, and the growing financial constraints on the public sector's massive investment program have recently led GOP to reassess its policies regarding the roles of public and private sectors in Pakistan's groundwater development, including usable groundwater areas that are currently covered by public (SCARP) tubewells. GOP's recently prepared (June 1983) version Sixth Five-Year Plan (FY84-FY88) includes the following related strategy: "the reclamation of fresh groundwater water zone where cultivation of crops is possible would be left to the private sector. The private sector would be encouraged to install tubewells by providing closely spaced electric grid, advancing loans and giving tubewell subsidy." Although the policy also has important implications for the role of public and private sectors in completed SCARPs located in FGW areas, the Sixth Plan document highlights the importance of the SCARP Transition Study that is currently underway. The study originated from GOP's own planning efforts (Revised Action Program Report dated May 1979) and it is seeking to establish the feasibility and approach to transferring groundwater development from public to private sector in two completed SCARPs. It is significant that the Sixth Plan indicates that the implementation of this policy is expected to not only shift the O&M burden from public to private sector, but also to make the operation of the SCARPs more efficient. To help implement this policy intention--better known as "SCARP Transition"--GOP requested UNDP to fund a SCARP Transition Project Preparation Study with the World Bank acting as executing agency. Based on agreed terms of reference between GOP and the Bank, the study was initiated by a joint venture of two Pakistani private consulting firms in mid-November 1982 and is scheduled to be completed in late 1983.

Report Objectives

iii. The main purpose of this subsector report is to assess Pakistan's public and private tubewell performance and to explore emerging issues and options for future development. This review is a synthesis of a vast body of information on the operational experience of public and private tubewells, and the Bank's related ongoing dialogue with GOP. Given GOP's current policy intention to implement feasible approaches to a possible first phase of a

SCARP Transition Program, this report aims to guide the focus of the project preparation study currently under way. The report has been revised based on the results of discussions by Bank staff with Federal and Provincial officials responsible for related policy and technical matters. (held in mid-1982) and on the initial findings of the SCARP Transition Study. The complexity of the issues and the early phases of a renewed debate of public and private initiatives in groundwater development confirm the need for a comprehensive and issue-oriented report on the subject at this time. Although this subsector report is intended primarily for concerned "working level" staff of GOP and donor agencies, the organization of the report is designed to facilitate easy reference to selected issues by a wider audience.

Conclusions

iv. This report's evaluation and comparison of the public (SCARP) and private tubewell experiences provide the following conclusions:

- Public Tubewell Performance. Since 1960, GOP has installed about 12,500 tubewells over twelve completed SCARP projects, covering a culturable command area of about 6.7 million areas (or 20% of the country's irrigated land) and costing approximately Rs 6.5 billion (US$650 million in current prices). There are currently about eleven additional SCARP projects under construction, costing about Rs 12 billion (nearly US$1 billion). Unlike the completed SCARPs, however, most of these are located in saline groundwater areas. With the exception of two or three SCARP projects under way, this pattern is consistent with GOP's policy of leaving the development of the usable groundwater areas to the private sector. On balance, assessment of the SCARP tubewells suggests that they have adequately fulfilled their primary role of providing drainage relief in waterlogged areas. However, the SCARPs have not performed satisfactorily in providing timely and reliable supplemental irrigation at a sustainable cost to Government. SCARP tubewell performance has fallen short of its targets for multiple reasons--technical, financial, economic, and--primarily--institutional and managerial. This performance is in sharp contrast to the unexpected boom in private tubewells. Private tubewells, in fact, have performed a major portion of the Indus Basin's drainage and supplemental water supply functions. The SCARP Program in usable groundwater areas has clearly evolved into a critical transitional stage that offers the GOP various options.

- Scope for Improvements. The operation and management (O&M) of the SCARP tubewells can be improved, if needed institutional reforms are successfully implemented, but progress will probably be slow given some of the inherent weaknesses in public sector management experienced not only in Pakistan but throughout the world. Even so, the SCARP tubewells represent a financial burden on scarce public resources that certainly will become unsustainable in future years, particularly in view of growing investment requirements that will not be carried out by the private sector (e.g., Kalabagh Dam and Left Bank Outfall Drain [LBOD] Program). The 14,000 public tubewells currently installed will probably have to be replaced over the next ten years at a capital investment cost of about US$500 million (1982 prices). This vast sum is equivalent to about 15% of the government's proposed expenditures for the entire water sector under the Sixth Five-Year Plan. The annual equivalent capital investment would be about US$50 million, which represents approximately 40% of the total allocation for all SCARP programs. Thus far, these funds for replacement have not been budgeted in the Sixth Plan expenditure program. The current O&M costs of the public wells take up nearly 60% of the country's total irrigation O&M budget, thus squeezing funds from an already deteriorating surface irrigation system. Therefore, it is critical for policy-makers to conserve public resources wherever possible for activities that the private sector cannot and will not perform, (proposed and priority programs and projects, such as LBOD, are lagging behind primarily because of unavailable financial resources). This implies that the SCARP tubewells in saline groundwater areas should continue to be the primary responsibility of the public sector.

- Private Tubewell Performance. Review of the impressive performance of the 186,000 private smaller-capacity tubewells suggests that the private sector can adequately meet some of the multiple goals of Pakistan's groundwater development. Groundwater pumpage from private tubewells now accounts for nearly 80% of Pakistan's total pumpage, about 20% of the total irrigation supply at source, and approximately 30% of total irrigation supply at the "root zone." The last figure reflects farmers efficient use of private tubewell water for meeting timely and reliable supplemental irrigation requirements. Such irrigation is for many farmers is an important "insurance policy" for which they willingly pay a cost five or six times that of unreliable and highly subsidized public tubewell water. The efficient management patterns of the private tubewell users are reflected in cropping intensities, yields, and usage of inputs relatively higher than those observed for non-users and public tubewell users. Although the private tubewells have been owned by larger farmers who have access to their own capital resources, the existence of an active "water market" has also enabled private tubewell owners to make irrigation supplies available to many small farmers. It appears, however, that public tubewells still provide irrigation more equitably than private tubewells.

- Issues and Options. Federal and Provincial Governments' financial and institutional constraints and policy intentions, and the comparison of public and private tubewell performance raise a fundamental issue: what should be the role of the public and private sectors in the future development of Pakistan's groundwater resources, particularly in relation to SCARPs located in usable groundwater areas? Since SCARP Transition is one of the options currently being considered by GOP, how can this concept be translated into a feasible approach for implementing a first-phase project in selected areas? In the course of addressing the above issues, this report highlights various options: transfer of SCARP tubewells to the private sector under various forms of farmer management; replacement by smaller-capacity and low-cost private tubewells; improving the existing O&M arrangements and substantially raising water charges; continuing the existing deficient SCARP arrangements; transferring O&M to private contractors under clearly defined arrangements; or status quo.

- Feasibility of SCARP Transition. The findings of this report suggest that implementation of a first-phase SCARP Transition option would be feasible provided that two main conditions are met. First, SCARP Transition would need to be initially restricted to an agreed area (e.g., SCARP I, SCARP N, Rohri and other areas agreed by Provincial governments). Within this area, the specific approach followed would vary according to each tubewell's physical condition and to farmer preferences. Some SCARP tubewells might be transferred to a group of farmers; other SCARP wells might be terminated and replaced by smaller-capacity private tubewells under individual or joint ownership. Under all options and specific approaches, the public sector would continue to play some role to ensure the achievement of the multiple objectives of groundwater development. Second, the SCARP Transition project preparation study would need to address adequately related issues that are briefly discussed in this report: technical, physical (including arrangements for adequate distribution of water supplies), management and institutional, legal; power supply; impact on drainage and equity requirements; and other policy matters (e.g., credit, pricing, SCARP policies, and cost recovery). Finally, the report suggests that many of these issues cannot be fully resolved in the abstract or by following other country experience that may not be applicable to Pakistan's specific features, needs, and policies. As argued, SCARP Transition should begin on a limited basis to gain practical experience as a sound basis for determining the scope, phasing, and approaches for future programs. In the interim, there are a number of policy decisions, some of which are being adopted in GOP's Sixth Five Year Plan, that could facilitate the process outlined above. The precise content and implementation time frame of these policies are expected to be guided by the findings of the SCARP Transition Project Preparation Study currently underway. These interim policies include:

- Phasing out the public sector funding of the tubewell replacement program in usable groundwater areas; as indicated in the Sixth Plan, the first step is for the Provincial Governments to take over the financial responsibility of tubewell replacement, which has previously being covered by the Federal Government; simultaneously, efforts should be made to involve the private sector in this replacement program;

- Phasing out further public sector financing of additional SCARP tubewells in ongoing SCARPs having usable groundwater supplies; in this conneetion, the completion of on-going SCARPs in FGW areas should be reviewed on a case-by-case basis;

- Stopping the approval of future SCARP projects in usable groundwater areas; this reclamation would be left to the private sector, with the public sector promoting support through adequate availability of credit and power supplies;

- Increasing surface water charges to induce private pumpage in SCARP areas having usable water supplies; increasing water charges for SCARP tubewells; and introducing an increased water charge to help cover the costly O&M expenditures in saline groundwater areas.

o SCARP Transition represents a good example of a policy decision that has important sectoral and macroeconomic repercussions, particularly in relation to implementing a sector policy to promote private sector initiative for the country's development. These policy and sectoral considerations may comprise the most compelling rationale for developing a feasible SCARP Transition Program and/or sustainable alternatives within prevailing technical and social constraints.

1. INTRODUCTION

Objectives and Scope of Report

1.01 In the early 1960s the Government of Pakistan (GOP) initiated the first of a series of Salinity Control and Reclamation Projects (SCARPs). They have become the world's most extensive and expensive vertical tubewell drainage program based on publicly owned and managed tubewells. Their slow start-up and uneven performance is in contrast with a boom in the growth of private tubewells. These contrasting experiences and related complex issues have led to an extensive debate on the role of public and private tubewells in the development (and conservation) of Pakistan's abundant groundwater resources. Over the last decade, numerous piecemeal studies have been carried out, which have highlighted the technical, institutional and managerial, and financial problems of the SCARP tubewells. Particularly because of Pakistan's increasing resource constraints and investment requirements, GOP has reassessed its mode of groundwater development; in principle, GOP is committed to phasing out or divesting the SCARP tubewells wherever possible (in usable groundwater areas) and transferring the primary groundwater functions to the private sector. In this process, the public sector's role would evolve to being a "facilitator" and "guardian" of this valuable resource. This concept is better known as "SCARP Transition." This policy intention is in the process of being translated into a feasible project for possible financing by the Bank. 1/ GOP's policy intentions of developing feasible approaches to "privatizing" SCARPs is also reflected in the draft Sixth Five-Year Plan (FY84-FY88). The overall objective of the present report is to identify and discuss main technical, financial, organizational, legal, and policy issues and implementation procedures related to GOP's efforts to promote improved groundwater development in SCARP areas in a manner that:

- Assesses the actual performance/experiences in Pakistan of public vis-a-vis private tubewell development, based on various evaluation criteria

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1/ GOP took the initiative to request the SCARP Transition Project Preparation Study; it is financed as part of the UNDP Investment Project Preparation in the Water, Agricultural, and Energy Sector (PAK/81/004), with World Bank as executing agency. The proposed study has two phases: a reconnaissance survey of available information and of a program nature; and project preparation for two of the earlier selected SCARP Projects (e.g., SCARP 1 and SCARP N. Rohri). The study was initiated in mid-November 1982 and is expected to be completed by late 1983. Associated Consulting Engineers and Specialists Group Incorporated (ACE/SGI) are carrying out the study.

- o Provides a framework of analysis and guidelines for formulating a strategy that seeks to improve the arrangements for groundwater development in existing SCARP areas and for implementing such a strategy in the context of the proposed SCARP Transition Program

- o Increases the Bank's sectoral knowledge and the strategic role of groundwater development in Pakistan's irrigation development, particularly in relation to formulating an appropriately designed first-phase SCARP Transition project

- o Helps strengthen GOP's and Provincial commitment and approach to the SCARP Transition concept and program while recognizing the various complex dimensions to implementing the program.

1.02 This report is based on synthesizing existing studies related to the performance of SCARP and private tubewells. The report does not presume to predetermine the possible results, and/or duplicate the proposed project preparation studies for, the SCARP Transition and the Private Tubewell Electrification Projects. Rather, based on available information, the present report focuses on assessing the underlying rationale for the SCARP Transition concept, including the provision of an analytical and policy framework that would facilitate both the implementation of the proposed SCARP Transition Project Preparation Study, including a sharpening of the data needs and main issues to be addressed by the project peparation study, and technical and policy discussions within the Bank and Pakistan in relation to the proposed concept, related options, and proposed project.

1.03 Some of the principal questions addressed in the report include:

- o What is the past and future role of groundwater in the development of Pakistan's irrigation and agricultural resources? (This section is presented as Annex A).

- o What have been the roles of SCARP and private tubewells in groundwater development and the main determinants of their observed patterns? How have these patterns been influenced by evolving GOP and Provincial policies?

- o What has been the actual performance and experience of public and private tubewells in Pakistan based on various evaluation criteria, particularly in relation to physical, management, and financial considerations?

- o What should be the role of the public sector in Pakistan's groundwater development, considering the main options in usable groundwater areas?

- o What are the principal issues related to the implementation of the SCARP Transition Program?

2. EVALUATION OF THE SCARP TUBEWELL PERFORMANCE

Origin and Evolution of the SCARP Program

2.01 A balanced assessment of the Salinity Control and Reclamation Projects (SCARP) and their future course needs to be viewed in the context of the origins and evolution of the SCARP program. Its origin dates to the 1940's when public tubewells were first installed by Irrigation and Power Department on a limited basis in an initial effort to address Pakistan's extensive problems of waterlogging and salinity. Through the 1950s, the Government of Pakistan (GOP) experimented with various tubewell drainage schemes, which included three projects that installed about 1,200 tubewells. However, these attempts to control waterlogging were generally unsuccessful, partly because they were not on a sufficiently widespread scale and were not provided a suitably designed grid covering a drainage unit. 1/ It was natural, therefore, that a more comprehensive approach should be advocated, which gave origin to SCARP I, the first large-scale project in a series of proposed similar projects. Their objectives were defined primarily to alleviate Pakistan's waterlogging and related salinity problems and secondarily to supplement canal irrigation supplies.

2.02 Shortly after SCARP I was initiated in 1959, a plan for eradicating waterlogging and salinity in the whole of Pakistan was prepared in 1961 by WAPDA with the assistance of various foreign consultants. 2/ The content of this plan which included regional plans and possible solutions to Pakistan's waterlogging and salinity problems, as reviewed by three separate missions of experts during the 1960s. The missions included: (1) a panel sent by the U.S. President in the early 1960s that prepared what is known as the "White House" or "Revelle Report"; 3/ (2) a group of three foreign consulting firms appointed by the World Bank at GOP's request; 4/ and (3) a World Bank study group, headed by Pieter Lieftinck, who in the late 1960s consolidated and

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1/ The Water and Power Development Authority (WAPDA) was established in 1958 partly to address water resource development and the related problems of waterlogging and salinity.

2/ These consultants included Harza Engineering Company International, Tipton and Kalambach, Sir M. MacDonald's and Huntings Technical Services.

3/ White House-Department of the Interior Panel on Waterlogging and Salinity in W. Pakistan, "Report on Land and Water Development in the Indus Plain," Washington, D.C.: 1964, U.S. Government Printing Office.

4/ The group of three consulting firms called themselves Irrigation and Agriculture Consultants Association (IACA).

added to the findings of the previous studies. 1/ Although there were variations regarding possible technical and organizational solutions to the waterlogging and salinity problems, the various studies concentrated on the technical matters and contained similar elements in the recommended solutions. There was some discussion about the merits of horizontal drainage versus vertical drainage. However, these studies emphasized the need for using vertical drainage technology, with particular emphasis on the Punjab. Another study, the Lower Indus Planning study, emphasized the need for surface drainage in Sind Province. Despite the recognized limitations in achieving a long-term solution of draining large quantities of saline water, these studies generally supported the use of vertical drainage technology. Regarding the focus of this paper, these studies recommended that groundwater development and the related alleviation of the waterlogging-salinity problems should be carried out by public tubewells. However, a small number of Pakistani experts (particularly Dr. Ghulam Mohammad of the Pakistan Institute of Development Economics, or PIDE) 2/ argued for a different mode of groundwater development that combined the roles of public and private sector involvement--namely that public tubewells should be installed in areas where groundwater was too saline to be applied to lands without dilution with canal water, and that in areas of nonsaline, good-quality groundwater, development should be left to private users, with the government facilitating development by providing the more economical electrical grid and credit schemes for purchase of pumps and motors. The almost unanimous recommendation for public tubewells can largely be explained by the fact that most of the original studies were completed before there was any significant degree of private tubewell development in the Indus Plain. As stated in the Revised Action Programme (RAP) report, the strategy of tapping the large usable groundwater potential of the Basin by installation of public tubewells was based on the rationale that private development of this resource: (1) would be inequitable (small farmers would not be able to benefit from this technology); (2) would be haphazard, and so would not be able to accomplish the required drainage objective; (3) would damage the groundwater aquifer through uncontrolled pumpage; and (4) could not be expected to proceed at the required

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1/ This report was published as follows: Pieter Lieftinck, Robert Sardove, and Thomas Creyke, Water and Power Resouces of W. Pakistan - A Study in in Sector Planning, 3 vols. Johns Hopkins University Press, (Baltimore, Md.: 1968).

2/ See Gulam Mohammad, "Waterlogging and Salinity in the Indus Plain: A Critical Analysis of Some of the Major Conclusions of the Revelle Report," Pakistan Development Review, Karachi, 1964, vol. IV. No. 3 and Karachi, " Private Tubewell Development and Cropping Patterns in West Pakistan," Pakistan Development Review, vol. V (1965) no. 1; G. Mohammed and others, "An Analysis of the Public and Groundwater Development Programme;" PIDE (1967). This paper is a critical analysis of the three missio reports mentioned above.

rate. Based on about twenty years of experience, the validity of these assumptions and criticism of the private sector are reviewed below.

2.03 The recommendations of the above studies regarding the mode of groundwater development have been reflected to varying degrees in GOP's five Five-Year Plans, which have covered the period from 1960-83. As a result, these Plans have allocated from 40-55% of the water sector budget to drainage and reclamation schemes, which have included the SCARP projects. Since the implementation of the SCARPs was progressing slowly, in 1973 GOP adopted an "Accelerated SCARP Program." As of mid-1980, the implementation progress of the SCARP program was as follows: (1) twenty-seven SCARP public tubewell projects were at different stages of implementation; (2) some 12,000 tubewells have been installed for draining or providing supplemental water for a cultivable command area (CCA) of almost 7.6 million acres; (3) roughly 5,000 miles of drainage works (primarily surface) have been completed; (4) expenditures have totalled about Rs 5,475 M or (US$553 M). Tables B.1(a-c) present a summary overview of the main features of the SCARP Program for each province and Pakistan. The public tubewells were originally intended for drainage to reduce waterlogging and the associated salinization of soils. Since drainage projects generally have low economic returns, priority was given to locating the SCARPs in areas that had groundwater of usable quality. As a result, about 90% of the tubewells and 95% of the design pumpage have been in these areas; in effect, SCARPs have evolved into water supply projects in which drainage is a by-product. This shift was partly an inevitable result of "discovering" an abundant aquifer that could be tapped for irrigation purposes. As will be discussed in the sections below, this shift and actual experience have raised a number of issues that have implications for future resource flows.

Overall Evaluation

2.04 The following section will highlight the performance of the SCARP tubewells by drawing on the results of various studies 1/ that have assessed the progress of the SCARPs. These studies were carried out during the 1970s and have focused on analyzing the results of selected parameters that have been monitored by WAPDA, particularly in regard to: control of waterlogging and salinity; groundwater pumpage and availability of water for irrigation; water quality; and tubewell performance, including its deterioation in capacities and its maintenance problems. Although some production-related data have been collected, such as yields and cropping intensities and patterns, no rigorous or systematic impact evaluations have been carried out for any of the SCARPs. Some data for most of these parameters are available through 1981, although most of detailed SCARP evaluations have been based on data up to about 1977. Since that date, most of the evaluation statements have been based on past trends and informed judgments, which still need to be integrated with updated and scientific data analysis.

2.05 To arrive at an overall assessment of the SCARP program, the present study has reviewed in detail the available findings of specific SCARPs. Some of the most relevant data are summarized in the tables included under Annex B. Therefore, the study approach has been to focus on synthesizing the dominant trends that have emerged and characterized the performance of the SCARPs. In general, the data, related studies and informed judgments present a generally uneven performance of the SCARP tubewells, particularly considering their relatively ambitious and optimistic targets. With the benefit of

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1/ The principal studies that collected the basic data were: (1) Government of Punjab, Land and Water Development Board, "Report of the Special Committee on the Working of the SCARPs," Lahore, 1971; (this report, better known as the "Irshad Committee Report," reviews the performance of SCARPs I, II, III, and IV, through 1970); (2) WAPDA, Central Monitoring Organization, "Review of Completed Salinity Control and Reclamation Projects," September 1978, (this report is the most comprehensive quantitative report of the SCARP projects-- SCARPs I,II, III, IV, Khairpur and N. Rhori projects, through 1975). Three other studies utilized for the present report were based on the above data but were relatively more interpretative and policy-oriented: (1) World Bank, "PAKISTAN - Special Agriculture Sector Review," Volume II on "Irrigation and Drainage," January 1976; (2) Dr. Bokhari, "Severity of Waterlogging and Salinity Problems in Pakistan," Paper presented to Proceedings of the 57th Annual Session of Pakistan Engineering Congress, 1980 (Paper no. 440); and (3) WAPDA, Master Planning and Review Division, "Revised Action Programme for Irrigated Agriculture", (3 vols.), Lahore, 1979. For a recent assessment of the SCARP I Project, see report prepared by Dr. N.M. Awan, "Technical, Social and Economic Aspects of Water Resources Management in SCARP I", (Lahore: December 1981), a University of Engineering and Technology, study under contract with United Nations University, Tokyo.

almost twenty years of accumulated experience, the reviews clearly suggest that the SCARP concept of public control of groundwater development, although sensible in theory and beneficial in numerous ways, has not functioned satisfactorily, primarily because: (1) public resources were not available to finance the requirements for efficient installation, operation, maintenance, and replacement of tubewells; (2) adequate pricing policies for irrigation water supplies were not introduced to promote water conservation and to generate resources from the beneficiaries; and (3) centralized management of a large battery of tubewells proved infeasible. The section below examines these issues and conclusions by highlighting the overall SCARP performance in terms of physical impact, management performance, and financial and economic burden to the public sector and the country.

Physical Impact

2.06 The various reviews of the SCARPs have shown that public tubewells have generally followed a cycle of improvement of the initial waterlogging problem, increase of irrigation water supplies, a subsequent decline in pumpage, and resulting rise of watertables. For example, the design-capacity pumpage for the principal twelve completed SCARPs was about 23.1 million acre feet (MAF) per year; instead, 1978/79 WAPDA data show that the actual pumpage for these aproximately 10,200 tubewells was only 7 MAF (or 30% of the design target). Table B.2 shows the significant declines in pumpage for various SCARP projects. For example, SCARP I pumpage has declined from 2.5 MAF in 1963/65 to about 1.5 MAF in 1979/80. As a result, SCARP tubewells are operating under very low capacity utilization rates--averaging about 30% in fresh groundwater areas and nearly 40% in saline groundwater areas. Much of these decreases in pumpage are due to deterioration of tubewell discharge capacity and protracted down-time before mechanical and electrical defects are repaired. Table B.3(a) presents data on the significant operational deterioration of SCARP tubewells expressed in terms of declining well discharge capacities and specific capacities. 1/ Table B.3(b) shows the extent of tubewell deterioration reached by 1981. For example, 44% of the SCARP I tubewells are operating at less than half their design capacity. This deterioration in discharge capacity for SCARP tubewells has declined an average of about 4.6% per year, 2/ which has been due to the combined effects of tubewell closures, decline in watertable, and reduction in specific capacity. 3/

1/ Discharge capacity refers to design pumpage capacity, whereas specific capacity refers to discharge per unit of drawdown (cusecs per ft).

2/ As reported by WAPDA, "RAP Report," vol. 1, p. V-40.

3/ "RAP Report" states that the specific tubewell capacity for the SCARP reviewed declined by 3.3% per year.

Waterlogging and Salinity Control

2.07 The physical facts of declining pumpages and pumping capacities as summarized in para. 2.06 have significantly contributed to the general underachievement of the drainage and agricultural targets that were used to justify the approval of the SCARPs. The drainage functions were partially achieved; Table B.4 clearly shows that the waterlogging problem in the SCARP areas has improved, particularly in the critical range of 0-5 ft. However, some of the available data show that the watertables are rising, in some cases to their preproject levels. For comparison, the status of waterlogging in the entire Indus basin in 1980 is summarized in Table B.5. For the 0-5 ft interval, 24% of the SCARP commands are waterlogged, compared with about 30% for the Indus Basin; for the 0-10 ft interval, however, SCARP commands are more waterlogged than the Basin (63% vs. 58%). 1/ Nevertheless, assuming that the 0-5 ft range is the most critical from the point of view of production, available data show that the SCARPs have adequately fulfilled their drainage functions, although not to the level originally planned. 2/ Various other studies have correctly shown that the waterlogging relief provided by SCARP tubewells often has been temporary, because the conditions tend to reverse as soon as the tubewell becomes inoperative for one reason or another. In some cases, this outcome has already resulted in existing SCARP areas where public tubewells were abandoned due to higher salinity or mechanical breakdown of the tubewells. 3/ Therefore, the assessment of Pakistan's waterlogging situation and the apparent controversy surrounding its relative severity need to receive greater attention in future monitoring and data interpretation for arriving at an appropriate action plan. This "management information" function is discussed further in paras 2.16 and

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1/ Although there are some discrepancies in waterlogging data, varying according to data source and period observed, the overall trends point to the same conclusions.

2/ During the SCARP preproject, implementation and operation stages, the 10-ft minimum depth to watertable has been a dominant target (at least implicitly) for all SCARPs. There is growing evidence suggesting that the criterion or guideline of maintaining the depth-to-water table between 10-15 ft (but at least 10 ft) is oversimplistic, overdesigned, and not applicable to all areas. At the same time, the original targets may have allowed a cushion for corrective action when deterioration takes place in well yield and for possible rainfall fluctuations. Realistic drainage targets should consider the depth of the crop root zone and zone and take account of regional variations in: soil texture, soil salinity, availability of irrigation supplies, quality of irrigation water, rainfall patterns, cropping intensities and patterns. Annex C presents some thoughts on watertable depth for optimal crop production.

3/ For further discussion, see Dr. Bokhari, "Severity of Waterlogging and Salinity Problems in Pakistan," 1980.

4.11. Finally, Table B.6 shows that surface and profile soil salinity indicators have improved for most SCARPs, particularly for the critical saline-related categories.

Production Indices

2.08 Table B.7 summarizes various agricultural production indices observed over time for SCARPs I, II, III, IV, Khairpur, and N. Rhori. The changes generally show improvements in terms of higher yields, higher cropping intensities, and some shifts toward the relatively more water-intensive and higher-value crops (paddy and sugarcane). However, the optimistic targets set at the planning stage were generally not met by most SCARPs. For example, early studies assumed that cropping intensities would double, from about 75% to 150%. Instead, intensities in most areas have stabilized at around 115%, with some increased crop yields and more area under high-value crops. Furthermore, various studies have correctly reported that the agricultural benefits observed in the SCARP areas cannot be attributed to SCARPs only, because significant private sector tubewell development plus other agricultural improvements have occurred in SCARP areas. As discussed in para. 2.14, the operational deficiencies of most SCARPs are attributed to their inabilty to adequately meet the crop water requirements; therefore, SCARP operations have resulted in a suboptimal use of the expected conjunctive use of surface and groundwater supplies.

Management and Institutional Factors

2.09 Numerous interrelated factors have contributed to the uneven and inefficient performance of the SCARPs, but most of the underlying problems can be traced to deficient management, beginning at the planning stage. These shortcomings have been reviewed in detail by numerous studies (see footnote to para. 2.04) and can be classified in terms of: (1) design and technology; (2) institutional arrangements and operational criteria; (3) maintenance; and (4) farmer organization and incentives.

Design and Technology

2.10 The SCARP tubewells were designed to maximize their "technical" efficiency to meet a multipurpose groundwater development program of drainage and supplemental irrigation. As a result, these tubewells used relatively sophisticated and large-capacity pumps--imported turbine pumps that ranged from 1 to 5 cusecs—that assumed the presence of an efficient centralized management system. In SCARP I and some areas of SCARP II, capacities of the tubewells were fixed so that the combined water supply from surface and groundwater at the watercourse head was about 1 cusec per 150 acres. In subsequent SCARPs, a cropping intensity for the area was projected, and the tubewell capacities were determined to provide the necessary water supply to meet this requirement of one to three watercourse commands. In practice, no provisions were made for constructing necessary link watercourses and for enlarging the main watercouse channel and distribution system, even though the planners expected the system would carry two to three times its previous flow quantity. In addition, appropriate mixing ratios between canal and tubewell water supplies fit for irrigation were frequently not achieved, in some cases because of a number of deficient design factors--in particular inappropriate siting of tubewells as assessment of groundwater (which has resulted in closures of certain tubewells in SCARPs) and inappropriate tubewell designs and mixing chambers (which lead to undesirable mixing and distribution of both surface and groundwater supplies).

2.11 Also, the rather high rate of SCARP tubewell deterioration, which has contributed to low capacity utilization rates, is partly due to inadequate design, construction, and maintenance of screens and gravel packs. 1/ In spite of almost twenty years of experience in declining tubewell capacity, no significant design changes have been made from the first SCARP tubewells except the change from mild steel to the fiberglass screens in 1963. 2/ As a result, the originally predicted thirty year service life of the SCARP tubewells has now been reduced to a practical average lifespan of approximately fifteen years, although the life is highly variable depending on the extent of repair and maintenance. Decreased life and operating efficiency of the SCARP tubewells have also been attributed to inadequate construction procedures that have adversely affected the quality control in gravel pack and development of the well. Systematic research leading to improvement in tubewell design and construction has not been pursued, partly because of lack of funds and partly because no institution has been designated for this specific responsibility. As stated by the "RAP Report", over the past 20 years there has been inadequate feedback from field experience to improve tubewell design and construction. Annex D highlights some additional features of the SCARP tubewell technology.

2.12 The various technical and management-related problems associated with the SCARP tubewell experience raise some fundamental questions regarding the appropriateness of technology used by the SCARPs. Rather than using vertical drainage as a relatively uniform technology to meet multiple objectives, there is a growing consensus in Pakistan of the need to adapt alternative technologies according to various physical and organizational parameters. 3/ For example, the following considerations emerge from past experience: the

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1/ Some of these principal problems and causes are summarized in the "RAP Report", p. V-40. These observations are based on detailed studies, including: WAPDA, "Review of Completed Salinity Control and Reclamation Projects"; Harza Engineering Co., "Evaluation of the Performance of Difference Screen Materials in SCARP Tubewells," Lahore, 1978, A summary of the report findings are attached as Appendix VII in the WAPDA report referred to above.

2/ For an evaluation of different screen materials for SCARP tubewells, see the Harza study, 1978.

3/ Some of these views are presented by Dr. Bokhari, "Severity of Waterlogging and Salinity Problems in Pakistan," 1980.

size of the tubewell should be according to the CCA of one watercourse (this point was adopted in the late 1970s); the approach to choosing the tubewell technology should reflect the relative importance of the drainage and supplemental irrigation objectives (for example, where drainage measures are to be adopted, consideration should be given to the horizontal surface/ subsurface drains after considering the appropriate physical characteristics, such as where water quality is deteriorating, and economic outcomes).

Institutional Arrangements and Operational Criteria

2.13 SCARP tubewell projects have been planned, designed, and constructed by WAPDA, operated by WAPDA initially for a year or two, and then handed over to the Provincial Irrigation Department (PID). Following the recommendations of the "White House Report" prepared in the mid-1960s, the SCARP I project in Punjab was operated initially on an integrated basis under the Land and Water Development Board. The entire project was under the executive control of a Project Director, under whom were field units responsible for operation and maintenance of tubewells, distribution of integrated irrigation supplies, and agricultural extension and cooperatives. In 1970, this approach was abandoned because it was top heavy, expensive, and creating unnecessary friction, and the various activities were taken over by the regular provincial agencies. Khairpur SCARP was also organized under a Project Director, but surface irrigation management was under a Senior Engineer of the PID.

2.14 With the exception of the earlier apparent 1/ unsuccessful experiments gathered under the SCARP I and Khairpur projects, there has been no formal integration of canal and tubewell water supplies as envisioned by the planners of the SCARP projects. The organizations responsible for canal operations, although a part of the same PID, are parallel to each other and do not have institutional cross-links below the level of Regional Chief Engineer. This arrangement presents a fundamental problem, since most day-to-day operating decisions of the irrigation system are made at the Divisional level under the charge of the Executive Engineer. Moreover, even

1/ There are differences of opinion on the relative successes and failures of the Land and Water Development Board.

at the planning stage, pumping schedules 1/ of the SCARP tubewells have not been adjusted to reflect estimated canal supplies and crop water requirements. Negligible consideration of the recommended plant-water relationship is reflected by the fact that the Irrigation Department has fixed the tubewell operational schedules with minimal consultation with the extension personnel of the Agriculture Department. When such consultations occurred, it was on an ad hoc basis. In some cases, in theory it would have been possible to divert canal supplies to water-short commands and to compensate for this deficit by pumping extra hours. In practice this adjustment has never been pursued. Therefore, the separated and uncoordinated institutional roles of various concerned agencies have made this type of operating procedure inadequate to achieve effective conjunctive use. The outcome has severely restricted the potential benefits of the envisioned conjunctive system envisioned under the SCARP projects.

2.15 One of the SCARPs' major operational problems that has aggravated an already deficient operating schedule has been directly related to the difficulties of managing the tubewell operators. They are employed by the Irrigation Department and comprise the largest number of staff working in SCARP circles. Poor performance of the operators is one of the main complaints about SCARP tubewells voiced by both farmers and the Irrigation Department staff. Some of the commonly reported problems refer to operators who: (1) are frequently absent from their tubewells, with the result that tubewells may not be restarted if tripped off by protective devices because of temporary electric supply problems; (2) disable the protective devices; (3) allow farmers to operate the tubewells, resulting in a high incidence of burned-out motors; and (4) provide preferential arrangements to some of the farmers in the tubewell command area. Attempts to discipline or dismiss operators have generally been unsuccessful because of a powerful operator labor union. Whatever the truth of these allegations, it is clear that day-to-day operations of tubewells are supervised very loosely if at all. An absence of effective control over activities of field staff--by senior officials, by standardized cross-checking procedures, or by the farmers through

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1/ SCARP tubewells are supposed to be operated on schedules developed in perennial, nonperennial, and uncommanded areas; schedules do not allow for rainfall nor power failures; data available on actual operating hours are sketchy and must be used with caution. Notwithstanding these qualifications, some general operating criteria have been developed as guides to lower the watertable and to provide supplemental irrigation water. In general, the drainage objectives have aimed to pump water such that the water table remains below 10 feet, although in practice this guideline was not always followed for various justified and nonjustified reasons. Regarding supplemental irrigation, the proposed "Lalian pumping schedule" used for the the SCARPs varies little from month to month and bears little relationship to a schedule that attempts to match expected water supplies with expected demand, which is a schedule usually followed by private pump operators.

some ability to reward or penalize--demonstrates the inherent weaknesses of current public sector management of the SCARP tubewells.

2.16 Other institutional factors that have hampered the management of the SCARP tubewells have been related to: the absence of properly defined water and soil quality standards that could be used to meet realistic salinity, drainage, and irrigation targets including appropriate mixing ratios of differing water qualities) and deficient monitoring and evaluation of the SCARP projects in a manner that ensures an independent and unbiased analysis of the data. 1/

Maintenance

2.17 The various studies that have assessed the performance of SCARP tubewells have consistently shown that maintenance has been deficient and has represented a significant shortcoming of the SCARP program. The principal underlying and interrelated causes have been technical, institutional, and financial, which ultimately have been affected by poor management. As already discussed in para 2.06 and as illustrated in Tables C.2 and C.3, these problems have resulted in declining pumpage and excessive deterioration of SCARP tubewells. For example, a significant portion of the declines in pumping capacity and specific capacity are due to deficient maintenance of screens and gravel packs. As a result, numerous wells experienced critical problems with encrustation and perhaps clogging of gravel pack, and corrosion, even after various attempts to modify the materials used in construction. To date, only a few attempts have been made at maintenance and rehabilitation of tubewell screens and tubewells start lose the yield. These methods, however, are costly and require large quantities of chemicals, special equipment, and a high degree of skill. 2/ Nonetheless, it may be useful to carry out a small rehabilitation program on a pilot basis. Also, the various reports have documented frequent and protracted maintenance problems caused by various mechanical and electrical defects of tubewells (see Table B.8). For example, various surveys have shown that, at any point in time, anywhere from 20-45% of the SCARP tubewells were not operating due to one maintenance-related defect or another. This performance is contrasted with the high operational functioning of private tubewells, which frequently

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1/ This point reflects a common view that the data collected through the monitoring activities of the SCARP projects are relatively unorganized and perhaps unreliable and therefore have been of limited value as an effective management instrument. Various proposals to improve this information system, such as the one proposed by Dr. Bokhari, should receive serious consideration; for reference, see footnote to para 2.04.

2/ Arrangements are being made for an applied research and demonstration project, with the assistance of the British Overseas Development Ministry (ODA), to determine appropriate procedures, effectiveness, and cost of tubewell screen maintenance and rehabilitation.

exceeds 90%. Even when funds have been available to repair the tubewells, the approval process has been slow, cumbersome, and centralized, often requiring the decision of the Regional Chief Engineer. Moreover, the funds for maintenance have not been used to implement an effective program of preventive maintenance, which effectively has resulted in higher maintenance costs. For most projects, this institutional deficiency has been partly due to an absence of systematic inspection and maintenance routines and standardized repair procedures. Only recently WAPDA, in consultation with the Punjab and Sind Irrigation Departments, prepared a series of maintenance manuals geared to the functions and responsibilities of the different organizational levels concerned with maintenance--from the project management level to the tubewell operator. These problems of poor maintenance in part have resulted in substantial reduction in the life of SCARP tubewells. In addition to the factors discussed above, one of the reasons for this poor maintenance record has been inadequate funding provided in the Operation and Maintenance (O&M) budget. These shortages have also been a major cause of the accumulated deterioration of Pakistan's overall surface irrigation system, a problem which is being addressed by the IDA-supported Irrigation Systems Rehabilitation Project. 1/

Farmer Organizations and Incentives

2.18 Another constraint that has contributed to the SCARP management problems is related to the inadequate planning at the watercourse level, including unrealistic assumptions regarding farmer's incentives and behavioral responses to the SCARP arrangements. Tubewells that potentially could serve one to three watercourses, over 500 hectares, and as many as 100 farmers reflect the fact that planners gave little thought to local conditions, particularly the role played by the farmers in using efficiently the additional water supplies. Field investigations during the planning stages would have revealed that farmers along a single watercourse had difficulties in organizing operation and maintenance. The bulk of court cases originating from rural areas concerns conflicts over water and associated land. Provision of large, publicly owned and operated tubewells that were designed to serve two or more watercourses immediately created a potential for all sorts of new conflicts. Adequate investigations of farmers' organizational capacities, as well as their technical ability to manage larger flows of water, would have indicated that smaller-capacity, more localized tubewells primarily for irrigation purposes were better suited to existing conditions. The argument that larger public wells are more "economic" and "efficient" than smaller private wells rests on the unrealistic assumption that management under both systems would be the same. Planners failed to recognize farmers' limited capacity to cooperate at the watercourse level, particularly

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1/ For further discussion of the maintenance problems and related financial causes, see IDA's Staff Appraisal Report for "Pakistan - Irrigation Systems Rehabilitation Project," April 9, 1982, pp. 12-15.

between several watercourses 1/ without establishing and strengthening appropriate forms of organization (e.g., highlighting a more generalized problem of the absence of farmer organization) and the technical difficulties and lack of incentives faced by farmers in the redesign and enlargement of watercourse channels and distribution systems required to carry higher flows (often two to three times the previous quantity). This outcome also reflects the impact of the traditional "warabundi" system, which was designed to share scarce surface supplies and which has continued to function with no significant adjustments with the coming of tubewell water. As a result, the high-capacity tubewells, which were designed to flow through a sophisticated diversion box that allocated the water to two or more watercourses, frequently bypassed these diversion boxes and served only one watercourse. Other problems that reflect poor farmer organization include inappropriate mixing of canal and tubewell water supplies and inadequate maintenance of watercourses. These shortfalls have aggravated the existing salinity and waterlogging problems in many of the SCARP areas.

Financial and Economic Impact

2.19 Most of the discussions of the SCARP tubewells have focused on their financial burden to the Government. The following section will take a broader view of the SCARP tubewells by highlighting their financial impact on farmers and the public sector and/or their economic impact. 2/ Considering the data limitations, the emphasis is placed on interpreting emerging trends. Further follow-up work is necessary to carry out more rigorous and quantitative analysis.

Financial Impact on Farmers

2.20 All of the SCARP projects were planned to generate substantial income benefits for the participating farmers, with increases exceeding 100% in many of these projects. Although there has been no systematic expost analysis, 3/ a comparison of the planned and actual agricultural parameters suggests that the expected increases in farm incomes have not been achieved (Table B.7 compares planned and actual crop yields and intensities). In addition, the

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1/ This factor of planning one SCARP tubewell for several watercourses fails to recognize Pakistan's traditional evolution of an almost autonomous water management unit created around a single watercourse.

2/ This distinction accounts for the differences in financial and economic prices of both inputs (particularly of energy) and outputs.

3/ Perhaps the only detailed expost impact analysis of the SCARPs was carried out for the SCARP I project in the late 1970s as part of the "RAP Report". The results and implications of this analysis are discussed further in para 2.29.

technical and management problems discussed in paras 2.06-2.18 have greatly reduced the potential production and income benefits of the SCARP tubewells.

2.21 At the same time, available data (see Table B.7) generally show substantial increases in production over the preproject levels, exceeding 50% for many of the SCARPs. Since these public tubewells have been highly subsidized, the financial returns to benefiting farmers in general appear to have been relatively high, particularly considering their low preproject income levels. 1/ It is noteworthy that, despite these high financial returns, numerous farmers have purchased private tubewells or water to compensate for the shortcomings of the SCARP tubewells. This farmer ambivalence toward the SCARP tubewells has been documented in various reports. For example, a recent WAPDA survey 2/ found that fixed irrigation timings, nonirrigation of high-level areas, and centralized management of SCARP tubewells are indicative of mixed farmer attitudes toward the SCARPs; these factors have also helped induce a high growth of private tubewells in SCARP areas. The role of private tubewell is reviewed in the following chapter.

Financial Burden on the Public Sector

2.22 One of the most important factors that has hampered the performance and impact of the SCARP tubewells has been related to the inadequate funding of their capital (replacement) and O&M requirements. As already discussed in paras 2.06-2.18, this O&M underfunding has contributed to some of the physical and management-related shortcomings of the SCARP tubewells. These problems are reflected in the SCARP tubewells' low utilization rates relative to their design levels, rapid deterioration, and more important, relative to the drainage and agricultural requirements. In fact, the deterioration of Pakistan's surface irrigation system has also largely been caused by O&M underfunding. 3/ More important, given that irrigation O&M requirements are a

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1/ As indicated in para 2.05, farmers are getting supplemental water supplies from the SCARP tubewells -- (although below the optimum agricultural potential), and paying about 20% of the actual tubewell O&M costs, and paying nothing towards the capital costs.

2/ WAPDA surveyed 520 farmers located in both SCARP and non-SCARP areas. See WAPDA (Master Planning and Review Division), "Private Tubewells and Factors Affecting Current Rate of Investment," Lahore, 1980, SCARP tubewell water supplies are mixed with canal water in accordance with fixed "warabandi" timings, which are not always based on crop water requirements.

3/ See IDA's Staff Appraisal Report on "Pakistan - Irrigation Systems Rehabilitation Project," pp. 13-15. This project has helped provide the momentum for the recent substantial increases in the O&M allocations, particularly for the surface irrigation system.

Provincial responsibility, the O&M allocations for the SCARP tubewells compete directly with the funding available for the surface irrigation system and other priority recurrent expenditures such as salaries, education, and transport O&M expenses. Table 1 summarizes the nondevelopment budget (NDB) allocations to the PIDs for carrying out the O&M of the irrigation system for the period FY78-FY83 (see Table B.9 for further details). Three important features emerge from the data. First, expenditures for tubewell O&M account for a substantial proportion of the total NDB allocations for Pakistan's vast irrigation/drainage system, reaching about 40% in FY81 onwards. It is alarming that this high percentage corresponds to funding of tubewells that are still experiencing some fundamental problems in their O&M. Second, the budgetary allocations show that the tubewell category has been growing at a sharp rate, exceeding 40% per year from FY78-FY82 onward--well ahead of the 10-15% annual inflation rate. Third, Punjab Province dominates in terms of the absolute amounts allocated for tubewell O&M, taking about 80% of the total for Pakistan. This dominance is expected, since about 90% of the SCARP operating tubewells are located in Punjab Province. Another factor that hampers the O&M of the SCARP tubewells relates to the complex budgeting process and the uncertainties in allocating and releasing funds, which introduce uncertainties in the operational decisions of the SCARP tubewells.

Table 1

Importance of Tubewell O&M Allocations in Provincial Nondevelopment Budget, FY78-FY83 (Rs M, Current Prices)

Item	FY78	FY79	FY80	FY81	FY82	FY83
Pakistan						
Establishment	293	312	355	345	366	462
Canals	221	272	241	287	381	461
Tubewells	127	194	278	408	575	603
Total	641	778	874	1,040	1,322	1,526
Punjab Province						
Tubewells	123	186	197	326	471	484

2.23 It is a well-known fact that two of the principal reasons for the underfunding of the irrigation system are the relatively low water charges for both canal and SCARP tubewell water supplies and the insufficient funds allocated for this purpose from general revenues. 1/ Table B.10 shows that, particularly since the early 1970s, water charge revenues have declined as a percentage of the O&M expenditures for both the canal system and SCARP tubewells. For example, in FY75 water charge revenues from Pakistan's irrigation system represented about 75% of its total O&M expenditures; by FY82 this percentage was estimated by IDA to be only 55%, with a total deficit of roughly Rs 602 M (or US$52 M). Given the relatively higher O&M cost of the SCARP tubewells vis-a-vis that of the canal system, this revenue/expenditure gap is substantially higher for the SCARP tubewells. For example, in FY82 the average O&M cost of the canal irrigation (excluding SCARP tubewells) is estimated to be about Rs 22 per irrigated acre, which compares with an average water charge of about Rs 21 per irrigated acre. In contrast, the O&M costs for the SCARP tubewells are estimated to be about Rs 107 per irrigated acre, which is substantially higher than the equivalent water charges attributable to these tubewells, which average about Rs 20 per acre. 2/ Further details on the assumptions used for these estimates are presented in Table B.11.

2.24 Given the substantial required subsidies to cover the gap and the competing claims on the provincial NDB, underfunding and undermaintenance have been dominant features of Pakistan's irrigation system and SCARP tubewells, particularly since the mid-1970s. To rectify this deficiency, and as part of IDA's recently appproved Irrigation Systems Rehabilitation Project and Structural Adjustment Loan (SAL) I, GOP and Provincial Governments have agreed to achieve full O&M recovery of a desirable level of maintenance through increasing water charges and/or establishing other apropriate financial arrangements according to an agreed timetable for each Province. 3/ Given the structure of the provincial revenue base and current government policies, water charges will probably continue to be the major source of

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1/ For example, the "RAP Report" presents the historical evolution of water charges over the past 60 years (Vol. II, Appendix Table 6.23). The data clearly show that water charge levels in current prices have only increased 3-5 times, which is substantially below the cost/price increases of about 10 times. It is relevant to mention that the existing mechanism for collecting water charges does not channel these funds into a separate O&M irrigation fund. Instead, O&M funds are provided by Provincial Governments from general revenues.

2/ In some of the Provinces--Punjab and just recently SIND--farmers are charged "double the water charge rate" in SCARP areas having usable water in order to recover a portion of the tubewell O&M costs.

3/ These recommendations build on the findings of the water charge study completed by PIDE in 1981. This study fulfilled a GOP-IDA agreement included in the IDA-financed SCARP VI project.

revenues to cover such O&M costs. 1/ Assuming that the Provincial Governments increase their revenues at the agreed levels and complete a program of divesting all SCARP tubewells in fresh groundwater areas, positive cash-flow will be achieved for the surface and tubewell system by FY92. In practice, if GOP and Provincial Governments implement such a policy, it is likely that the transfer of pumpage responsibilities would focus on selected usable groundwater areas.

2.25 Although the estimates on the above figures are rough approximations based on aggregate data, one of the important conclusions refers to the sharp difference in O&M recoveries/expenditures from the canal system vis-a-vis those obtained from the SCARP tubewells. 2/ the water charges from the surface system cover about 70-85% of the costs, whereas the equivalent water charges (collected in SHARP areas) are less than 25% of the O&M costs of the SCARP wells. 3/ Obviously, increased maintenance expenditures, plus the inclusion of an equivalent annual capital cost for tubewell replacement, would only increase the present substantial gap in SCARP expenditures and water charges, particularly if water charges are not increased. 4/

1/ In theory, there are various alternative financing sources to cover the irrigaton O&M costs, including indirect taxation on farmers and funding provided by the provincial NDB. In practice, however, the water charge has been the dominat revenue-generating instrument followed by the government for covering the O&M expenditures. GOP's current policies for the future follow the same approach.

2/ The current O&M expenditure levels for both the canal system and the tubewells are based on significant undermaintenance and underutilization. Thus far, the water charges are deposited in the Provincial general revenue account. O&M funds are then provided from general revenues. As discussed in para 2.23, there is a need to improve the administrative mechanism for collecting the revenues and for establishing a more direct linkage between revenues and expenditures.

3/ The recoveries are probably lower if one considers collection rates below 100%, which are reported to occur frequently. Also, some of the Provinces do not charge an additional water charge for the use of SCARP tubewell irrigation supplies.

4/ Given the magnitude of the gap, water charges attributed to SCARP tubewells would need to increase almost fivefold in real terms, which would probably meet insurmountable farmer resistance, particularly given the unreliability (and, possibly, inherent inefficiencies) of the publicly managed SCARP tubewells.

Table 2

ESTIMATED O&M EXPENDITURES FOR IRRIGATION SYSTEM
(Rs M, Constant mid-1981 Prices)

Scenario	FY82	FY86	FY92
Without Scarp Transition			
Surface System	747	1,034	1,041
Scarp Tubewells	575	1,071	1,240
FGW	(503)	(850)	(850)
SGW	(72)	(221)	(390)
Total	1,322	2,105	2,281
With SCARP Transition ("Full-Program")			
Surface System	747	1,034	1,041
SCARP Tubewells	575	696	390
FGW	(503)	(475)	(0)
SGW	(72)	(221)	(390)
Total	1,322	1,730	1,431
Difference ("Without" - "With" SCARP Transition Program)	0	375	850

Source: Figures are taken from IDA's Staff Appraisal Report, "Irrigation Systems Rehabilitation Project," April 1982. Figures for FY82 are revised and reflect estimated actuals.

2.26 The financial burden of continued public sector responsibility for the SCARP tubewells worsens as one constructs various scenarios over the next decade. IDA 1/ recently estimated one possible scenario whereby the SCARP tubewells would have a total O&M cost of approximately Rs 1200 M per year by FY92 (US$105 M, constant mid-1981 currency, see Table 2 for a summary and Table B.12 for more details). This estimate assumes: (1) an increase in capacity utilization from 35% to 60%; (2) all of the current SCARP tubewells

1/ IDA's Staff Appraisal Report, "Irrigation System Rehabilitation Project," April 9, 1982.

in the fresh groundwater areas would continue to be operated by the public sector; and (3) an additional 4,700 SCARP tubewells would be added to saline groundwater areas. Assuming the tubewells in the fresh groundwater areas are completely divested by FY92, Table 2 shows that this action could "save" the public sector about Rs 850 M; even a "SCARP Transition" program on a limited scale could result in substantial savings. Moreover, the entire stock of existing SCARP tubewells would need to be replaced over the next fifteen years; the capital cost of such replacement would be approximately Rs 7,000 M (or about US$500 M in constant 1981 prices). Although a large number of scenarios are possible depending on various critical assumptions, 1/ the fundamental outcome is the same--the current stock of SCARP tubewells represent a substantial financial burden on the public sector that is sustainable only at an extremely high cost. One of the principal costs refers to claiming scarce public resouces that could otherwise be released for activities that the private sector cannot perform--saline groundwater drainage, major hydropower generation, transport infrastructure, education, health, and others.

Economic Impact of SCARPs

2.27 The ex ante economic analyses of various SCARP projects estimated relatively high economic rates of return (ERRs), with benefit-cost ratios ranging from 2:1 to 7.5:1, and ERRs exceeding 20% for most SCARP projects. As vertical drainage projects on a wide scale had never before been attempted in Pakistan or elsewhere, the projected economic returns were extremely dependent on the underlying assumptions. Available ex-post evaluations for selected SCARP show that benefit-cost ratios range from 1.1 to 2.2:1 (see Table B.13), and ERRs vary from marginal to unacceptable levels. Obviously, these results are very sensitive to some of the key assumptions, which involve a number of judgments not fully supported by field data. For example, in the SCARP I project, actual experience and available data show that many of these assumptions were optimistic and therefore overestimated the economic benefits of the various SCARPs.

2.28 Three of the principal assumptions that have proven incorrect and have adversely affected the ERRs for SCARPs in usable groundwater areas refer to: (1) the growth of private tubewells; (2) agricultural production increases; and (3) the life, O&M requirements, and more broadly the management difficulties of the SCARP tubewells. First, there was a significant underestimation of the number of private tubewells that would be developed "without" and "with" the implementation of the public tubewell schemes. Obviously, this outcome would significantly increase the original estimates of production projections for "future without project." Second, the agricultural benefits that have occurred in SCARP areas have not reached the planned

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1/ Such as number of operating tubewells, pumpage and capacity utilization rates, divesting/transfer rates of SCARP tubewells to the private sector, water charge levels and collection rates, and power tariffs.

levels (see para 2.08). For example, many of the SCARPs assumed that cropping intensities would increase from about 60-80% to nearly 120-150%. In practice, intensities have not exceeded 120% in most SCARPs. Moreover, not all of the benefits can be attributed to SCARPs only; other sources of production increases include the unexpected growth of private tubewells, improved crop varieties and agricultural extension, increased farm mechanization, and additional canal water supplies (from Tarbela, for example). 1/ Third, planners assumed that the SCARP tubewell would have a life of thirty years and that the public sector would have the capacity to provide adequate O&M of the SCARP wells. In retrospect, most of the SCARP tubewells had an average life of fifteen years and were planned prior to the sharp price increases in fossil fuels during the 1970s. More important, planners underestimated the difficulties of managing the SCARPs. The overall effects of these optimistic assumptions are decreased incremental benefits that can be attributed to the SCARP projects vis-a-vis those benefits originally assumed.

2.29 The points presented in para 2.28 are illustrated in the expost evaluation of the SCARP I project. To separate the partial effects of SCARP and private tubewells, an economic evaluation of SCARP I was undertaken by WAPDA's Master Planning and Review Division. The ERR was estimated to be 6% on the strong assumption that private tubewell development without SCARP I would have achieved a density of one tubewell per 165 acres by 1975, but without adjusting the benefits from the existing private tubewells in SCARP I. The 165 acre per tubewell estimate is lower than achieved in comparable areas adjacent to SCARP I. In Upper Rechna, which borders SCARP I with a CCA of 400 thousand acres, the private tubewell density was 80 acres per tubewell; in Lower Rechna, having a CCA of 270,000 acres, the density was 140 acres per tubewell. That is, the WAPDA study findings clearly imply that the estimated ERR of 6% is in fact an optimistic estimate. 2/ However, it is important to highlight the sensitivity of these results to the assumptions used by WAPDA, which may not be fully verifiable and applicable to all SCARPS. This point needs further clarification through carrying out, on a systematic basis, evaluations of ongoing SCARPs.

2.30 To reflect this past experience, WAPDA estimated exante ERRs for a number of proposed SCARPs in usable groundwater areas. The ERR estimates range from 4-9% and, according to WAPDA's assumptions, are not economically

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1/ With the possible exception of an expost evaluation of the SCARP I project, there have been no other evaluations or systematic attempts to disaggregate the production increases according to various causes and their relative importance.

2/ As discussed in para 2.31, it is likely that the "future without project" scenario re-ormulated by WAPDA was influenced by the positive demonstration impact of the SCARP tubewells. Therefore, it is possible that the WAPDA estimate of 6% or less is unrealistically low.

justified, 1/ ERRs for SCARPs in saline groundwater areas ranged from 12-20%, which reflects the assumption of a deteriorated "future without project" scenario if the investments are not carried out (see Table B.13 for summary of WAPDA's available economic results).

2.31 Despite the reported low ERRs of the SCARP projects, both WAPDA's evaluation study of SCARP I and the "RAP Report" directly recognized that the early SCARP projects produced important demonstration benefits. Without the initial SCARPs, it is likely that the private tubewells would have increased at a significantly reduced rate. Prior to 1960, when the decision to undertake SCARP I was made, very little development of the Indus Basin aquifer had taken place. Through public involvement in the SCARPs, attention was focused on the potential of groundwater for increasing irrigation supplies; this initiative acted to spur private development of the groundwater in SCARP I and other areas. Also, the SCARP I area was more severely waterlogged before project implementation than many of the areas where intensive development of private tubewells has occurred.

1/ Assuming that the opportunity cost of capital for Pakistan's water sector is 10%.

3. EVALUATION OF PRIVATE TUBEWELL PERFORMANCE

Overview

3.01 A relatively large number of studies have reviewed the various aspects of private tubewell experience in developing Pakistan's groundwater resources. Table C.1 presents a chronological summary of the more important studies. To assess the future role of private tubewells, particularly considering the uneven experience of the SCARP public tubewell, the following section will highlight the available research findings 1/ that address the following points: (1) growth of private tubewells, their principal determinants, and main features; (2) physical impact; (3) management experience; (4) financial and economic impact.

Private Tubewells: Number, Growth, Determinants and Technology

3.02 Number and Growth of Private Tubewells. Until the early 1960s, private sector development of Pakistan's groundwater resources was primarily through about 200,000 dugwells, which used animal power for pumping, with some mechanical tubewells, mainly outside canal commanded areas. Private tubewells have increased from about 439 tubewells in 1940 to about 186,000 in 1981. The "boom" period for private tubewells was mainly from 1964 to about 1976, when the number of private installations increased from 23,140 to 150,840--an annual growth rate of 38%. Given abundant usable groundwater supplies, particularly in relation to the other provinces, most of the private tubewells (nearly 90% in 1980) are located in Punjab Province. Table C.2 summarizes the number of private tubewells in each province from 1964-81. Also, the majority of private tubewells, nearly 65% in 1977, are located in the canal commands. This growth of private tubewells was largely unassisted by the public sector and represents a distinguishing feature in Pakistan's agricultural development. It is perhaps the most convincing evidence regarding the attractive financial returns obtained from investing in private tubewells. Moreover, the growth of private tubewells was seriously underestimated by WAPDA, Government, and donor agencies. For example, the Indus Special Study (ISS) projected the growth of private tubewells "with" and "without" the recommended level of SCARP tubewells. "With" the ISS SCARP

1/ Given the focus of the present report, the principal studies that were consulted include: (1) Directorate of Land Reclamation, "Economics of Groundwater Development Quality of Water and Its Effects on the Agricultural Productivity in the Punjab Area of Pakistan," (Phase II Report), July 1979; (2) M. Malik, "Evaluation of Private Diesel Tubewell Subsidy Scheme in the Punjab," Punjab Economic Research Institute, Publication No.193, Dec. 1981; (3) WAPDA, "Private Tubewells and Factors Affecting Current Rate of Investment," Planning Division, 1980; and (4) preliminary background findings of the SCARP Transition project preparation currently underway.

program, private tubewells were expected to decrease from 55,000 in 1970 to about 48,000 in 1975; "without" the ISS program, private tubewells were expected to number 65,000 in 1970 and 95,000 in 1975. Instead, even with a portion of the ISS SCARP program, actual growth of private tubewells exceeded both scenarios, numbering 83,000 in 1970, and 132,000 in 1975.

Determinants of Private Tubewell Growth

3.03 To better understand the farmer's decision-making process and future role in helping to develop Pakistan's groundwater resources, it is relevant to assess the various determinants of investment in private tubewells. Based on a synthesis of previous research findings and on a WAPDA field survey of 521 farmers, WAPDA recently completed a study 1/ that assessed the relative importance of the following investment determinants: (1) financial returns to farmers; (2) ownership patterns; (3) farm size; (4) public sector water supplies; (5) water quality; (6) SCARP demonstration impact; (7) financial availability; (8) driller's availability; (9) water selling and water trading; (10) electrification; (11) component availability/repairs; (12) timeliness of water availability; (m) rebate in water rates. WAPDA's analysis confirmed earlier findings that the rapid growth of private tubewells is largely due to their relatively high financial return, which is interrelated with various other factors. First, farm size emerged as an important determinant and was explained by the smaller farmer's limited access to financing and the nonavailability of "fractional" (less than 1 cusec) tubewell technology, which tended to be attractive to farmers who had larger areas to irrigate. 2/ Second, the SCARP tubewells provided a qualified but positive demonstration effect, particularly in showing farmers the potential benefits that could be reaped if the tubewell were managed efficiently (including tubewells that meet crop water requirements). At the same time, available information suggests that many of the private tubewells were established partly to compensate for insufficient and unreliable water supplies from both public canals and tubewells. For example, in the SCARP I area, private tubewells in 1980/81 totalled almost 11,000 and pumped over 2.0 MAF, which is substantially higher than the SCARP tubewell population; about 2,069 SCARP tubewells pumped about 1.3 MAF in 1980/81. This pattern is illustrated in Table C.3 for numerous SCARP areas.

1/ See footnote to para 3.02.

2/ At the same time, the availability of domestically manufactured, low-cost pumps and diesel motors and the spread of electrification helped induce private tubewell installation.

Tubewell Technology

3.04 Compared with the public tubewells, the private tubewells are of smaller capacity and have lower pumping lifts. 1/ The capacities of the private tubewells range from less than 1 cusec to slightly more than 2 cusecs, with an average of about 1.2 cusecs. The proportion of tubewells less than 1 cusec is 23%, and only 2% have a capacity of over 1.5 cusecs. Drilled to a diameter of 8 inches using manual percussion methods, private tubewells generally have shallow depths ranging from less than 100 ft to slightly over 200 ft, averaging about 110 ft. The tubewells are provided with locally made strainers, generally 6 inches in diameter and 35-50 ft in length. The most commonly used strainer for about 70% of tubewells consists of coir string wound over a cylindrical cage. Other types of strainers used are slotted brass and PVC (polyvinyl chloride) pipe, and concrete pipe with formed slots and nylon string wrapped on iron cage. The average life of the strainers is reported to be about seven years. There is considerable scope for improving the technology of fractional tubewells, particularly to simplify their O&M and to benefit the smaller farmers, of which many are not receiving the full benefits from tubewell water supplies.

3.05 Approximately 95% of the private tubewells are equipped with centrifugal pumps that are installed in pits so as to remain within the suction lifts. This limits the practical range for the utilization of centrifugal pumps to watertable depths generally from 15-20 ft, rarely exceeding 50 ft. About two-thirds of the private tubewells are diesel operated (primarily slow-speed diesel), with the remainder powered by electricity. Sample surveys have shown that the average power rating of the engines and motors installed on the private tubewells is about 17.6 horsepower (HP), which is generally about 100% more than the required HP for the discharges and lifts involved. Annex E provides additional information by summarizing the features of the main types of private wells and reviewing the present design criteria and current cost estimates for shallow private tubewells; Annex E also discusses the design and construction modifications that would generate savings in capital, replacement, and O&M costs.

Evolution of Government Policies Affecting Private Tubewells

3.06 Although the boom in the private tubewell population was largely unsupported by explicit government policies, these have had an indirect effect. As background material, some of the important policy measures

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1/ The main types of private tubewells include: shallow wells; deep wells; dug and bored wells; dugwells with pumpset; dugwells with traditional lifting devices. Since most of the private pumpage is done by shallow wells, the discussion will concentrate on these. It is relevant to mention that the definition of "shallow tubewell" refers to the method of construction and the type of pumping unit installed rather than to the absolute depth of the well.

regarding irrigation development are highlighted below according to Pakistan's various plan periods. First, during the pre-plan period (prior to 1955), the greatest emphasis was placed on the traditional trends of expanding irrigated areas through surface flows. Groundwater as a supplemental source of irrigation supply received little attention, particularly in relation to the role of the private sector. During the First Plan (1955-60), public policy began to address the waterlogging and salinity issues, primarily through preparing plans for public sector tubewells. Although in the 1950s some limited credit facilities were extended for tubewell installation, no specific emphasis was made on private tubewell development. The extent of groundwater resources was hardly known at this time. The Second Plan (1960-65) helped promote a substantial reallocation of public investments to the agricultural and water sectors, from 7% to 18%. The first SCARPs were initiated during this period, and private tubewells began to increase significantly with no direct policy support. The Third Plan (1965-70) included an increase in the development of groundwater through increased public and private tubewells, with a policy emphasis on accelerating the SCARP projects. To help promote private tubewells, the government provided some incentives in terms of liberal imports of pipe and accessories, credit, and electrical connections. However, except for tariff subsidies, no specific tubewell subsidies were granted. The Fourth Plan (1970-75) continued to support the SCARP projects and provided subsidy and some credit incentives to encourage tubewell development by the private sector. A diesel tubewell subsidy scheme was introduced in 1972, which helped install almost 8,000 tubewells during this plan period (or nearly 20% of the total increase in private tubewells). Differential subsidies were granted, ranging from 32-46%, with the higher subsidies provided to areas having smaller water supplies. For example, barani and sailaba (or flood) areas received higher tubewell subsidies than those located in the canal irrigated areas. See Table C.4 for further details. Also, the amount of institutional credit extended for private tubewells doubled, reaching Rs 36 M at the end of the Plan Period. This amount, however, supported only a small increase in the number of private tubewells (less than 10%) during the Plan Period.

3.07 During 1975-78, the basic government strategy continued to be an encouragement of private tubewell development through subsidy for diesel tubewells, credit (for both diesel and electric tubewells), and extension of electrification facilities. Also, SCARP tubewell programs continued to be planned. The Fifth Plan (1978-83) envisioned a continuation of policies, with an emphasis on: (1) increasing SCARP tubewells to alleviate the waterlogging and salinity problems, including the installation of 5,000 public tubewells in fresh groundwater areas to provide about 3 MAF for supplemental irrigation; (2) increasing surface and groundwater supplies for irrigation, such that water availability would increase at farmgate from roughly 92 MAF to 103 MAF; (3) supporting continued increases in the private tubewell population (by about 8,000 per year), which would add an additional 6 MAF; (4) encouraging the development and use of fractional tubewells and farmer groups that would suit small-farmer needs; and (5) promoting integrated planning for location of public and private tubewells to avoid overdevelopment. Therefore, in principle, this Plan Period has approached groundwater development through a mixed public and private investment policy. In practice, however, the overall roles of public and private sectors in groundwater development have not been changed fundamentally, and measures to accelerate private tubewells--say, under points (4) and (5) above--have not been adopted by the Government. As will be discussed in the sections below, the country's financial constraints are leading policymakers to seriously reassess the role of the SCARP tubewells in usable groundwater areas.

3.08 More recently, based on the RAP recommendations, GOP has expressed an explicit policy commitment to translate its intentions of accelerating private development into public sector investment and policy decisions. This view is based on a deeper understanding of the public and private tubewell experiences and on recognizing the growing scarcity of public resources, particularly in the context of massive investment requirements that the private sector cannot provide. Such a policy is reflected in GOP's statements made in the National Agricultural Policy Paper (February 1980), and more recently, in GOP's Letter of Intent, as part of IDA's recently approved SAL (SAL 1). These funds support GOP's set of policy reforms at the macro level and for the key sectors of agriculture and water, energy, and industry.

Physical Impact of Private Tubewells

3.09 Pumpage and Capacity Utilization. The importance and dramatic increase in the private tubewell population is reflected in the level and increase of groundwater pumpage attributed to private tubewells. Private pumpage increased from 3.3 MAF in 1959-60 to approximately 28.4 MAF in 1977/78, which represents an annual growth rate of about 13% (see Table C.5). Private tubewells have the following features; it has 75% of its total in canal command areas, accounts for 80% of total groundwater pumpage in the Indus Plain, and contributes about 30% of total irrigation water supplies provided at the farmgate (see Table C.6). WAPDA's most recent estimates of capacity utilization show that these rates range from 15-25%. 1/ These rates

1/ Numerous studies (see references listed in Table C.1) have attempted to measure the discharge and utilization rates of private tubewells. The most recent estimates are based on previous data and are presented in a recent report prepared by WAPDA, "Groundwater Development and Potential in Canal Command Areas of the Indus Plain," Planning Division, July 1981. In this study, different data on the discharge and power consumption of private tubewells were obtained during the surveys carried out by the various concerned agencies. The discharge of sample wells was determined by manometer, flume or coordinate method. The power or fuel consumption was determined by running the tubewells for a certain length of time and obtaining the total oil consumption in a year, from WAPDA power consumption records or from the tubewell owner's record. The pumpage of private tubewells in various canal commands was determined by WAPDA from the number, average discharge, and average utilization in each canal.

are relatively low, primarily because the tubewell water is used to supplement canal supplies. To meet crop water requirements, particularly during periods of water shortage, the annual pumpage per tubewell is approximately 170 acre-ft; this figure varies to account for differences in rainfall, availability and reliability of surface supplies, and cropping patterns and intensities. Finally, the most significant fact of the above data on pumpage in Pakistan is that a major portion of the drainage, reclamation, and groundwater supply functions are being performed by the private tubewells.

Agricultural Impact

3.10 Most of the private tubewells are located in canal commands and are used as supplementary source of irrigation. WAPDA estimates that 65% of the private tubewells in the canal commands are used as supplemental sources of irrigation, whereas the remaining tubewells provide the principal source of irrigation. Although there are variations according to area, tubewells alone account for about 60% of the total irrigation in rabi and about 45% in the kharif season. The WAPDA survey found that the area irrigated per tubewell averages 38 acres. The total area served by private tubewells is difficult to quantify because of limited data, but using indirect evidence, WAPDA estimates that an area of 7.5 million acres receive irrigation supplies from private tubewells and can be said to have irrigation on demand matched to the crop water requirements.

3.11 The agricultural impact of private tubewells per acre and for different farm sizes has been reviewed in detail by numerous field surveys (see Table C.1). 1/ In summary, all of these studies have generally found that farms served by private tubewells have achieved significantly higher production levels than farms that are not. 2/ Although there is a wide range of variation in the key agricultural parameters, these increases are reported along the following orders of magnitude: (1) yields: 15-30%; (2) cropping intensities, 120-140%, (averaging nearly 140%); (3) cropping patterns frequently shift to the higher-value and delta crops, such as orchards, paddy,

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1/ For example, there is one study that was carried out over a period of nine years (from 1965-78) and two phases. See Directorate of Land Reclamation, "Economics of Groundwater Development, Quality of Water and Its Effects on the Agricultural Productivity in the Punjab Area of Pakistan," Final Report, Phase II, Lahore, July 1979. This extensive study aimed to highlight the changes in agricultural practices and their impact on the farm economy due to the use of groundwater.

2/ These surveys have also shown that users of private tubewell water, including those who purchase water, have obtained higher increases in productivity. This finding was shown in a recent study that confirmed the positive effects of an active water market. See R. Renfro, "Economics of Local Control of Irrigation Water in Pakistan: A Pilot Study," Ph.D. dissertation, Colorado State University, Summer 1982.

and sugarcane. Table C.7 summarizes these increases based on the findings of various field surveys. As would be expected, these surveys have also found that tubewell farmers have a higher usage of modern inputs -- fertilizer, mechanized farm implements, improved seed varieties, farmyard manure, plant protection measures -- than non-tubewell farmers (see Table C.8). Similar to the SCARP tubewells, these input and output increases associated with private tubewells cannot be attributed entirely to the tubewell water. Nonetheless, the various control groups studied by the surveys clearly suggest that most of the production increases can be attributed directly and indirectly to the presence of the private tubewell water. In contrast, the field surveys used by the SCARP studies have not included "control groups."

Management Performance of Private Tubewells

3.12 Operation and Maintenance of Tubewells. Since private tubewells were established primarily by individual farmers for irrigation crop requirements, the management of these tubewells has been relatively efficient in terms of ensuring quantity and timing of water supplied and length of down-time when a malfunction occurs. The O&M efficiency of tubewell repairs is aided by the generally available tubewell technology and town-level workshops. Some of the principal O&M problems 1/ that have been reported include the availability of small engines and motors at competitive prices, availability of good quality pipe, of diesel fuel, and the inconvenience of operating diesel tubewells. 2/ However, the private ownership of tubewells--usually by individuals--and their highly decentralized management are probably the main reasons for the apparent problem-free operation and maintenance performance of private tubewells. Obviously, this positive experience contrasts sharply with the highly centralized management patterns that have hampered the O&M of the SCARP tubewells (see paras 2.12-2.15).

1/ All of the studies that have evaluated the performance of private tubewells have not reviewed in detail the operation and maintenance aspects of private tubewells. At the same time, enough information has been collected by these studies to support the view that private tubewells have relatively minor O&M problems. Although their low capacity utilization rates (of about 20%) imply a technical and economical inefficiency, this is explained by the individual ownership patterns, use as a supplemental source of water supplies to highly subsidized surface water charges, limited availability of fractional tubewell technology, and limited access to credit facilities.

2/ WAPDA, "Private Tubewells and Factors Affecting Current Rate of Investment," pp. 94-95.

Farmer Organization

3.13 A dominant feature of the private tubewells is the pattern of individual ownership and management. WAPDA has reported that nearly 75% of the private tubewells are owned by individual farmers, with the remaining 27% owned jointly. As expressed in the Fifth Five-Year Plan, the government has supported the concept of group ownership and management through Water Users Associations or Cooperatives. In practice, however, only a relatively small percentage of private tubewells (about 20%) are owned and/or operated by such farmer groups. This outcome is largely explained by the available technology, financing, farmer's traditional and mistrustful attitudes toward cooperatives, and negligible efforts by Government to help organize farmers, particularly based on local customs. As a result, these factors have favored individual ownership and larger farmers. For example, the average farm size of tubewell owners is about 40 acres. Moreover, about 70% of the tubewell-owning farmers (individual and joint) have a farm size that exceeds 25 acres; this ownership pattern excludes almost 70% of the farmers in Pakistan. 1/ Not surprisingly, the percentage of jointly installed tubewells is high in small farm groups; for example, WAPDA found that 44% of tubewells are jointly installed in the 0-5 acre farm-size category. Also, approximately 90% of the tubewells have been financed entirely by farmer's own resources (see Table C.9). The Government's financing facilities for private tubewells (credit and subsidy programs) have not provided any special facilities to spur the formation of farmer organizations. Finally, two important points emerge in this section. First, the greatest scope for future development of private tubewells lies in extending their use to smaller farmers (less than 12.5 acres) through promoting appropriate fractional technology, credit facilities, electricity extension, and reliability, and appropriate forms of farmer organization. Second, the limited evaluations of farmer group experiences in the management of private tubewells highlights the need for further field research that could provide insights to the most effective ways of strengthening farmer organizations. 2/

1/ WAPDA, "Private Tubewells," 1980, p. 87. Approximately two-thirds of the farmers in Pakistan have a farm size less than 12.5 acres.

2/ Recently, GOP and Provincial Governments have emphasized the need to strengthen the role of farmer groups in the O&M of irrigation facilities. For example, the IDA-financed On-Farm Water Management Project has introduced a Water Users Association Ordinance in each province as a means of promoting farmer groups for production purposes. This experience needs to be monitored and evaluated carefully such that the results can inform future similar efforts.

Management of Aquifer

3.14 The SCARP demonstration impact of water usability has resulted in intensive pumpage by private tubewells in certain canal command areas. 1/ The absence of any control or aquifer management of the pumpage has led to close siting of many private tubewells, with a mean distance of about 1,500 ft. With the exception of the Bari Doab area, the growth of tubewells and pumpage has not seriously threatened groundwater quality or its depletion in any large areas. Uncontrolled pumpage, however, may pose a future problem in other areas, especially where there is a high concentration of private tubewells. This issue highlights possible differential private and social benefits and costs that may result from uncontrolled pumpage. Therefore, the public sector will need to carefully monitor the aquifer and to introduce appropriate and efficient measures that support a favorable pattern of tubewell development and groundwater recharge.

Financial and Economic Aspects

Financial Returns to Farmers

3.15 All of the studies on private tubewells have shown that the dominating factors that have contributed to the boom of installation are the relatively high financial returns and, more important, the provision of reliable water supplies to meet the time-bound crop water requirements. This conclusion is strengthened by the relatively negligible support provided by the public sector for promoting private tubewell installation. Field studies since the 1960s have calculated these private financial returns to the tubewell owners and users. Increases in the underlying agricultural parameters are highlighted in para 3.11. Although the returns vary according to farm size, cropping pattern, availability of other water supplies, and source and price of energy, financial returns have varied along the following orders of magnitude: (1) an increment Rs 150-400 per cropped area; (2) 20-40% increase of total farm income; (3) financial rate of return of 7% to over 50%. Since a large percentage of tubewell owners have large farms (70% exceeding 25 acres), the investment is fully recovered for many farmers in from one to four years. 2/ Table C.10 summarizes these returns based on the findings of the principal field surveys. A recent Bank estimate shows the

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1/ For example, in Lahore, Sahiwal, and Multan Districts of Punjab Province.

2/ For example, one well-known study in the early 1970s reported that high financial returns were sufficient to repay capital costs after one year. See Gulam Yasin, "Private Tubewells in the Punjab," Punjab Board of Economic Inquiry, 1975.

financial rate of return to private tubewell investment ranges from 25-35%, which is still a financially attractive investment. 1/

3.16 Because of the relatively weak support provided by the public sector deficient extension services and input supplies, limited access to credit--the actual financial returns derived from the private tubewells are generally below their potential levels. Furthermore, the financial returns in absolute, real, and relative terms appear to be declining over time. The main reasons for this deterioration: increasing levels of surface and groundwater water supplies at highly subsidized prices and increases in world energy prices during the 1970s. The rising energy prices have particularly affected farmers using tubewells powered by diesel energy sources, nearly 70% of all private tubewells. Moreover, all of the field surveys, including the Bank's recent estimates, show that the financial returns are higher for electrical tubewells than for diesel tubewells, even given the Government's existing diesel subsidy program and recent increases in power tariffs (see Table C.11). The apparent decline in the high financial returns perhaps helps explain the relatively smaller increases in private tubewell investment observed since about 1977. 2/ Updated field surveys on tubewell financial returns and their main determinants should be a high priority in future efforts to promote private tubewell development, including the transition of groundwater development from the public to the private sector.

Subsidies and Burden on Government

3.17 Punjab and Sind have budgets available for direct cash subsidies for construction of private sector tubewell facilities. Direct subsidies are also granted for power connections to tubewells. The Agricultural Engineering Departments of Punjab and Sind have hand-operated and winch-operated drilling equipment which provide custom service to farmers at subsidized rates. All the above sources of subsidy are, to a greater or lesser extent, limited by the subsidy budgets available to the Government or semi-autonomous government agencies concerned. Implicit operational subsidies are also available to private sector tubewell operators. The agricultural tariff for electrical energy is less than the actual cost of generation, transmission, and distribution, and the average sale price per energy unit is considerably

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1/ See IDA's Staff Appraisal Report, "Fifth Agricultural Development Bank Project," April 1983. As expected, the lower returns are obtained for diesel tubewells, whereas the higher returns are for electric motors. It is relevant that the returns fall to 20% when the utilization rate is halved. In this connection, farm size and the extent of a "water market" are critical determinants of these rates.

2/ Another possible determinant may possibly be the effective availability of institutional credit due to existing institutional credit procedures and security requirements. These factors may have limited the effective demand for tubewells by the smaller farmers.

lower for the agricultural consumer than for other consumers. A subsidy is also in theory available on light diesel oil used for agricultural pumping, but it is, in fact rarely claimed by tubewell operators with diesel-engine-powered facilities. Agricultural credit is provided at favorable rates compared with credit facilities for other types of investment. Further details on the various subsidy schemes are provided in Annex F. The section below highlights some of the main features and issues related to tubewell subsidies.

3.18 One of the main features of the private tubewell boom has been its relatively small burden on the public sector. Excluding electrification capital costs and the subsidies on the electricity tariffs, the main direct public expenditure has been the diesel tubewell subsidy scheme introduced in 1972 for barani, sailaba, and canal commanded areas. This subsidy scheme was introduced despite the remarkable growth of private tubewells, which was largely unsupported by the public sector. In 1974, the tubewell subsidy levels were revised according to tubewell size, whereby maximum subsidy was given to a barani farmer installing a 1-cusec tubewell. In April 1979, the diesel tubewell subsidy scheme had supported the installation of about 11,500 tubewells for a total subsidy cost of Rs 132 million; this represents only about 20% of the total private tubewells installed during the period and less than 3% of the total expenditures on the SCARP tubewells.

3.19 Various studies have analyzed the effectiveness of the subsidy scheme and have documented a number of major deficiencies. 1/ These include: (1) subsidy allocations did not satisfactorily reach the target group and small farmers 2/; (2) ethnic links, political influence, and contacts largely determined farmer's access to the subsidy program; (3) the subsidies were frequently misused, whereby farmers frequently sold the diesel engine or converted their diesel tubewell into an electrically powered tubewell. In attempting to assess the effect of subsidies on farmer's decision to invest in the tubewell, the Punjab study found that a majority of the farmers surveyed, especially in canal irrigated areas, stated that they would have

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1/ Most of the subsidy scheme was concentrated in Punjab Province. For a recent comprehensive evaluation, see Muhammed Bakhsh Malik, "Evaluation of Private Diesel Tubewell Subsidy Scheme in Punjab," Lahore, Punjab, Economic Research Institute, Publication No. 193, December 1981.

2/ For example, to account for tubewell size and efficiency, the subsidy scheme was directed to "single" or "grouped" farms of over 25 acres; however, in practice most of the subsidies were allocated to individuals who comprise only about 10% of the farm population for this size of farm.

invested, even without the subsidy. 1/ Based on benefit-cost analysis and assumed levels of farmer incentives, the principal studies reviewing this matter question the approach and levels of the subsidy program. 2/ Although the studies differ in their specific calculations and recommendations, they both show that the level and targettng of diesel tubewells need to be revised to account for smaller farm size, fractional tubewell technology, and differential returns according to different water supply conditions, for example, the barani area tubewells warrant higher subsidies. The WAPDA study reported higher financial returns to electric tubewells than those obtained from diesel tubewells and strongly suggested that subsidies were not necessary incentives for promoting the use of electric tubewells, especially for the larger farmers.

Economic Impact

3.20 Equity Considerations. The latest data available (1972 Agricultural Census and 1978 WAPDA Survey) show that private tubewell ownership is concentrated on the larger farm holdings, with about 50% of the tubewells owned by farmers having more than 25 acres. This percentage rises to 70% for farm sizes exceeding 12.5 acres (see Table C.12). These figures seem to point toward an adverse effect of private tubewells on income distribution within agriculture. However, available data show that the existence of a private market for tubewell water is more widespread than ownership. 3/ Small farmers "buy" water from tubewell owners in cash, crop share, and/or labor. For example, considering different farm size intervals, tubewell ownership varies from about 6-20% of total farmers, whereas tubewell usage varies from

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1/ Forty percent of the sample farmers in both the sailaba and barani areas, and 56% of those in canal areas, reported that they would have been willing to install tubewells without the subsidy. Since the farmers surveyed had received subsidies, their responses were probably biased and not reliable. Therefore, a more unbiased farmer response would probably have indicated a higher percentage.

2/ The two studies referred are: (1) WAPDA, "Private Tubewells and Factors Affecting Current Rate of Investment," 1980; and (2) Malik, "Evaluation of Private Diesel Tubewell Subsidy Scheme in the Punjab," 1981.

3/ For example, 30% of the tubewell owners reported selling water in 1975. At the same time, the quantity of water sold appears to be negligible and is also seasonal. WAPDA's survey in 1978 showed that only 3.7% of the tubewell utilization is operated for water-selling purposes. However, it is likely this low figure may represent some significant underreporting. A related issue concerns the relatively high selling price of private tubewell water. In part, this reflects highly subsidized public water, the below-optimum number of tubewells, and competitive market structure. These market imperfections worsen the equity effects of private tubewells.

about 20-34% of total farmers. 1/ Nonetheless, this information suggests that there is substantial scope for improving the equity effects of future investments in private tubewells. Improved arrangements for providing credit and power connections can be important instruments in making tubewells more accessible to small farmers. 2/ Any approaches adapted to SCARP Transition should adequately consider equity implications and should aim to adopt the necessary arrangements that will make groundwater available to small farmers at a reasonable cost.

Overall Economic Assessment

3.21 Despite the existing price and market distortions in Pakistan, including those distortions introduced by the diesel tubewell subsidy scheme, the economic impact of private tubewells has been very favorable. 3/ A recent farm budget analysis conducted by the Bank showed that the ERR of investing in private tubewells ranged from 11% to 18%, with higher returns occurring to shallow electric wells. 4/ There is, however, substantial scope for increasing the economic impact of private tubewells in both efficiency and equity, provided there is formulation and implementation of appropriate policies and supporting measures. The focus of this "package" should be to consider carefully the future investment plans of the SCARP tubewells, the updated financial and economic returns to tubewell investments, required electrification (subject to cost and power supply considerations), extension services, fractional or small-capacity tubewell technology, farmer organization, and access to credit facilities.

1/ As expected, the largest difference is observed for farm size below 2.5 acres.

2/ For example, the IDA-financed Agricultural Development Bank of Pakistan (ADBP) V Project is supporting improved credit procedures on the part of ADBP (e.g., improved appraisal and supervision quality) that could lead to relaxed security requirements. Annex G presents additional background information on ADBP's historical and proposed lending plans for private tubewells.

3/ Although no studies have carried out comprehensive economic analysis of private tubewell investments, the relatively high financial returns clearly suggest that ERRs exceed 10%, the Bank's estimate of Pakistan's opportunity cost of capital.

4/ It is important that these results are based on the same assumptions used to calculate the financial returns as presented in para 3.15 but include the appropriate adjustments for economic prices. Also, the results are based on limited data and should be viewed as indicative. The 20-acre farm model makes the following main assumptions: wheat and rice are dominant crops; groundwater supplements surface water; cropping intensity would increase from 90% to 170%; yields increase by about 20%; the 1-cusec well in the 20-acre farm is underutilized; and it is assumed that 1,000 hours of pumped water are sold.

4. PUBLIC AND PRIVATE SECTOR ROLES IN GROUNDWATER DEVELOPMENT--EMERGING ISSUES AND OPTIONS

4.01 The above evaluations of the public (SCARP) and private tubewell experiences clearly suggest the emergence of two principal types of issues concerning public and private sector roles in the development of Pakistan's groundwater resources. First, this comparison of roles gives rise to what is generally known as the SCARP Transition concept--the need for transferring SCARP tubewells to the private sector on appropriate terms and conditions in such a manner that meets various objectives. Second, the implementation of this concept raises a series of complex issues that should be addressed and monitored during the SCARP Transition project preparation study. These two types of issues will be addressed in the following section, with the immediate objectives of facilitating discussion among concerned persons, sharpening the focus of the above project preparation activities, and providing a framework for follow-up discussions of public and private sector roles in Pakistan's groundwater development.

Main Issues and Options

4.02 The analysis presented in chapters 2 and 3 clearly shows that there are advantages and disadvantages associated with both the SCARP and private tubewells. These results are summarized in Table 3 and are highlighted below. 1/

Overall Assessment of Public (SCARP) vis-a-vis Private Tubewell Experience

4.03 First, the SCARP tubewells have provided important benefits in alleviating waterlogging and salinity, increasing agricultural production, and helping to spur the growth of private tubewells. At the same time, the performance of SCARP tubewells has included the following shortcomings: underachievement of ambitious targets; inefficient centralized management, which has resulted in serious technical, operational, and maintenance problems; a significant and unsustainable financial burden on scarce public resources; questionable economic performance. Second, the performance of private tubewell experience has exceeded general expectations and has performed particularly well where the SCARP tubewells have been the weakest. Private tubewells have: (1) been managed efficiently, particularly in helping meet peak crop water requirements; (2) represented a relatively insignificant burden on public resources; and (3) produced returns that are economically justified. Private tubewells have also provided the bulk of groundwater irrigation supplies as well as drainage where their density is adequate, resulting in significant increases in production and financial

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1/ Although the results vary according to specific SCARPs and tubewells, the findings below focus on reporting overall trends emerging from analyses of specific SCARPs and private tubewells.

returns to benefiting farmers. Moreover, planners' concerns about the private tubewells' ability to alleviate waterlogging problems are not supported by experience and by realistic watertable guidelines (see para 2.07). Private tubewells, however, have not helped promote a significant impact on an equitable use of groundwater resources, a result which has been aggravated by inappropriate public policies. Given Pakistan's rich aquifer resources, however, overexploitation by private tubewells has not emerged as a significant problem to date. 1/ Also, the private tubewells have not allowed the drainage problems to worsen, as expected, but rather have provided sufficient drainage to maintain watertables at a reasonable level. The comparison of SCARP and private tubewell performance according to various evaluation criteria present legitimate arguments for modifying the presents mode of groundwater development, particularly in relation to the role of the SCARP tubewells in usable groundwater areas. Some of the principal options for approaching Pakistan's future groundwater development include: (1) status quo; (2) all the project deficiencies should be improved where possible by the Government, and the SCARP tubewells should be managed according to the current arrangements (e.g., Department of Irrigation); (3) improve the existing SCARP deficiencies as in (2), but hand over the SCARP tubewells to a public/private limited corporation on mutually agreed terms and conditions; (4) after renovation of the SCARPs, they should be handed over to an autonomous Land and Water Development Board, which should be manned by a group of experts and experienced professionals, selected from various disciplines to run these projects on scientific lines and supported by appropriate development policies; (5) individual tubewells should be sold and handed over to the owners of lands adjoining the tubewells, individually or collectively (farmers' association or cooperative); (6) project tubewells should be divided into manageable small lots and transferred to local private enterprises for their day-to-day operation and management; and (7) farmers should be encouraged to install one or more tubewells in replacement of the deteriorated SCARP wells in such a manner that the multiple groundwater objectives are met.

1/ Perhaps the main exception refers to the Bari Doab area. In any case, long-term planning strategies would require systematic evaluation of the implications of a random exploitation of groundwater where these supplies are limited in the short to medium term.

Table 3

Pakistan's Public (SCARP) and Private Tubewell Experience:

Comparison of Potential/Planned and Actual Performance

A. Physical Comparison:

Item	Comparison	Implementation	Technology	Salinity and Drainage	Production
1. Public (SCARP) Tubewells	Potential/planned result	Rapid & smooth	Sophisticated, large, efficient	Problems alleviated	High increases
	Actual result	Slow & difficult	Sophisticated, large, inefficient	Significant alleviation	Positive, but below targets
2. Private tubewells	Potential result	Slow	Small & domestic	Marginal	Positive
	Actual result	Rapid	Small, domestic, & efficient	Better than expected	Exceeded expectations

B. Management/Institutional Comparison

Item	Comparison	Operation and Maintenance	Conjunctive Use of Ground and Surface	Farmer Organization	Aquifer
1. Public (SCARP) tubewells	Potential/planned	Good	Good	Good	Good
	Actual result	Poor	Fair	Poor	Good
2. Private tubewells	Potential result	Good	Poor	Deficient	Satisfactory
	Actual result	Good	Fair	Deficient	Satisfactory

C. Financial and Economic Comparison

		Financial		Economic	
Item	Comparison	Farmer Incentives	Burden on Government	Efficiency	Equity
1. Public (SCARP) tubewells	Potential/planned result	Strong	Sustainable	Good	Good
	Actual result	Sufficient	Unsustainable	Poor	Satisfactory
2. Private tubewells	Potential/planned result	Sufficient	Negligible	Good	Poor
	Actual result	Strong	Negligible	Excellent	Poor

Note: This summary comparison is based on the present analysis and is aimed to facilitate discussion of the main evaluation criteria. It is recognized that the phrases are subject to a wide range of interpretations; the summary statements indicate the broad direction of the overall result.

4.04 Although the various options outlined above have their merits, at this time available information strongly suggest a number of important conclusions. Most of these have been agreed in principle by GOP and Provincial Governments and have been reflected in various policy agreement with IDA. For example, GOP's "Letter of Development Policies," which provided the basis for the recently approved SAL I operation, states that: 1/ "Steps will be taken towards the objectives of reducing the budgetary burden of public tubewells by phasing out and/or divesting tubewells to the private sector where possible in fresh groundwater areas." More recently, these policies are reflected in GOP's Sixth Five-Year Plan (FY84-FY88). It presents the following related strategy: "the reclamation of fresh groundwater zone where cultivation of crops is possible would be left to the private sector. The private sector would be encouraged to install tubewells by providing closely spared electric grid, advancing loans and giving tubewell subsidy." The Government would like to leave the development of other sweet water areas to the private sector; in fact, it is propsing to transfer some of the public sector tubewells already existing in certain SCARPs to the private sector, providing this move does not result in worsening of waterlogging of a denial of water to the small farmers. Considering the above proposed policies, a first conclusion is that SCARP tubewells in saline groundwater areas should be continued and increased where necessary and based on appropriate technical and economic justification. 2/ Clearly, pumpage of saline groundwater areas is an example of a "public good," whereby individual farmers will not have any incentive to pump water. Therefore, it is the role of the public sector to drain saline groundwater areas and/or where the water quality is deteriorating. This view is consistent with GOP's current investment policies and plans. However, it is essential to improve the management of these saline groundwater SCARPs, including their O&M and financing arrangements. For example, increased water charges and/or other appropriate financial arrangements should be considered that are realistic with farmers' ability and general willingness to pay. A second conclusion is that SCARP tubewells in fresh groundwater areas where the physical conditions are suitable (e.g., where sufficient incentives exist to ensure adequate pumpage) should be transferred and/or terminated/phased out such that the private

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1/ A more detailed statement in the Letter of Intent is as follows: "... in the medium to long-term, we intend to reduce the budgetary burden of public tubewells by promoting private tubewell development in all usable groundwater areas, wherever this is consistent with drainage requirements, and by phasing out and/or divesting public tubewells, based on the findings of the SCARP Transition Project Preparation Study, which is being prepared with the assistance of the UNDP and the World Bank. This transition is to be supported by the expansion of rural electrification and supervised credit schemes."

2/ The justification should also consider the relative merits of using horizontal drainage technology where it is appropriate based on technical and economic considerations.

sector (farmers and/or farmer groups) takes over the full responsibility for operating and maintaining these tubewells as well as for installing new wells in replacement for those deteriorated. This transfer is consistent with GOP's policy statements of using public sector resources for activities that the private sector cannot perform, such as expensive saline groundwater drainage works in irrigated areas. 1/ Given the implementation complexities involved, this SCARP Transition should: (1) have specific arrangements that would vary according to particular SCARP; (2) be phased over a realistic timeframe (say, ten to fifteen years) beginning in FY85; (3) begin with approximately two of the earlier SCARPs 2/ that demonstrate having the pre-conditions of a successful first-phase experience. Initial transition arrangements should be carefully planned to ensure feasible solutions to the problems that are likely to arise during SCARP transition; obviously, intensive monitoring and evaluation are essential for determining the scope and approach to implementing a future expanded SCARP Transition Program. Otherwise, policy ambiguity on this important matter will seriously hamper the project's preparation and implementation and, more important, field-level experience to guide future phases of the program.

4.05 A third conclusion or aspect of SCARP Transition refers to policies and measures that could be adopted by both GOP and Provincial Governments in the short term and prior to initiating the first-phase project. The measures that should be reviewed carefully include policies and related actions that: (1) stop or phase out public sector funding of the tubewell replacement program in usable groundwater areas; (2) stop or phase out further public sector financing of additional and replacement SCARP tubewells in on-going SCARP having usable groundwater supplies; (3) implement related institutional improvements and policies that promote: (a) private investment in usable groundwater areas; (b) adequate pumpage to balance recharge by private and public sector tubewells; (c) more efficient use of both surface and groundwater supplies for crop water requirements and for appropriate aquifer management with regard to both depth and quality; and (d) increased surface water charges to help induce private pumpage in SCARP areas of usable

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1/ For further technical discussion on the need for massive flushing of saline effluent to achieve eventually an adequate salt balance, see the "RAP Report". An example of the urgent financial need to reallocate scarce public resources into projects that would be carried out only by the public sector is the proposed Kalabagh Project and the Left Bank Outfall Drain Project (LBOD). The implementation of the latter project is being delayed partly because of scarce public resources.

2/ SCARP I in Punjab and SCARP N. Rohri in Sind apppear to be promising candidates and have been selected by these Provinces to be included in the proposed SCARP Transition Project Preparation Study. The project preparation study should carefuly confirm the suitability of these two SCARPs or perhaps any other(s) (such as Maudi Baha and Dau Units of SCARP II).

water supplies and increased water charges for SCARP tubewells, which would include a reasonable charge for covering the O&M in both fresh and saline groundwater areas. These measures should consider strengthening the institutional arrangements and mechanisms to carry out the above functions, particularly considering farmer's views and those between and within concerned Provincial agencies (such as between Departments of Irrigation and Agriculture). To strengthen the current institutional arrangements for monitoring and evaluating the performance of SCARP tubewells, the quantity, quality, and use of data for management of on-going SCARPs should be reviewed and improved wherever appropriate. 1/

Implementation Issues in SCARP Transition

4.06 The second group of SCARP Transition issues refer to the transfer arrangements and supporting measures that will be required to implement successfully the proposed SCARP Transition Program and yet meet the multiple objectives of developing Pakistan's groundwater resources. Some of these issues have been listed in the agreed Terms of Reference for the SCARP Transition Project Preparation Study currently underway (see Annex I). The section below will draw on the findings of the present study to sharpen some of these issues and, therefore, to facilitate the focus of the preparation study and ongoing dialogue with Government. 2/ The nature and scope of these issues will vary according to various factors, such as SCARP tubewells that are either terminated, replaced, or transferred. The issues can be grouped under seven general categories: (1) technical; (2) power supply; (3) physical; (4) management and institutional; (5) legal; (6) project content; and (7) policy issues, particularly investment priorities, equity considerations, and conserving total public resources.

Technical

4.07 The review of the SCARP projects have shown that these tubewells have deteriorated more quickly than expected due to various design, construction, and O&M problems. The preparation study should carefully examine the technical operating conditions of the SCARP tubewells and, based on appropriate criteria, determine the SCARP tubewells that should be terminated, replaced, or transferred. In this manner, each SCARP tubewell, in effect, would represent a separate subproject. Given the limited life of the SCARP tubewells, the study should consider appropriate project measures that would enable feasible replacement during and after project implementation in a manner that

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1/ The nature of the information shortcomings are discussed in para 4.14.

2/ It is possible that some of the issues discussed are not explicitly included in the final Terms of Reference. They are discussed here not with the intention of complicating the preparation study, but rather, to clarify some of the issues that could help determine the success of the SCARP Transition Project.

is acceptable to participating farmers. In addition, the study might consider the logistical and technical feasibility and economics of: (1) adopting small-capacity tubewells wherever possible (for further background information on the scope for technical improvements, see Annex D); (2) technical alternatives to vertical drainage using horizontal methods in some of the project subareas, particularly where the water quality is marginal; 1/ and (3) the scope for improving the technology of the larger public SCARP wells in a manner that could be realistically managed by the public sector or transferred to the private sector.

Power Supply

4.08 Private sector pumping for irrigation from tubewells was historically based on low-speed diesel engines, and this type of equipment still outnumbers electric motor-powered units. However, since 1979, the price of light diesel oil has tripled, and electrical energy has become a significantly cheaper source of power supply to the farmer. The result is that cultivators are reluctant to invest in diesel engine pumping units, and there is an increasing demand for power connections. It may bseen that the availability of electrical power will become increasingly critical to the development of groundwater on the Indus plain by the private sector. The quality of the energy in the rural grid leaves much to be desired, and voltage fluctuations lead to a high incidence of motor burn-outs. WAPDA, capacity to make connections is limited by budget contraints. A decision to implement SCARP Transition by replacing the SCARP tubewells by low-discharge capacity, private sector tubewells would increase this demand for connections, could increase the load, and could possibly lead to excessive load factors.

4.09 Notwithstanding the above, a balanced assessment of the power issue in the context of the SCARP Transition Program needs to consider the following factors: (1) the severe power shortages are expected to occur in the mid-1980s, after which Pakistan will be benefiting from an increased power supply; (2) the incremental electric power requirements of a possible first phase SCARP Transition Project (e.g., additional to the electric power supplies currently being taken by the corresponding SCARP tubewells) would be relatively minor, even after considering higher distribution losses; (3) any significant expansion of private electric tubewells as part of SCARP Transition would not occur until the later stages of a possible first-phase project

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1/ The preparation study should periodically consult the concerned persons and agencies working on various proposed projects in the irrigation sector, such as LBOD and Drainage IV projects, which are exploring the technological alternatives to drainage. Numerous studies have compared the relative merits of vertical and horizontal drainage. Those studied should be reviewed and updated where necessary (for example, to consider the sharp rise in energy prices). In any case, these technological alternatives are applicable mainly for drainage requirements in saline groundwater areas.

(e.g., late 1980s--at that time, Pakistan's power supplies are expected to increase over current levels. The above points suggest that power supplies, although an important factor in Pakistan's current era of shortages and load-shedding, are not a critical constraint to the implementation of a possible SCARP Transition first-phase project. Annex H presents additional background information on Pakistan's power supplies (e.g., generation, generation demand forecasting, transmission and distribution, and consumption).

Physical

4.10 The SCARPs have frequently been hampered by an absence of appropriate pumpage guidelines in practice and of schedules that would reflect realistic targets in watertable depth and supplemental irrigation. Also, based on such a review, recommended targets should be developed that would be used for management decisions, including guidelines for determining appropriate capacity utilization rates. The SCARP evaluations have frequently cited water quality problems due to inadequate mixing of canal and tubewell water and to deteriorating water quality, including the intrusion of saline groundwater. The preparation study should recommend appropriate improved institutional arrangements that would (1) help establish realistic technical guidelines for drainage and and supplemental irrigation (the SCARP Khairpur O&M manuals could be a good starting point); (2) monitor these technical parameters in a reliable and timely manner, including improvements in data collection, processing, storage, analyses, and publication; and (3) help ensure the adequate implementation of these guidelines, especially in areas where privatization takes place.

4.11 Since the responsibility of operating and maintaining the SCARP tubewells would fall on the farmers, the study should investigate the cropping patterns that would support possibly higher costs of privately pumped water, particularly considering the current subsidies in both canal and SCARP tubewell water supplies. It would be useful to examine the cropping patterns and agricultural experiences in non-SCARP usable groundwater areas. Also, potential agricultural production benefits have been below their potential levels partly because of a deficient extension service; the study should verify such conclusions and recommend measures that would strengthen the extension service, emphasizing water management aspects and improved usage of nonwater inputs.

Management and Institutional

Farmer's Organizational Arrangements

4.12 One of the most important aspects in the successful implementation of the SCARP Transition Project refers to the incentives and organizational mode of the participating farmers. Given the large-size SCARP tubewells, it is expected that appropriate forms of farmer organization (such as Water Users Associations) would be the principal means of operating and maintaining the SCARP tubewells that are transferred to the private sector. Past experience suggests that many of the SCARP tubewells offer adequate potential incentives to elicit a favorable farmer response. The preparation study should carefully review the past "successes" and "failures" of farmer groups; such a review could provide insight into likely farmers' organizational problems that may emerge in the proposed SCARP Transition Project, particularly considering dominant land tenure patterns and related issues. 1/ The study should then recommend measures that would help strengthen the role and effectiveness of farmer organizations. In cases where the SCARP tubewells are replaced by smaller-capacity wells, it is expected that individual farmers and/or small groups of farmers would take overall responsibility. Therefore, it is important to consider alternative approaches to farmer organizational arrangements that may vary according to each specific area.

Operation and Maintenance (O&M)

4.13 The review of SCARP tubewells has shown that a major cause of poor performance of SCARP tubewells is related to problems of deficient O&M. The operational problems have been directly related to deficient scheduling of surface and groundwater supplies; this matter should be reviewed by the study to ensure the changes required and ensure an efficient and decentralized management of the tubewells. In this connection, it will be important to consider the relevant aspects of other projects and ongoing studies (e.g., Command Water Management Study, which is aiming to improve the conjunctive use of ground and surface water supplies). Since the operation of SCARP tubewells requires a higher level of technical know-how, the study should identify possible measures, such as training support, that facilitate their operation by farmer groups, particularly in cases where the SCARP well is transferred. This review should consider the future role and "transition" of the currently unionized tubewell operators. The maintenance problems frequently experienced by SCARP tubewells should also be investigated, accounting for the possible causes and their relative importance (budgetary, technical, and operational). This factor may have a direct bearing on farmers' willingness to take over the SCARP tubewells. Also, the study should review the appropriateness of transferring SCARP repair facilities and equipment to the private sector, including the necessary legal and financial arrangements.

Monitoring and Evaluation

4.14 Under the SCARP Transition concept, the public sector role in monitoring and evaluation becomes extremely important. This "management information system" should be of two types: one for monitoring groundwater hydrology and quality, which extends beyond the immediate proposed project and the other for reviewing the progress and impact of the proposed SCARP Transition projects. Comments below apply to the first category. The second

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1/ For example, the IDA-financed On-farm Water Management Project relies on the important role of the Water Users Association. These preliminary experiences should be reviewed; the experiences of Punjab Province's Canal Advisory Committee should also be examined.

type of monitoring and evaluation follows the considerations that generally apply to most project preparations. Since there is some controversy regarding the reliability, analysis, and use of the SCARP monitoring data, the preparation study should consider formulating a project component that would review the institutional arrangements and make appropriate recommendations for compiling, analyzing, and using the data of key parameters (such as watertable depth, water quality, and conjunctive use of surface and groundwater supplies). 1/ In particular, the role of and interrelationships between provincial and federal agencies in monitoring should be carefully reviewed and recommended.

Legal

4.15 The preparation study should review the legal implications and feasibility of transferring and terminating SCARP tubewells and related facilities. In addition, the study should identify the legal procedures for such a transfer and should review any legal actions required to ensure that the SCARP tubewells perform the necessary drainage and water supply functions. The need for enforcing appropriate groundwater legislation to help promote appropriate siting of tubewells and aquifer management should also be reviewed by the project preparation study as a possible component for the proposed project. 2/ Such a stipulation should not give overriding powers to licensing authorities.

Scope of Project Components

4.16 Past evaluations have shown that SCARP tubewell water has generated agricultural benefits substantially below its potential for various reasons including: unreliable and fluctuating power supplies, inadequate distribution channels, insufficient mechanization, deficient extension services and

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1/ Such a "groundwater information component" should consider the usefulness of establishing a computerized data bank of important parameters; these data, such as on watertable depth, are presently unorganized and difficult to use. A related matter that requires further investigation is the establishment of agreed guidelines on drainage and water quality that could be used to establish realistic targets for tubewell pumpage and acceptable water quality for supplemental irrigation, accounting for the differing physical characteristics. Again, perhaps the proposed project can provide funds for supporting such a study, which is an essential element in developing an efficient monitoring system and ensuring a sound approach to groundwater development in Pakistan.

2/ Some of the Provinces already have a draft legislation; the major problem appears to be formal enactment and enforcement of such legislation. It is likely that draft legislations for some of the Provinces might already be available, which would greatly facilitate implementation of this study-oriented component.

farm-level use of water and non-water inputs, and limited access to credit. 1/ Since the proposed project will require the strong support of the participating farmers, the study should carefully assess the scope of possible project components and include those that are essential for meeting the project's objectives and for securing strong farmer support. The various project design options should be assessed within the framework of the project's financial and economic analysis, using representative farm budget analysis and appropriate economic criteria (i.e., net present value criteria to assess mutually exclusive project design options). Given the complexity of the proposed project and scope of project components, it is imperative that the project preparation team comprise of multidisciplinary experts at all stages of the study.

4.17 Given the issues involved, a first-phase SCARP Transition Project should consider two additional factors that will have a bearing on the project's components. First, the most feasible optional approaches, as indicated in para 4.03, should be reviewed for possible concurrent implementation (e.g., improving existing SCARP arrangements, transferring SCARP wells to farmer groups, replacement with smaller-capacity wells). The selection of a specific approach for a particular location should be based on various guidelines that need to be developed, reflecting high priority for farmers' preferences. Second, the project concept and components should carefully consider other related projects under implementation and preparation (e.g., Command Water Management Project that aims to improve the conjunctive use of public ground and surface water supplies.

Other Policy Issues

4.18 The SCARP Transition Project will involve a number of complex policy issues that should receive high priority in the project preparation study and from other concerned officials during and after the study. Based on appropriate financial analysis and sound judgments, 2/ the preparation study should propose realistic policy options for: (1) defining clearly the GOP and Provincial Governments' roles in financing future SCARP tubewells in usable groundwater areas, including a clear policy on replacement of SCARP wells (this policy will be an important determinant of future investments and

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1/ Given that a relatively small percentage of farmers used credit to purchase private tubewells (about 10%), the preparation study should highlight the various factors that have limited the use of institutional credit and make recommendations that could be considered by the participating credit institutions. Annex G provides some pertinent background information regarding ADBP's current and future lending operations for private tubewell development.

2/ For example, based on farm budget analysis and judgments that account for fiscal, efficiency, and equity considerations, including farmers' ability and willingness to repay.

O&M outlays by both public and private sectors); (2) the terms and conditions of transferred SCARP tubewells; 1/ (3) making adequate credit provisions for replacement of SCARP tubewells, 2/ considering the equity objective of providing access to water supplies to small famers; (4) establishing canal water charges in the project area at levels that will eventually cover the full costs of a stepped-up O&M program and that help induce the necessary tubewell pumpage to meet realistic drainage requirements; (5) increasing water charges for SCARP tubewells that are not being transferred to help reduce the financial burden on the government and to reflect more accurately the costs of providing this water, (this could include appropriate charges to cover O&M costs in saline groundwater areas). In formulating appropriate policies, it will be important to consider the implications of SCARP Transition on total government outlays and receipts, drainage, and agricultural production. This balanced assessment will help formulate policies that could support a multiple set of objectives and could avoid shifting the drain on public financial resources from one source to another (e.g., O&M subsidies vis-a-vis credit arrears).

4.19 In addressing the above policy issues, the preparation study should carefully weigh the legitimate concerns and suggestions of farmers and concerned agencies, including farmer groups, union and district Councils, Provincial Departments of Finance, Planning and Development, Irrigation and Power, Agriculture, Law, and Board of Revenue. Finally, the study coincides with GOP's preparation of the Sixth Five-Year Plan and should account for the relevant policies and programs outlined in the final Plan document (para 4.04).

1/ Financial arrangements for recovery of a portion (if any) of capital costs should also consider the farmer's likely resistance to repaying and should account for the operating condition and life of the particular SCARP tubewell.

2/ Given the demonstrated importance and high financial returns of fractional tubewell technology, the study should assess the possible role of these tubewells, and recommend appropriate measures that promote their availability, adoption, and practicable use, especially by the smaller farmers. The lending operations of the ADBP, which is being supported by the Bank Group, is currently increasing substantially the line of credit in "minor irrigation"; this category includes primarily credit funds for private tubewells.

ANNEX A

BACKGROUND ON PAKISTAN'S IRRIGATION SYSTEM: FOCUS ON ITS GROUNDWATER RESOURCES

Overview

1. Pakistan has the world's largest single gravity-flow irrigation network, providing about 65 million acre feet (MAF) of water annually (in FY81) at farmgate to irrigate an area of about 34.5 million acres. In addition, Pakistan's abundant aquifer resources provide an additional 33 MAF of irrigation water supplies, which are exploited by nearly 190,000 public and private tubewells. The surface irrigation system comprises the Indus River and its major tributaries, three major storage reservoirs, 19 barrages/headworks, 12 link canals, 43 canal commands, and some 89,000 watercourses. Other features of this vast system include a large number of flood-protection dikes and embankments and a large network of surface drainage. Despite the impressive dimensions of this irrigation system, its economic output per unit of water diverted at the source is perhaps the lowest in the world. There are a number of reasons for such a low economic efficiency of the water system, including: a wide gap between supply and demand of irrigation water, excessive water losses in the system, low irrigation efficiency, inadequate drainage, outdated land and water management practices, fragmented landholdings, and the twin menace of waterlogging and salinity. These last two problems and their primary causes are reviewed below.

Waterlogging

2. Before the introduction of permanent barrages, diversion weirs, and irrigation systems, there was a natural balance between the annual precipitation, stream flows, evaporation/evapotranspiration, deep percolation, accretion/depletion of water table, outflow of river water into the sea, and other components of the hydrologic cycle. Beginning in the late 1800s, the natural balance between recharge, groundwater movement, and discharge was upset by the development of extensive, barrage-controlled perennial irrigated systems. As a result, Pakistan's development of its irrigation resources has lead to rising watertables that threaten its already low levels of agricultural production. According to a recently completed soil salinity survey (41 M acres) carried out by WAPDA for the Indus Basin, about 22% of the area has a critical waterlogging problem, with a watertable within 6 feet of surface, which is about double the area similarly affected in 1953. Also, this survey

indicated that an additional 20% of the Indus Plain has a pending waterlogging problem, with a watertable between 6 and 10 feet of the ground surface. The primary causes of this waterlogging problem include: (1) seepage from rivers and irrigation channels; (2) flat slope of the natural surface having poor natural drainage; (3) unscientific irrigation practices -- overirrigation in some parts, and underirrigation in others -- and lack of adequate artificial drainage; (4) contribution made by development efforts such as irrigation networks, road and rail links, replacement link canals and other infrastructural developments in the flood plains, which have interrupted the seepage of surface runoff at many places. These patterns have resulted in accumulation of ponded waters during monsoon seasons, part of which contributes to deep percolation.

Salinity

3. Pakistan's agricultural development has also been hampered by large areas of salt-affected soils. Although there are varying estimates, salt-affects soils in the Indus Plain total about 15 million acres, of which nearly 8 million acres (or 23%) are within Pakistan's cultivable command area (CCA). In addition, other are large areas having soils affected by high sodicity, which is caused by the use of low-quality pumped groundwater. The principal causes of soil salinity include: (1) salinity originating from within the soil characteristics; (2) addition of salt from the irrigation supplies that are not balanced through natural processes; (3) poor irrigation practices, including the use of poor quality groundwater, that give rise to salt concentrations at the ground surface and within the root zones; (4) a by-product of waterlogging, whereby the soluble salts present in the groundwater add excessive salt concentration within the wet zone as well as at the surface; (5) salt accumulation from hill torrents; (6) improper land use, such as improper patterns of following lands.

Water Resources: Focus on Groundwater

Overview

4. The vast and readily manageable groundwater aquifer underlying the Indus Plains is a significant asset in Pakistan's water resources system. Until twenty years ago, groundwater was viewed more as a hazard in regard to waterlogging than as an asset. However, the utilization of groundwater for irrigation supply has grown rapidly since 1960; as a consequence, in most of the fresh groundwater areas the waterlogging problem has diminished. Considerable potential for development remains, in the canal commands, and by the utilization of the aquifer as a storage reservoir in riverain areas. In fact, the aquifer provides the ultimate water storage reservoir system for Pakistan, with usable volume far in excess of all existing and potential surface reservoirs, immune to sedimentation and evaporation losses, and located close to the areas of use.

Regional Distribution of Water Resources

5. Pakistan has a land surface of about 200 M acres (80 M ha). It may be subdivided into the following broad regions: (1) the Indus plain in the east; (2) the Himalayan mountain zone in the west and north; and (3) the coastal zone of Baluchistan and Sind. About 74 M acres or 38% of the total land surface are regarded as cultivable though only about 48 M acres are actually cultivated. The greatest proportion of the cultivated land is located on the Indus plain.

Rainfall

6. The mean annual rainfall ranges from less than 2 inches in western Baluchistan to more than 60 inches in localized parts of the Kashmir range. An extensive area of the central Indus plain receives on average less than 6 inches of rainfall per annum. About 95% of the country has a mean annual rainfall of less than 24 inches, and some 60% has less than 10 inches.

7. The interannual variation of rainfall amount is high, and the amount of variation increases with decreasing average rainfall. The eastern part of Pakistan has a monsoon climate, though frontal storms occur during the winter months. The seasonal distribution of rainfall is less pronounced in the dry, western Himalayan zone but, on average, winter rains predominate.

Surface Water

8. All the major rivers converge onto the Indus plain to form part of the Indus drainage system. Peak flows occur during the monsoon, but perennial flows are sustained through the dry season by snow melt in the Himalayas and water released from groundwater storage. Most of the rivers of Baluchistan which drain to the Arabian sea are ephemeral and typified by flash floods.

9. The mean annual inflow to the Indus River system is about 150 MAF, of which 138 MAF is on average recorded at the rim gauging stations; the balance is generated in the Indus basin within Pakistan. The rim station inflows ranged from 104 to 187 MAF about the mean of 138 MAF (standard deviation 19.8 MAF) in the 1949/50-1977/78 record period (Table 1). Outflows to the sea ranged from 8.2 to 97 MAF during the period 1961/62 to 1977/78 and averaged 52 MAF. The flow regime of the river has been profoundly modified by regulation structures for storage and diversion. During the past decade, diversions for irrigation have averaged 97 MAF per annum.

The Aquifer

10. Essentially all of the Indus Plain is underlain by deep, mostly over 1,000-ft, deposits of unconsolidated, highly permeable alluvium consisting primarily of fine to medium sand, silt, and clay. Fine-grained deposits of low permeability generally are discontinuous so that sands, making up 65 to

75 percent of the alluvium, serve as a unified, highly transmissive aquifer. Aquifer characteristics vary substantially from place to place, but overall average parameters broadly indicate a high-yielding aquifer with substantial storage capacity. Outside the Indus Plain, aquifers are isolated and of widely differing characteristics. Compared with the Indus Plains, the potentials for development are small and less economical.

Water Quality

11. Quality is one of the most important factors in the development of Pakistan's groundwater resources. In the Indus Plains aquifer, although groundwater can be extracted virtually anywhere, its quality varies considerably, both with area and with depth. The use of ground-water, however, is conditioned not entirely by its quality but also by the mode of its utilization through dilution with canal supplies. Considering the concentration of the dissolved salts in the groundwater, which is a fairly reliable index of the water quality for irrigation when other parameters are also taken into account, the Revised Action Programme (RAP) presents the extent of areas where groundwater can be usefully developed by means of tubewells with present specifications. These areas within canal commands total about 28 million acres, which represent about 70% of the total gross area.

12. The importance of water quality highlights the need for appropriate management of the aquifer. The interface between fresh and saline groundwater is found at different depths and in some areas is located at relatively shallow depths. The phenomenon of the upcoming of saline groundwater under the influence of tubewell pumping imposes strict limits upon tubewell penetration and capacity. Therefore, the installation of shallow, low-capacity tubewells is necessary. These are frequently used by the private sector. The installation of large-capacity public irrigation tubewells might lead to undesirable deterioration of the pumped effluent, which would then be unfit for irrigation purposes and would require the extension of the surface drainage system for disposal of the effluent, mostly into evaporation ponds. As a result, other sources of irrigation water would have to be found to meet the crop water requirements, particularly during the rabi season. The salinization of the public irrigation tubewells is illustrated by the experience observed in Unit 1 of the SCARP VI project (Allahabad Pilot Project) after one to two years after their installation.

Groundwater Recharge and Pumpage

13. Total groundwater recharge in the irrigated areas of the Indus Plain has been estimated to be of the order of 45.6 MAF, out of which 28.9 MAF occurs in usable groundwater areas and the remaining 16.7 MAF in saline

groundwater areas. 1/ About 80% of the recharge in usable groundwater areas occurs in Punjab, 5% in North West Frontier Province, and 15% in SND-Baluchistan. The recharge is obtained primarily from the seepage losses of the canals, watercourses, and fields, followed by rainfall, rivers, and subsurface groundwater inflow/outflow. Desirable groundwater development should lead to pumpage that equals recharge to prevent depletion of the aquifer. However, in the case of private tubewells there is presently no restriction on the number of tubewells that can be installed in a certain area and the quantity of water that can be pumped by these tubewells. As a result, there has has been a high concentration of private tubewells in some areas, resulting in overdevelopment of groundwater; in other areas, the density of private tubewells is low, leading to inadequate development of groundwater. The rates of groundwater pumpage from public and private tubewells combined are also different in different areas. Total pumpage of groundwater in the irrigated area of the Indus Plain in 1979/80 is estimated to be about 26.7 MAF, out of which 6.8 MAF are pumped by the public sector and 19.9 MAF are in the private sector.

Groundwater Development Potential

14. The development of groundwater in the canal-commanded area of the Indus Basin Plain for irrigation is in the order of 27 MAF per year, or about 70 percent of the exploitable potential. WAPDA's estimate of the remaining potential -- 11.4 MAF -- is considerable, but should be developed under carefully regulated plans. Adverse impacts may result if further overdevelopment is allowed. It is important to indicate areas where potential for further development exists, and also to demarcate areas where overexploitation is taking place so that further development is carefully controlled or halted. 2/

Constraints to Groundwater Development

15. The ultimate physical constraint to groundwater is the continuing availability of a supply of acceptable quantity and quality. Accepting a long-term safe yield principal, this could be interpreted as development up to the maximum abstraction rate that the aquifer system can sustain with water levels at dynamic equilibrium and/or avoiding an unacceptable deterioration in water quality. In practice, financial or economic considerations often set limits to development which are lower than the maximum safe yield.

1/ For a recent study on Pakistan's groundwater resources, see WAPDA, "Groundwater Development and Potential in Canal Commanded Areas of the Indus Plain," Planning Division, July 1981.

2/ WAPDA has identified some of these areas; see the footnote to para 13.

16. The areas of Pakistan where water-level decline has become critical are limited. Quality deterioration has become limiting for deep tubewell abstraction in at least one SCARP (SCARP VI) where the wells were intended for the dual purpose of water-level control and irrigation water supply. Fortunately, private sector shallow tubewells have better characteristics for skimming fresh water from aquifer systems where water quality deteriorates at depth. Given the relative freedom of action so far as the resource is concerned, the existing constraints on its rate of development are: (1) well construction capacity; (2) availability of power supply; (3) availability of subsidies; and (4) farmers' beliefs and prejudices. More dynamic banking policies and practices for extending credit to the farmers could also enhance the rate of development.

17. Finally, the above overview of Pakistan's irrigation resources highlights the critical role of its groundwater and the urgency of addressing questions such as the following: What has been the performance experience of the public and private sectors in groundwater development? What should be their roles, particularly in usable groundwater areas? How can their present roles be modified to meet multiple objectives? How can the constraints to further development of Pakistan's groundwater resources be appropriately addressed? These matters are discussed in the text and in Annexes D-G.

Table B.1(a)

ALLOCATIONS AND EXPENDITURES ON RECLAMATION PROGRAMMES DURING VARIOUS PLAN PERIODS.

(Million Rs.)

Plan Period	Allocations			Expenditure		
	Water Sector	Recla-mation	%	Water Sector	Recla-mation	%
Ist Plan (1955-69)	1,769 1/	137	8	1,420 1/	61	4
2nd Plan (1960-65)	1,575	229	15	1,443 2/	259 3/	18
3rd Plan (1965-70)	2,211	1,133	51	1,510	864	57
4th Plan 4/ (1970-75)	2,545	1,281	50	2,513	1,121	45
1975-78	6,031	2,029	34	6,897	2,063	30
5th Plan (1978-83)	17,120	6,702	39	16,474	4,345	26
TOTAL	31,251	11,511	37	30,257	8,713	29

1/ Including allocation to Power project during the plan period.

2/ Figures taken from "Final Evaluation of The Second Five Year Plan (1960-65)", Planning Commission, December, 1960.

3/ Expenditure of amount Rs 259 million was shown in "Proposal for an Accelerated Programme of Waterlogging and Salinity Control in Pakistan", Government of Pakistan, September, 1973.

4/ The outside Plan amount of Rs 3000 million for Tarbela/IBP is not included.

Table B.1(b)

PAKISTAN

SCARPs Completed and Under Construction

MAIN SCARPs Completed
(Up to 1982/83)

Provinces/SCARPs	Culturable Command Area (000 Acres)
(A) PUNJAB PROVINCE	5,392
Rechna Doab:	
1. SCARP - 1	1,141
2. SCARP - IV	544
3. SCARP - V	
(Satiana P.P.)	98
(Shorkot Kumalia P.P.)	154
Chaj Doab:	
4(a) SCARP - II (FGW)	1,490
4(b) SCARP - II (SZ)	550
5. SCARP Shahpur	90
Thal Doab:	
6(a) SCARP - III (FGW)	952
6(b) SCARP - III (SZ)	98
Bahawalpur Arani	
7. SCARP Panjnad Abbasia (Allahabad P.P.)	202
8. SCARP Fordwah Sadiqia (Minchinabad P.O.)	73
(B) SIND PROVINCE:	1,192
9. SCARP Khairpur	376
10. SCARP North Rohri	686
11. Sukkur Right Bank Proj.	130
(C) N.W.F. PROVINCE:	106
12. SCARP Peshawar	26
Kufur Dhori Unit	26
Jue Sheikh Unit	52
Pabbi Unit	28
Warunk Unit	N.A.
SCARP Mardan (Phase I)	N.A.
Total	6,690

N.A. = Not Available

SCARPs Under Construction 1/

Provinces/SCARPs	Estimated Total Cost (Rs M)
(A) PUNJAB PROVINCE	3,301
1. Panjnad Abbasia (Units II-V)	(1,777)
2. SCARP II (Saline Zone)	(1,293)
3. SCARP Fordwah Sadiqia	(231)
S-T	
(B) SIND PROVINCE	7,313
4. S. Rohri (FGW)	(993)
5. Ghotki (FGW)	(769)
6. Left Bank Outfall Dr. 2/	(3,577)
7. East Khairpur	(536)
8. Larkana Shikupur 3/	(380)
9. Kotri Surface	(430)
10. North Dadu	(628)
S-T	
(C) N.W.F. PROVINCE	1,790
11. SCARP Mardan	(1,790)
TOTAL	12,404

1/ Most of these SCARPs are located in saline groundwater zones.
2/ Cost is estimated and includes only drainage costs.
3/ This SCARP is nearly completed.

Table B.1(c)

SALIENT FEATURES OF COMPLETED AND ON-GOING SCARPS

Sr. No.	PROJECTS	AREA (M.A)		Estimated Cost (M.Rs.)	Expenditure upto 30.6.82 (M.Rs.)	SCOPE				PROGRESS UPTO JUNE 1982			
		G.A.	C.C.A			TUBEWELL (NO) FGW	TUBEWELL (NO) SGW	Surface Drain Km/Mcft	Tile Drain Collector + Lateral Km	TUBEWELL (NO) FGW	TUBEWELL (NO) SGW	Surface Drains Km/Mcft	Tile Drains Collector + Lateral Km
1	2	3	4	5	6	7	8	9	10	11	12	13	14
(A)	**PUNJAB**												
1.	SCARP I	1.217	1.141	240.000	240.000	2069	-	-	-	2069	-	-	-
2.	SCARP II	1.649	1.490	1293.272	1327.367	2205	-	749/541	-	2205	-	628/516	-
3.	SCARP II SZ	0.690	0.550			-	821		-	-	816		-
4.	SCARP III	1.138	0.952	407.153	473.831	1635	-	242/135	-	1635	-	242/135	-
5.	SCARP III SZ	0.142	0.098			-	61		-	-	61		-
6.	SCARP IV	0.558	0.544	192.000	193.000	935	-	-	-	935	-	-	-
7.	Shahpur (P)	0.112	0.090	125.420	113.073	258	-	-	-	258	-	-	-
8.	Shorkot Kamalia (P)	0.169	0.154	61.214	59.771	101	-	-	-	101	-	-	-
9.	Minchinabad (P)	0.078	0.073	110.704	93.840	203	23	-	-	203	23	-	-
10.	Allahabad (P)	0.216	0.202	194.591	291.313	623	-	-	-	623	-	-	-
11.	Satiana (P)	0.118	0.098	28.097	37.387	20	51	-	-	20	51	-	-
12.	Paharang Drain 1/	0.142	0.140	56.445	54.770	-	-	84/101	-	-	-	84/101	-
13.	AWL along TP Link	0.020	0.020	42.085	32.171	16	64	-	-	16	64	-	-
14.	AWL along RQB Link	0.054	..050	58.590	40.504	-	85	2/1.6	-	-	85	2/1.6	-
15.	Panjnad Abbasia (Rem)	1.460	1.267	1882.000	144.383	-	307	460/337	-	-	-	NA/8	-
16.	Fordwah Sadiqia II	0.111	0.110	127.000	7.358	-	30	177/50	-	-	-	NA/9.3	-
17.	AWL along CJ Link	0.023	0.020	44.553	20.482	-	74	24/22	-	-	-	NA/6	-
18.	AWL along TSMB Link	0.090	0.090	57.364	14.064	-	56	31/27	-	-	-	NA/179	-
19.	Lower Rechna (Khairwala)	0.104	0.100	344.436	52.753	-	96	200/227	-	-	-	NA/78.4	-
20.	CBDC (Pandoki)	0.196	0.190	151.370	12.204	-	101	43/78	-	-	-	/8.2	-
21.	Replacement of T/Ws Phase I+II 2/			444.569	298.516	1450 *	-	-	-	1115 *	-	-	-
	S.TOTAL:-	8.241	7.329	5860.863	3506.787	8065 (1450)*	1769	2012/1519.6	-	8065 (1115)*	1100	/881.4	-

1	2	3	4	5	6	7	8	9	10	11	12	13	14
(B)	**SIND**												
1.	Khairpur	0.441	0.380	255.000	257.489	175	365	550/38	-	175	365	550/38	-
2.	N. Rohri	0.793	0.686	500.000	432.186	1192	-	-	-	1192	-	-	-
3.	Shikarpur (P) 3/	0.017	0.014	9.800	12.930	50.	-	-	-	50	-	-	-
4.	Sukkur (P) 3/	0.005	0.004	5.110	2.725	18	-	-	-	18	-	-	-
5.	Larkana (P) 3/	0.008	0.005	6.900	7.421	35	-	-	-	35	-	-	-
6.	Sukkur RB FGW 3/	0.150	0.130	170.696	150.422	400	-	-	-	400	-	-	-
7.	Kandkot (P)	0.013	0.012	9.890	9.735	26	-	-	-	26	-	-	-
8.	Larkana Shikarpur Surface Drainage Project Stage I+II	0.701	0.594	431.245	305.290	-	-	1252/757	-	-	-	1070/691	-
9.	South Rohri FGW	0.541	0.375	511.238	129.881	1350	-	-	-	180	-	-	-
10.	Ghotki FGW	0.441	0.400	768.785	165.669	1050	-	-	-	300	-	-	-
11.	North Dadu Surface Drainage	0.514	0.445	321.134	72.409	-	-	807/481	-	-	-	121/99.3	-
12.	East Khairpur Tile Drainage	0.045	0.036	372.170	223.832	-	-	-	1175	-	-	-	165.5
13.	LBOD Phase I 4/	1.810	1.706	3576.732	454.344	-	-	968/1255	-	-	-	206/468	-
14.	Kotri Barrage S.Drainage Phase I Stage I Part I&II	3.216	2.671	463.000	297.582	-	-	4700/2780	-	-	-	2557/1536	-
15.	Replacement of T/Ws 2/			39.757	17.689	250	-	-	-	68	-	-	-
	S.TOTAL:	6.705	5.599	7441.457	2539.604	4296 (250)	365	8277/5311	1175	2376 (68)	365	4504/2832.3	165.5

Table B.1(c) (Contd)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
(C)	N.W.F.P.												
1.	Pabbi I+II	0.036	0.028	54.753	65.738	84	-	85.5/85.5	-	84	-	85.5/85.5	-
2.	AWL along Peshawar City	0.002	0.002	15.251	15.251	9 51 (DW)				9 51(DW)			
3.	Kafur Dheri	0.030	0.026	44.170	39.451	48 3 (DW)	-	-	-	48 3(DW)	-		
4.	Jue Sheikh	0.057	0.052	51.716	55.896	22 1 (DW)	-	106/62	-	22 1(DW)	-	NA/51.15	-
5.	Narangi (P)	0.025	0.025	1.420	2.938	10[3](DW)	-	-	-	10[3](DW)			
6.	Mardan New	0.220	0.180	1790.400	59.776	65 35 (DW)	-	NA/127	3478	65 35(DW)	-	-	-
7.	Bannu Phase I	0.090	0.080	93.805	72.646	176	-	NA/23	-	176	-	NA/23	-
	S.TOTAL:	0.460	0.393	2051.515	311.696	507	-	NA/297.5	3478	507	-	NA/159.6	-
(D)	BALUCHISTAN												
1.	Hairdin Surface Drainage	0.087	0.074	72.925	93.043	-	-	195/109	-	-	-	195/109	-
	S.TOTAL:	0.087	0.074	72.925	93.043	-	-	195/109	-	-	-	195/109	-
	TOTAL (A+B+C+D)	15.493	13.395	15426.760	6451.130	12868 (1700)	2134	NA/7237.1	4653	10948 (1183)	1465	NA/3982.3	165.5

DW = Dug Well FGW = Fresh Groundwater SGW = Saline Groundwater. P = Pilot

1/ G.A of 0.096 MA and CCA of 0.090 MA have been taken in total as remaining lies in SCARP I.

2/ Number of replacement tubewells have not been added in totals.

3/ Areas of these project have not been included in total as the same are located within Larkana-Shikarpur project.

4/ Area not included in total as the trunk and main drains do not provide drainage relief to any area.

Table B.1(c) (Contd)

Table B.2

PAKISTAN

SCARP Tubewell Performance

Trends in Annual Groundwater Pumpage for Selected SCARPs

Project	Designed Pumping Capacity (MAF)	Initial Pumpage (MAF)	Reference Year: Year	Reference Year: Index	Relative Pumpage (as % of Initial) in Years Following Reference Years: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average % Decrease Per Year	% Capacity Utilization 1/ (1978-79)
SCARP I	4.36	2.509	1963-64	100	97	99	67	74	78	78	77	74	65	58	55	63	51	55	54		33
			Year (FY)2/		(65)	(66)	(67)	(68)	(69)	(70)	(71)	(72)	(73)	(74)	(75)	(76)	(77)	(78)	(79)		-
SCARP II	6.01		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		34
Lalian	-	0.26	1964-65	100	122	76	60	62	57	58	51	48	39	57	53	44	37	44	46		
			Year (FY)		(66)	(67)	(68)	(69)	(70)	(71)	(72)	(73)	(74)	(75)	(76)	(77)	(78)	(79)	(80)		
Khadir	-	0.265	1968-69	100	93	105	71	70	55	133	77	75	77	62	65	-	-	-	-		
			Year (FY)		(70)	(710	(72)	(73)	(74)	(75)	(76)	(77)	(78)	(79)	(80)	-	-	-	-		
Mona	-	0.175	1968-69	100	117	119	119	67	66	80	66	69	70	64	65	-	-	-	-		
			Year (FY)		(70)	(71)	(72)	(73)	(74)	(75)	(76)	(77)	(78)	(79)	(80)	-	-	-	-		
Sub-project II-A	-	1.066	1970-71	100	87	90	91	98	78	74	56	67	77	-	-	-	-	-	-		
			Year (FY)		(72)	(73)	(74)	(75)	(76)	(77)	(78)	(79)	(80)	-	-	-	-	-	-		
Sub-project II-B	-	0.661	1973-74	100	150	151	-	-	-	-	-	-	-	-	-	-	-	-	-		
			Year (FY)		(75)	(76)	-	-	-	-	-	-	-	-	-	-	-	-	-		
SCARP III	4.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		26
Alipur Unit	-	0.615	1971-72	100	98	71	114	79	43	67	71	64	-	-	-	-	-	-	-		
			Year (FY9		(73)	(74)	(75)	(76)	(77)	(78)	(79)	(80)	-	-	-	-	-	-	-		
Kot Adu Unit	-	0.791	1974-75	100	67	56	73	73	74	-	-	-	-	-	-	-	-	-	-		
			Year (FY)		(76)	(77)	(78)	(79)	(80)	-	-	-	-	-	-	-	-	-	-		
Kangpur Unit	-	0.464	1973-74	100	161	91	96	119	100	100	-	-	-	-	-	-	-	-	-		
			Year (FY)		(75)	(76)	(77)	(78)	(79)	(80)	-	-	-	-	-	-	-	-	-		
SCARP IV	2.68	0.533	1970-71	100	113	132	180	180	179	163	153	155	156	-	-	-	-	-	-		29
			Year (FY)		(72)	(73)	(74)	(75)	(76)	(77)	(78)	(79)	(80)	-	-	-	-	-	-		
SCARP Khairpur	3.65	0.365	1968-69	100	90	133	143	124	126	73	99	98	119	37	36	24	-	-	-		38
			Year (FY)		(70)	(71)	(72)	(73)	(74)	(75)	(76)	(77)	(78)	(79)	(80)	(81)	-	-	-		
SCARP Rohri	2.95	0.625	1973-74	100	87	90	115	92	118	112	158	-	-	-	-	-	-	-	-		23
			Year (FY)		(75)	(76)	(77)	(78)	(79)	(80)	(81)	-	-	-	-	-	-	-	-		

Source: WAPDA (RAP report and CMO for more recent data--FY77 onwards).

1/ Capacity utilization rates refer to the actual pumpage as % of designed pumping capacity for the year 1978-79. Background tables for the recently approved Structural Adjustment Loan showed the following overall capacity utilization rates for the SCARP Tubewells (1978-79): (a) fresh groundwater zone: 30%; (b) saline groundwater zone 39%.

Table B.3(a)

Pumping Capacities and Their Deterioration for Selected SCARP Projects 1/

Project	Initial Value (CFS)	Reference Value Year	Reference Value Index	Relative Value in Years Following Reference Years 2/: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Pumpage Capacity Reduction Since Acceptance 3/ (% in 1975-76)	Average Reduction/Year (% p.a. up to 1976-75)	Main Reasons for Deterioration (In Descending Order of Importance 4/
SCARP I	6343	1962-63	100	-	-	-	-	-	-	67	62	62	61	61	52	52	-	67	72	72	72	47.9	3.7	Pump breakdowns
SCARP II	8463	-	-	-	-	-	-	-	-	-	-	-	-	-	-	93	-	90	90	-	86			
Lalian	676	1962-63	100	-	-	-	-	-	-	86	84	-	78	75	72	69	-	-	-	-	-	30.7	2.4	Pump defects; well deterioration; decline in watertable
Khadir	981	1966-67	100	-	-	83	76	-	71	71	68	65	-	-	-	-	-	-	-	-	-	35.1	2.7	Pump defect; watertable
Mona	456	1965-66	100	-	-	-	90	88	81	79	76	73	71	-	-	-	-	-	-	-	-	29.3	2.2	
Sub-project II-A	4433	1966-68	100	-	84	81	78	74	71	65	65	-	-	-	-	-	-	-	-	-	-	34.6	2.7	Pump defects; decline in watertable; well deterioration
Sub-project II-B	3970	1970-72	100	-	94	93	88	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11.6	1.0	
SCARP III	23[illegible]	1972	100	-	-	-	-	-	-	90	-	85	73	73	65	-	-	-	-	-	-	-	-	Poor pump maintenance; decline in watertable; reduction in specific capacity
Alipur Unit	-	1972	100	-	-	86	81	80	74	-	-	-	-	-	-	-	-	-	-	-	-	25.6	2.0	
Kot Adu Unit	2391	1972	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.3	1.1	
Rangpur Unit	2411	1972	100	-	-	-	-	92	75	77	-	-	-	-	-	-	-	-	-	-	-	23.0	1.8	
SCARP IV	4492	1972	100	-	85	79	75	73	-	-	85	85	89	-	-	-	-	-	-	-	-	26.4	2.1	Deterioration of well screens; decline in watertable; pump problem
Khairpur SCARP	1693	1967	100	-	-	-	-	-	-	-	-	74	72	84	82	93	-	-	-	-	-	26.3	2.0	
SCARP N-Rohri	2427	1972	100	-	-	-	90	60	100	93	87	85	-	-	-	-	-	-	-	-	-	11.9	N.A.	Heavy discharge of sand; screen failures.

Sources: Review of Completed of Completed Salinity Control and Reclamation Project, Appendices Vol.II, Sep. 1978 (for data up to 1974-75).

1/ WAPDA, CMD (for data from 1975-76 - 1980-81); this source was also used for establishing the initial discharge capacity for the indicated SCARPs.

2/ Actual pumping capacity as a percentage of initial pumping capacity is shown for the years 1975-76 - 1980-81; initial capacity is assumed to approximate

3/ Data was provided by WAPDA's Groundwater and Drainage Section.

4/ Data/information taken from WAPDA, "Review of Completed SCARP Projects;" Refers to reduction in pumpage capacity as a percent of initial value of pumpage; therefore, the figure may not necessarily equal the figures corresponding to the source provided under footnote 3.

PAKISTAN

Performance of SCARP Tubewells

Median Specific Capacities and Their Reduction by 1975-76

	No. of Tubewells				Operation Period (Yrs)	Median Specific Capacity		Percentage Reduction	
	M.S.	Brass	Fibreglass	S/S		Original	1975-76	Total	Pe Yea
SCARP I	1584	407	-	-	13	97	49	49	3.
SCARP II									
Laman	163	-	-	-	13	90	55	39	3.
Mana	137	-	-	-	11	87	64	26	2.
Kadir	56	-	157	-	9	91	76	15	1.
	-	-	249)	-	-	-	-	-	-
SCARP II-a	96	-	239)	-	9	109	70	39	4.
	34	-	215)	-	-	-	-	-	-
	-	-	51)	-	-	-	-	-	-
SCARP III									
Alipur	-	-	542	-	4	100	68	32	8.
Kot Adu Unit	-	-	523	-	3	91	82	9	3.
Rangpur	-	-	570	-	4	95	75	20	5.
SCARP IV	-	-	935	-	4	110	63	47	12.
SCARP Khairpur	-	-	420	120	9	68	43.4	37	-
SCARP									
Rehu	-	-	566	-	3	93	84	9	-
Larkana TW/Pilot Project	-	-	35	-	4	80	80	0	-
Sukkur TW/Pilot Project	-	-	18	-	4	48	46	2	-
Shikar TW/Pilot Project	-	-	50	-	5	88	90	2	-

* (gpm/ft)

Source: WAPDA, CMO, "Review of Completed SCARP Projects", 1978

Table B.3(c)

PAKISTAN

SCARP Per Tubewell Performance

Deterioration in Discharge Capacity of Tubewells (In 1981)

Percentage of Deterioration	SCARP I	SCARP II	SCARP III	SCARP IV	SCARP V
No. of Tubewells	2069	2205	1635	985	172
Percent of Acceptance Test Value	Percent of Total Number				
Up to 90%	8	6	5	7	47
89% to 75%	17	34	40	21	22
74% to 50%	31	35	33	23	22
49% to 30%	24	15	14	22	7
29% to 0%	20	10	8	27	2

Source: WAPDA, Central Monitoring Organization.

WATERLOGGED AREAS (1000 x Acres) in SCARPS

Year	Month	Depth	SCARP-I	SCARP-II Units: Mona	Khadir	Lalian	II-A b/	Kot Momin, Shah Jewana and Ara	SCARP-II Total	SCARP-III Units: Alipur	Kot Adu	Rangpur	SCARP-III Total	SCARP-IV	SCARP Khairpur	SCARP North Rohri
1975	JUN	0-5'	12	8.4	-	-	2.2	3.3	13.9	-	55.3	15.7	71.0	5.6	N.A.	N.A.
		5-10'	190	71.8	14.4	6.0	322.5	97.6	612.3	57.6	120.4	41.2	219.2	17.9	N.A.	N.A.
	OCT	0-5'	43	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	23.7	151.5	47.1	222.3	8.9	N.A.	N.A.
		5-10'	270	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	226.6	163.4	169.3	599.3	61.9	N.A.	N.A.
1976	JUN	0-5'	31	20.2	-	-	73.6	30.0	123.8	30.0	71.4	22.4	123.8	0.6	197.1	15.9
		5-10'	251	63.0	23.8	22.4	447.7	181.6	738.5	170.2	181.6	118.2	470.0	36.8	202.9	348.9
	OCT	0-5'	168	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	101.1	197.0	71.9	370.0	15.0	N.A.	N.A.
		0-10'	542	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	267.0	143.8	178.0	588.8	181.9	N.A.	N.A.
1977	JUN	0-5'	27	23.0	-	-	99.8	27.2	150.0	20.9	92.0	22.7	135.6	1.7	110.2	Nil
		5-10'	370	60.8	24.6	23.8	395.5	179.5	684.2	233.0	218.0	145.0	596.0	50.2	273.4	436.0
	OCT	0-5'	63	41.0	-	1.0	248.0	47.9	337.9	182.8	248.8	55.0	485.8	12.8	230.0	
		5-10'	452	50.0	28.0	20.9	365.0	163.0	576.9	201.0	101.1	132.8	434.9	149.0	441.0	
1978	JUN	0-5'	15	13.9	2.2	-	111.7	18.0	145.8	71.1	128.1	18.8	218.0	Nil	83.0	5.0
		5-10'	316	67.7	32.4	24.7	359.0	153.6	637.4	219.1	210.0	139.9	641.0	38.5	332.0	237.0
	OCT	0-5'	162	39.0	10.0	-	274.0	60.7	383.7	193.1	224.0	73.0	490.0	17.3	129.0	14.0
		5-10'	452	51.0	18.0	43.9	371.9	173.1	657.0	193.9	126.0	134.7	454.6	139.5	262.0	334.0
1979	JUN	0-5'	39	42.0	7.9	3.9	149.0	41.8	244.6	90.0	183.0	44.0	317.0	0.6	81.1	6.3
		5-10'	456	48.9	39.9	42.0	415.7	198.9	745.4	291.9	166.9	119.0	577.8	65.9	331.2	301.0
	OCT	0-5'	94	43.0	6.9	4.9	256.0	60.9	371.7	86.1	222.9	84.8	393.8	3.9	88.0	6.0
		5-10'	426	55.0	22.9	33.0	351.0	175.1	637.0	297.8	127.0	115.9	540.7	91.5	300.0	200.0
1980	JUN	0-5'	14	N.A.	NA.	N.A.	N.A.	N.A.	108.0	N.A.	N.A.	NA.	261.0	4.0	68.8	2.4
		5-10'	323						680.0				616.0	29.0	323.1	279.1
	OCT	0-5'	168						369.0				371.0	11.0	100.0	4.0
		5-10'	547			-do-			643.0		-do-		542.0	126.0	274.0	216.0
1981	JUN	0-5'	49						113.0				294.0	1.0	134.0	7.0
		5-10'	549						750.0				602.0	54.0	280.0	347.0

N.A. = Not Available. Source:- CMO, WAPDA, Lahore.

Table B. (a)

Table B.4(b)

WATERLOGGEDAREA (NON SCARPS)
1000 x ACRES

Years	Months	Ranges (ft)	Non-SCARP Area 1000x Acre	Rechna Doab	Chaj Doab	Thal Doab	Bari Doab	Bahawal pur Area	D. G. Khan	SIND	NWFP
				DISTRIBUTION OF NON-SCARP AREA 1000 ACRES							
1976	June	0-5'	1988	288	235	376	65	431	166	331	96
		5'-10'	5961	1149	349	970	622	1385	272	1094	120
	Oct.	0-5'	N.A.	1214	N.A.	521	407	934	320	N.A.	N.A.
		5'-10'	N.A.	986	N.A.	992	891	1867	239	N.A.	N.A.
1977	June	0-5'	2734	207	191	465	121	813	259	599	79
		5'-10'	7036	1301	323	826	783	1784	283	1438	298
	Oct.	0-5'	11291	702	298	508	295	1016	372	7927	173
		5'-10'	8771	1175	282	893	1022	2106	221	2830	242
1978	June	0-5'	4348	226	146	408	74	579	281	2561	73
		5'-10'	13725	1444	436	1014	688	2114	283	7434	310
	Oct.	0-5'	12209	1142	363	779	339	1160	391	7869	166
		5'-10'	9068	1286	257	738	1008	1827	247	3350	355
1979	June	0-5'	5433	276	316	674	124	683	336	2952	72
		5'-10'	13359	1608	305	932	724	1975	245	7245	325
	Oct.	0-5'	11167	752	392	644	227	1081	393	7578	100
		5'-10'	9420	1438	244	1025	908	1976	223	3241	365
1980	June	0-5'	4739	138	163	576	88	505	343	2872	54
		5'-10'	13682	1202	445	895	645	2253	233	7699	310
	Oct.	0-5'	10940	727	343	623	282	977	395	7469	124
		5'-10'	9183	1412	285	965	854	2023	234	3070	340
1981	June	0-5'	4541	237	150	517	98	564	342	2526	107
		5'-10'	14511	1642	432	914	619	2149	243	8161	351

N.A. = Not Available.

Source:- Drainage Section, Planning Division, WAPDA.

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Status of Waterlogging in SCARP Areas and INDUS Basin

(October 1980 data on Area Waterlogged as Percent of Gross Area)

PROVINCE	SCARP AREA[1/]		INDUS BASIN	
	0-5'	0-10'	0-5'	0-10'
1) NWFP	27	68	10	38
2) Punjab	26	65	17	48
3) Sind	19	54	52	77
Pakistan	24	63	30	58

1/ Based on a gross area of 7.6 million acres, of which 1.85M are in the 0-5' range, and 2.97M are in the 5-10' range.
Source: WAPDA, Depth to Water Table Map, October 1980.

Province-Wise Distribution

Province	Area Within 5 Feet Water-table Depth (Million Acres)	%
1) NWFP	.1	.1
2) Punjab	3.7	31.7
3) Sind/Baluchistan	8.0	68.2
Total	11.8	100.0

"Disastrous Area" (Area Within 5ft Water Depth)
October 1981

SCARP and Non-SCARP Distribution

	(Million Acres)	%
1. SCARP	4.3	36
2. Non-SCARP	7.5	64
Total	11.8	100

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Table B.5(a)

Table B.5(b)

Percentage Area Under Various Depths To Watertable For Selected SCARPs During Various Years

Project	Gross Area (N.A.)	Year Year	Percentage under various depths to Watertable 0-5'	5-10'	-10'	Average depth (feet)
SCARP I	1.22	1961	13.5	61.2	25.3	8.2
		1971	-	8.1	91.9	16.7
		1977	2.2	30.4	67.4	12.5
		1981(Apr)	4.0	45.1	50.9	
SCARP II		1981(Oct)	9.4	44.0	46.6	N.A.
Mona	0.112	1965	34.3	53.1	11.8	8.8
		1971	0.9	36.1	51.8	11.8
		1977	20.0	56.3	23.8	8.1
		1980	20.0	58.2	21.8	-
Hadir	0.17	1966	-	8.6	91.4	15.2
		1971	-	2.5	97.5	19.0
		1977	-	14.5	85.5	14.8
		1980	0.6	10.6	88.8	-
	0.745	1968	14.9	57.5	27.6	8.5
		1971	1.1	34.4	64.5	12.4
		1977	13.4	53.1	33.5	9.0
Nomin	0.14	1970	14.7	60.2	25.1	8.4
		1974	1.5	51.8	46.7	10.3
		1977	19.3	55.0	24.9	7.9
Jewana	0.346	1972	0.7	45.0	54.3	10.4
		1975	-	13.4	86.6	13.1
		1977	2.2	29.1	68.7	12.0
SCARP III	1.07	1969	41.2	42.5	16.3	6.33
		1975	6.2	19.2	74.6	11.95
		1977	12.0	52.4	35.6	9.06
		1981	25.8	52.9	21.3	-
SCARP IV	0.56	1969	0.2	21.7	78.1	11.7
		1974	-	7.2	92.8	15.6
		1977	0.5	8.9	90.6	14.8
		1981	0.2	9.7	90.1	-
SCARP Khairpur	0.441	1960	29.7	70.3	-	5.5
		4/77	25.0	62.0	13.0	6.9
		1981 (Oct)	36.0	5.8	6.0	
SCARP Rohri(N)	0.790	4/66	11.0	22.0	67.0	11.0
		4/77	0.0	55.0	45.0	10.5
		1981(Oct)	3.3	34.0	37.3	

Source: WAPDA, Review of Completed SCARPs.

Table B.6(a)

PROVINCE-WISE SUMMARY OF SURFACE AND SOIL SALINITY

Province	Survey period	Total Acreage	Surface Salinity: Salt Free S 1	Salinity Saline S 2	Moderately Saline S 3	Strongly Saline S 4	Misc. Land Type
N.W.F.P.	1977-79	1517214	1186202	124005	32666	23622	150719
		%	78	8	2	2	10
Punjab	1977-79	25117363	21058757	3920067	1073306	739570	489209
		%	84	7	4	3	2
Sind	1977-79	13785975	6906687	2566649	1428963	2468954	414722
		%	50	19	10	18	3
Baluchistan	1977-79	873291	646636	149554	39033	34654	3414
		%	74	17	5	4	-
Total	1977-79	41293843	29798282	4596729	2573968	3266800	1058064
		%	72	11	6	8	3

Province	Total Profiles (M.A.)	Soil Salinity (72" Soil Profile): Non.Saline Non. Sodic	Saline Non. Sodic	Saline Sodic	Non.Saline Sodic
Punjab	39963	29334 (73%)	2803 (79%)	5757 (14%)	1813 (5%)
Sind	20543	7918 (38%)	3430 (17%)	8677 (42%)	373 (2%)
N.W.F.P.	1958	1553 (79%)	216 (11%)	138 (7%)	28 (2%)
Baluchistan	1402	497 (35%)	365 (26%)	528 (38%)	12 (1%)
Total	63866	39302 (61%)	6814 (11%)	15100 (24%)	2226 (3%)

Source: WAPDA, 1981, Soil Salinity Survey, (41 MA), Survey and Research Organization, (Data based on 1977-79 Survey) Tables I and II.

SCARP PROJECT PERFORMANCE

Surface Salinity and Profile Salinity Indicators for Selected SCARPs and Years

SCARP Project	Year	Surface Salinity: Non-Saline (S_1)	Slightly Saline (S_2)	Moderately Saline (S_3)	Strongly Saline (S_4)	Misc.	Soil Salinity: Year	No of Bores	Non-Saline Non-Sodic	Saline	Saline Sodic	Now Saline Sodic	Missing Data
1. SCARP I													
	1955-65	64	14	6	14	2	1952-63	1,929	34	5	41	13	7
	1977	86	4	5	3	2	1977	2,042	70	3	16	9	2
2. SCARP II													
Lalian Unit	1955-65	72.0	20.7	3.8	.7	2.8	1962-63	989	65.7	10.3	17.0	7.0	-
	1977	84.0	11.1	1.4	.4	3.1	1977	984	84.2	4.5	7.3	3.6	.4
3. SCARP III													
	1955-65	55	26	8	10	1	1962-63	1,905	49	6	7	38	-
	1977	74	4	16	4	2	1977	1,919	69	6	16	6	3
4. SCARP IV													
Mangtanwala Unit	1964-65	42	41	2	14	1	1962-63	293	39	4	39	18	-
	1977	84	2	1	11	1	1977	293	66	1	20	13	-
5. SCARP Khairpur													
	1953-54	N.A.	N.A.	-----28-------			----------	----------	----------	N.A.	----------	----------	----------
	1977	N.A.	N.A.	-----28-------			----------	----------	----------	N.A.	----------	----------	----------

Source: WAPDA, "Review of Completed SCARP Projects."

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Table B.6(b)

PERFORMANCE INDICES (a) - SCARP I (b)

Crop/other	Cropping Pattern Base Year 59-60 (1000 acres)	76-77	77-78	78-79	79-80	80-81	Crop Yield Base Year 59-60 (Maunds per acre)	76-77	77-78	78-79	79-80	80-81
Cropped Area												
Kharif												
Sugarcane	63.7	84.5	83.6	59.6	57.3	84.5	26.4 (Gur)	41.25	41.74	38.86	43.00	48.07
Cotton	70.4	40.0	44.2	30.7	47.2	20.8	5.2	5.24	7.19	5.60	6.77	9.3
Maize	49.4	59.5	64.5	75.0	69.5	82.6	8.9	15.43	16.19	14.10	14.56	14.2
Rice	90.2	183.3	181.1	262.3	251.8	230.1	10.0	19.10	23.0	24.90	21.43	21.5
Millets	31.9	37.0	38.9	32.0	33.2	33.2	5.0	7.16	7.20	7.20	7.15	7.6
Fodder	53.1	94.1	108.5	98.8	113.4	106.6	-	-	-	-	-	-
Vegetable & Orchards	3.4	17.5	20.4	25.8	22.7	20.5	-	-	-	-	-	-
Other	[illegible].3	48.1	32.7	32.8	11.5	19.1	-	-	-	-	-	-
Sub-total:	435.4	567.0	575.0	619.0	611.2	597.4	-					
Rabi												
Wheat	251.8	471.2	466.8	494.4	504.6	488.8	8.7	19.20	15.76	18.80	22.48	22.60
Barley	2.1	1.9	4.1	8.0	5.3	4.4	6.2	10.56	9.52	10.10	9.72	10.0
Grams	5.8	11.3	14.6	23.1	11.7	10.8	6.0	8.22	8.70	7.00	8.68	9.2
Oilseeds	8.9	23.0	27.6	27.3	27.6	22.3	4.9	6.88	7.06	7.20	7.67	8.3
Fodder	117.4	156.7	165.6	151.1	157.0	167.9	-	-	-	-	-	-
Vegetable & Orchards	9.4	12.9	16.1	18.3	18.2	20.8	-	-	-	-	-	-
Other	19.3	21.6	20.7	4.2	3.4	0.2	-	-	-	-	-	-
Sub-total:	414.7	698.6	715.5	726.4	727.8	715.2	-					
Total:	850.1	1265.6	1290.5	1345.4	1339.0	1312.6	-					

(a) From WAPDA (Planning)
(b) Gross Area is 1.22 million acres

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PERFORMANCE INDICES (a) - SCARP I (b)

Percent of affected area reclaimed (c)

Reclamation Progress by(%)	Jaran-Wala	Beran-Wala	Harse-Sheikh	Hafiz-abad	Pindi Bha-ttian	Shad man	Chicho-ki mallian	Zafar-Wal	Khanqa Dogran	Chauhar Rana	Shah Kot	Sangla Hill	Total
1976/77	91.1	59.0	96.0	80.4	93.0	83.1	97.1	79.3	93.7	92.3	71.6		82.01
1977/78	91.3	59.0	96.1	80.4	93.0	73.6	97.1	71.0	88.9	90.0	66.8		75.96
1978/79)													73.75
1979/80)	BY SCHEME DATA NOT AVAILABLE												73.73
1980/81)													

Cropping Intensity Base Yr	59-60	74-75	75-76	76-77	77-78	78-79	79-80	80-81
Kharif	38.2	48.8	48.8	49.70	50.48	54.33	53.58	52.42
Rabi	41.9	65.9	67.9	68.65	70.05	68.90	68.83	62.66
Total:	80.1	114.7	116.7	118.35	120.53	123.23	122.41	115.08

Percentage area under	1961	1971	1977	1978	1979	1980	1981
LT 5 feet	13.5%	-	2.2	1.2	3.2	1.2	4.0
5-10 feet	61.2%	8.1	30.4	26.0	37.5	26.5	45.1
GT 10 feet	25.3%	91.9	67.4	72.8	59.3	72.3	50.9

(a) From WAPDA (Planning)
(b) Gross Area is 1.22 million acres.
(c) Meaning of "reclaimed" not defined.

Source:- CMO, WAPDA, Lahore.

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PERFORMANCE INDICES - SCARP II

Base year for Units Base year: Principals Crops	Phalia, Sohawa, Busal 1966-67 Ac/	 Yd/	Mona 1965-66 A	 Y	Lower Hujjan 1967-68 A	 Y	Khadir 1968-69 A	 Y
1	2	3	4	5	6	7	8	9
Sugar Cane	37.1	475	3.7	403	1.2	360	6.4	360
Cotton	28.2	6.5	15.7	4.2	4.8	6	25.2	6
Rice	54.1	16	2.9	14	0.9	11.8	1.5	11.8
Maize	27.2	12	3.1	12	1.4	12.5	7.9	12.5
Millets	44.9	6	-	-	2.7	7.0	10.6	7
Kharif Fodder	42.5	290	17.7	300	1.4	260	4.6	250
Wheat and Barley	146.3	16	28.3	15.6	8.3	16	38.2	16
Oil seeds	15.7	5.5	1.5	6	0.3	6.9	1.5	6
Rabi Fodder	80.9	286	15.4	350	3.6	310	13.2	300
TOTAL AREA	524.3	-	100	-	27.6	-	119.3	-
1976-77 Principal Crops								
Sugar Cane	52.3	422	8.1	370	2.5	454	9.1	413
Cotton	18.4	4	11.3	5.7	1.3	3	17.3	5.8
Rice	77.5	23.8	6.5	23.1	3.0	22.1	7.6	21
Maize	25.5	12.3	2.9	16.7	2.2	14	-	17
Millets	33.7	9	-	-	-	7.5	8.4	7.5
Kharif Fodder	62.8	-	18.3	-	2.6	-	15.7	-
Wheat & Barley	211.1	24.2	36.1	23.5	11.1	24.7	51.4	24.1
Oilseeds	6.9	8	1.4	5.7	0.3	7	0.9	7.3
Rabi Fodder	110.6	-	17.2	-	4.3	-	1.7	-
TOTAL AREA	598.8	-	101.8	-	27.3	-	112.1	-
1977-78 Principal Crops								
Sugarcane	69.5	430	8.1	401.5	2.6	440	8.7	405
Cotton	14.8	4.4	9.0	6.4	1.3	3.0	15.2	6.3
Rice	105.2	27	8.0	27.0	3.1	26.4	9.2	25.3
Maize	16.5	12.5	3.1	17.0	2.3	14.0	-	17.3
Millets	46.4	11.3	-	-	-	9.0	7.3	7.5
Kharif Fodder	43.8	-	18.3	-	2.7	-	6.4	-

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Table B.7

Contd. P/2.

1	2	3	4	5	6	7	8	9
Wheat & Barley	232.8	20.4	35.8	26.5	9.3	22.7	48.9	21.4
Oilseeds	9.4	8.0	1.6	6.0	0.2	7.5	0.6	6.1
Rabi Fodder	81.8	-	17.3	-	6.0	-	13.5	-
TOTAL AREA	620.2	-	101.2	-	27.5	-	109.8	-
1978-79 Principal Crops								
Sugarcane	45.3	395	7.0	405	1.9	420	5.5	392.4
Cotton	14.6	4	8.3	6	1.1	3.0	13.9	6.0
Rice	129.8	27.7	8.8	27.5	3.3	26.6	9.6	25.8
Maize	17.9	14.5	3.0	15.0	2.0	14.5	-	15.7
Millets	54.3	9.2	-	-	-	9.0	8.2	7.0
Kharif Fodder	7.2	380	18.3	395	2.9	380	7.4	400.0
Wheat & Barley	252.9	20.8	37.7	28.9	10.8	23	50.7	21.5
Oilseeds	12.2	6.8	2.6	6.5	0.2	6.8	0.9	6.0
Rabi Fodder	75.3	410	15.2	400	5.1	425	15.6	445.0
TOTAL AREA	609.5	-	100.9	-	27.3	-	111.8	-
1979-80 Principal Crops								
Sugarcane	37.9	367.0	5.3	-	1.6	421.0	5.1	390.0
Cotton	14.9	5.3	8.7	6.5	1.6	4.5	16.8	6.0
Rice	147.2	25.4	11.3	24.2	3.3	22.0	12.4	25.0
Maize	17.6	14.0	2.4	15.0	2.2	14.8	-	14.8
Millets	72.7	9.0	-	-	-	7.0	7.5	7.0
Kharif Fodder	21.6	-	13.2	-	2.6	-	6.4	-
Wheat & Barley	264.4	19.6	37.6	28.2	11.1	23.5	56.0	21.0
Oilseeds	11.6	8.0	2.4	7.0	0.3	7.5	0.7	6.8
Rabi Fodder	77.0	-	14.3	-	3.9	-	12.5	-
TOTAL AREA	664.9	-	95.2	-	26.6	-	117.4	-

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Table B.7

Contd..P/3

1	2	3	4	5	6	7	8	9
1980-81 Principal Crops								
Sugercane	60.1	381.0	5.9	424.0	2.0	457.4	8.6	447.3
Cotton	12.8	6.5	7.0	6.6	0.9	6.0	10.6	6.6
Rice	114.6	25.0	9.9	25.2	3.5	21.3	9.7	23.5
Maize	16.0	14.8	2.4	15.2	3.0	15.2	14.2	4.2
Millets	41.0	8.8	3.3	8.1	2.3	8.1	7.0	7.1
Kharif Fodder	50.6	380.0	14.3	400.0	3.2	425.0	7.2	390.0
Wheat & Barley	41.8	20.3	38.0	27.4	12.7	23.5	54.9	21.0
Oilseeds	2.2	8.1	2.1	-	0.3	7.6	0.6	7.9
Rabi Fodder	12.1	425.0	14.4	7.6	3.7	405.0	18.3	387.0
TOTAL AREA	351.2	-	97.3	-	31.6	-	131.1	-

Source: - CMO, WAPDA, Lahore.

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Table B.7

Contd..P/4

Table B.7

Cropping Intensity	Phalia, Sohawa and Busal	Mona	Lower Hajjan	Khadir
Base Year	93	102	87	80
1976-77	115.8	125.7	107.2	90.9
1977-78	121.4	129.9	110.9	88.3
1978-79	121.4	127.7	108.9	86.8
1979-80	126.2	127.5	114.2	91.7
1980-81	124.5	127.1	118.9	94.7
Percent Area with water table				
IN BASE YEAR				
LT 5 feet	14.9	34.3	Same as	-
5-10 feet	57.5	53.1	above	8.6
GT 10 feet	27.6	11.6	--do--	91.4
IN 1978				
LT 5 feet	15.0	12.7		1.3
5 - 10 feet	48.2	61.6		19.1
GT 10 feet	36.8	27.7		79.6
IN 1979				
LT 5 feet	20.0	38.2		4.7
5 - 10 feet	55.8	44.5		23.5
GT 10 feet	24.2	17.3		71.8
IN 1980				
LT 5 feet	9.5	20.0		0.6
5 - 10 feet	55.2	58.2		10.6
GT 10 feet	35.3	21.8		88.8

Source: CMO, WAPDA, Lahore.

Contd..P/5

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Table B.7

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PERFORMANCE INDICES

SCARP III

SCARP - III

Principal Crop's Acreage (Thousand Acres)

Cropping Pattern	Base Year 1968-69	1976-77	1977-78	1978-79	1979-80	1980-81
Cotton	89.9	109.8	100.8	146.7	152.7	168.3
Rice	42.1	36.2	40.1	40.7	46.6	46.3
Maize	6.9	12.7	9.9	10.8	13.5	24.3
Millets	9.2	9.1	8.2	4.6	1.9	2.8
Sugarcane	14.4	33.8	38.1	30.2	24.8	36.3
Kharif Fodder	105.9	94.5	133.7	82.2	104.3	101.5
Wheat & Barley	325.5	373.6	375.5	411.0	411.9	435.6
Barley	-	7.0	9.6	8.6	8.6	2.4
Pulses	12.9	6.0	5.8	7.0	3.4	2.7
Oilseeds	3.6	7.6	7.8	3.6	3.9	4.9
Rabi Fodder	37.4	59.5	62.9	69.5	41.6	69.6
Total Area:	750.2	749.8	792.4	814.9	813.2	894.7
Cropping Intensity (%)						
Kharif	33.6	42.8	42.5	45.1	46.6	50.2
Rabi	45.9	56.1	56.2	61.0	60.8	62.3
Total:	79.5	98.9	98.7	106.1	107.4	112.5

Crop Yields (Maunds Per Acre)

Cropping Pattern	Base Year 1968-69	1976-77	1977-78	1978-79	1979-80	1980-81
Cotton	7.5	9.5	9.7	6.0	9.8	12.5
Rice	12.5	15.9	18.5	22.0	23.5	22.1
Maize	12.0	16.0	16.5	14.1	14.3	14.8
Millets	6.5	7.5	7.6	7.1	7.7	8.4
Sugarcane	320	365.0	365.0	341.0	352.0	406.6
Kharif Fodder	-	-	-	-	-	290.0
Wheat & Barley	12.5	16.5	15.9	17.3	18.5	19.0
Barley	8.0	7.7	7.7	10.0	10.2	10.0
Pulses	6.0	7.5	7.6	8.0	7.9	7.0
Oilseeds	4.0	5.8	6.0	6.0	7.5	7.0
Rabi Fodder	-	-	-	-	-	38.0

Percent Area with Water Table

	1969	1978	1979	1980	1981
LT 5 feet	41.2	19.2	27.9	22.9	25.8
5-10 feet	42.5	56.3	50.8	54.1	52.9
GT 10 feet	16.3	24.5	21.3	23.0	21.3

Source: CMO, WAPDA, Lahore.

Contd..P/6

PERFORMANCE INDICES

SCARP IV

Cropping Pattern	Principal Crop's Acreage Base Year 1968-69	1976-77	1977-78	1978-79	1979-80	1980-81	Crop Yields Base Year 1968-69	1976-77	1977-78	1978-79	1979-80	1980-81
	Thousand Acres						Maunds Per Acre					
Cotton	7.4	2.29	4.42	4.24	1.11	4.0	6.5	5.58	5.00	4.30	5.00	8.0
Rice	134.2	191.52	187.53	202.06	209.01	209.9	14.4	14.96	22.90	24.00	21.40	21.5
Maize	4.6	13.68	13.71	14.32	16.91	20.7	13.3	13.11	11.00	11.00	13.60	14.3
Millets	0.9	0.98	1.65	1.39	16.36	1.6	5.8	6.27	8.50	7.50	6.60	7.3
Sugarcane	4.1	9.10	8.88	4.37	3.05	7.4	419	373.00	377.00	395.00	431.00	494.6
Kharif Fodder	23.0	31.25	32.69	30.59	21.37	39.0	-	-	-	-	-	-
Wheat and Barley	104.4	144.53	145.73	150.32	164.19	161.1	12.2	16.58	15.50	16.60	19.00	20.5
Barley	-	5.30	5.30	6.36	5.51	1.2	8.2	10.56	9.52	10.10	9.72	-
Pulses	-	-	-	-	-	1.7	-	-	-	-	-	-
Oilseeds	0.7	2.50	2.80	3.44	3.04	3.8	4.8	7.50	6.00	6.00	8.30	8.9
Rabi Fodder	50.1	54.45	60.38	69.43	68.02	71.1	-	6.35	7.00	6.70	7.50	7.6
Total Area:	344.8	455.60	463.09	486.52	508.57	521.5						

Cropping Intensity (%)	
Kharif	33.9
Rabi	30.1
Total:	63.4

Percent Area with Water Table	1969	1978	1979	1980	1981
LT 5 feet	0.2	Nil	0.1	0.7	0.2
5-10 feet	21.7	6.9	11.8	5.2	9.7
GT 10 feet	78.1	93.1	88.1	94.1	90.1

Source:- CMO, WAPDA, Lahore.

Table B.7

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Contd..P/7

Table B.8

SCARP-II: Lost Time Due to Various Component Failures, 1972-76
(Percent of Capacity)

Section	Year	Total utili-zation	Shutdown due to electrical nonavailability	Shutdown due to burnt motor	Transformer defect	Assorted other components failures[a]
Bhusal	1976	43.0	10.0	12.4	5.4	11.5
	1974	64.0	18.0	6.5	6.5	10.6
	1973	53.0	11.0	7.5	10.1	11.1
Sohawa	1976	44.0	10.0	15.9	10.6	12.8
	1975	51.0	22.0	5.7	11.9	17.2
Lower Hujjan	1976	33.0	11.0	5.9	--	18.9
	1975	50.0	5.0	5.9	3.2	7.7
	1974	45.0	13.0	1.0	8.8	7.0
	1973	21.0	22.0	--	--	--
	1972	30.0	36.0	--	--	--

* Source: SCARP-II Records

[a] Includes motor defect, starter defect, blown fuse, and cable problems.

Table B.9(a)

Non-Development Budget Allocations for the O&M of the Irrigation System According to Province and Major Category, 1980/81 - 1982/83 (Rs in Million)1/

Province and Category	1980/81	1981/82	%change	1982/83	%chance
1. Baluchistan					
- Establishment2/	{ 20	{ 27	+35	53{ 21	+96
- Canals				32	
- Tubewells3/	-	-	-	.5	-
Sub-total:	20	27	+35	53.5	+98
(Rehabilitation Project)	-	-	-	(10)	-
2. NWFP					
- Establishment	30	35	+17	35	0
- Canals	39	62	+59	57	- 8
- Tubewells	9	16	+78	24	+50
Sub-total:	78	113	+45	116	+2.6
(Rehabilitation Project)	-	-	-	(14)	-
3. Punjab					
- Establishment	245	229	- 6	259	+13
- Canals	87	126	+45	208	+65
- Tubewells	326	471	+44	484	+2.7
Sub-total:	658	826	+26	951	+15
(Federal grant)	-	(100)	-	-	-
(Rehabilitation Project)	-	-	-	(105)	-
4. Sind					
- Establishment	70	75	+ 7	147 4/	+96
- Canals	161	193	+20	164 4/	-15
- Tubewells	72	88	+22	95	+ 8
Sub-total:	303	356	+17	406	+14
(Federal grant)	-	(50)	-	-	-
(Rehabilitation Project)	-	-	-	(68)	-

1/ Based on data provided by GOProvinces. Irrigation Rehabilitation Project allocation is for civil works and represents an additional allocation as "deferred maintenance" The Federal grant was an additional contribution to the GOProvincial, NDB for Canal O&M expenses during FY82 (Punjab and Sind).

2/ Establishment costs refer to canals and drainage works.

3/ Includes the direct establishment costs (e.g. tubewell operators and other SCARP personnel); in FY83, about 80-90% of the total costs comprise power charges.

4/ These figures reflect a transfer of staff from contractual to permanent basis.

Table B.9(b)

PAKISTAN

Relative Importance of Public Tubewell O&M Allocations in Total Provincial Non-Development Budget 1/

	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83
1. P&D Allocations for Public TW O&M (Rs M)	129	127	194	278	408	575	603
2. P&D Allocations for O&M of Irrigation System (Rs M)	597	631	778	874	1,040	1,322	1,526
3. O&M for TWs as % of Total Irrigation O&M Allocations	22	20	25	32	39	43	40
4. NDB Expenditures (Rs)	5,432	7,035	7,227	8,225	9,066	10,315	11,911
5. TW O&M as % of NDB Expenditures	2.3	1.8	2.7	3.4	4.5	5.6	5.1
6. Total Provincial NDB Subsidies (Rs M)	472	704	569	993	1,024	1,167	940
7. TW O&M as % of Provincial Subsidies	27	18	34	28	40	49	64

1/ Figures on irrigation O&M allocations are based on Table 2.9(a); other figures were taken from World Bank, "Pakistan - Economic Developments and Prospects", February 1983, Table 5.03.

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Table B.10

WATER RECEIPTS AND IRRIGATION O&M EXPENDITURES
(Including for SCARPs)

	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78[a/]
			(Million Rupees)			
Water Receipts						
Punjab	234.6	267.5	256.0	294.6	314.9	321.6
Sind	60.5	96.0	68.9	62.5	55.0	70.0
NWFP	10.5	10.6	13.1	10.7	11.8	14.9
Baluchistan	2.9	3.1	3.1	3.1	3.2	4.0
Total:	308.5	377.2	341.1	370.9	384.9	410.5
O&M Expenditures						
Punjab	192.9	209.9	329.9	370.6	390.0	436.2
Sind	58.3	70.4	72.8	96.2	95.1	123.6
NWFP	12.4	15.6	10.1	28.5	29.4	36.1
Baluchistan	7.4	5.5	7.1	1.7	19.5	26.1
Total:	271.0	301.4	419.4	497.0	534.9	622.0
Surplus or Deficit:	37.5	75.8	- 78.3	- 126.1	- 150	- 211.5

Soruce: IBRD Development Issues and Policies Report (1978).

a/ Budget estimate.

PAKISTAN

Table B.11

Estimates of SCARP Tubewell O&M Expenditures and Revenues 1/
(Mid-1982 Currency)

(1)	Area Irrigated with SCARP Tubewells (M Acres) 2/	5.5
(1)	No. of Operating Tubewells (TWs)	10,275
(2)	O&M Expenditures (Rs M)	592
(3)	O&M Cost Per TW (Rs) 3/	57,600
(4)	Tubewell O&M Per Acre	108
(5)	Average Water Charge (Rs Per Acre) 4/	27
(6)	Water Charge Attributed to SCARP Tubewells (Rs per acre) 5/	24
(7)	Water Charge as % of Tubewell O&M Cost	22

1/ Estimates are based on figures used in connection with the Irrigation Systems Rehabilitation Project. Some of the assumptions were based on aggregate data; as further information is obtained, this table will be revised accordingly. Nonetheless, the figures provide an order of magnitude.

2/ Assumes, on average, one SCARP tubewell irrigates one watercouse (of 450 acres) with a cropping intensity of about 120%.

3/ Assumes a 30% capacity utilization rate and includes related establishment.

4/ Represents a weighted average of water charges for main crops.

5/ Assumes the water charge attributed to SCARP tubewells is double the abiana rate in Punjab and SIND Provinces.

Table B.12

PAKISTAN

Current and Estimated Revenues and O&M Expenditures (Rs M)

Item	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	(1992) 10/
I Expenditures												
O&M for Surface Irr System												
Base Cost 1/	704.0	794.0	882.0	972.	1,034.0	1,038.0	1,041.0	1,041.0	1,041.0	1,041.0	1,041.0	
Price Contingencies 2/	46.0	152.0	280.0	429.0	588.0	723.0	867.0	1,019.0	1,185.0	1,362.0	1,554.0	
Subtotal	750.0	946.0	1,162.0	1,401.0	1,622.0	1,761.0	1,908.0	2,060.0	2,226.0	2,403.0	2,595.0	
O&M for Public TWs												
Existing TWs Base Cost 3/	556.0	654.0	775.0	925.0	925.0	926.0	926.0	926.0	926.0	926.0	926.0	
Base Cost for Prop. Program												
FGW (Divesting Program) 4/	486.0	549.0	584.0	587.0	475.0	364.0	253.0	161.0	68.0	-	-	(818.0)
SGW												
Existing 5/	70.0	76.0	90.0	108.0	108.0	108.0	108.0	108.0	108.0	108.0	108.0	
To be added 6/	0.0	20.0	47.0	101.0	113.0	141.0	169.0	197.0	225.0	253.0	282.0	
Subtotal SGW	70.0	96.0	137.0	209.0	221.0	249.0	276.0	305.0	333.0	361.0	390.0	
Subtotal FGW & SGW	556.0	645.0	721.0	796.0	696.0	613.0	529.0	466.0	401.0	361.0	390.0	
Price Contingencies 7/												
FGW TWs	32.0	115.0	216.0	310.0	337.0	381.0	286.0	217.0	111.0	-	-	(1,865.0)
SGW TWs	4.0	20.0	51.0	111.0	157.0	227.0	312.0	418.0	546.0	700.0	889.0	
Subtotal	36.0	135.0	287.0	421.0	494.0	608.0	598.0	635.0	657.0	700.0	889.0	
TW O&M Expenditures												
FGW TWs	517.0	664.0	800.0	897.0	812.0	745.0	539.0	377.0	179.0	-	-	(2,683.0)
SGW TWs	75.0	116.0	188.0	320.0	378.0	476.0	588.0	723.0	879.0	1,061.0	1,279.0	
Subtotal	592.0	780.0	988.0	1,217.0	1,190.0	1,221.0	1,127.0	1,100.0	1,058.0	1,061.0	1,279.0	
O&M Expenditures												
Surface & FGW Supplies	1,267.0	1,610.0	1,962.0	2,298.0	2,434.0	2,506.0	2,447.0	2,437.0	2,405.0	2,403.0	2,595.0	(5,278.0)
SGW TWs	75.0	116.0	188.0	320.0	378.0	476.0	588.0	723.0	879.0	1,061.0	1,279.0	
Subtotal	1,342.0	1,726.0	2,150.0	2,618.0	2,812.0	2,982.0	3,035.0	3,160.0	3,284.0	3,464.0	3,874.0	(6,357.0)
II Water Charges												
For Surface & FGW Sply 8/	740.0	925.0	1,156.0	1,445.0	1,590.0	1,749.0	1,924.0	2,116.0	2,328.0	2,560.0	2,817.0	
For All Irr Systems 9/	740.0	925.0	1,156.0	1,445.0	1,734.0	1,995.0	2,294.0	2,639.0	3,033.0	3,488.0	4,012.0	
III Cash Flow Water Chgs to O&M												
Surface & FGW Supplies 8/	-527.0	-685.0	-806.0	-853.0	-844.0	-757.0	-573.0	-321.0	-77.0	+157.0	+222.0	
All Irrigation Systems 9/	-602.0	-811.0	-1,018.0	-1,173.0	-1,100.0	-987.0	-741.0	-521.0	-251.0	+ 24.0	+138.0	

1/ Based on Tables 1-5, Annex 5 (Includes distribution, surface drainage and flood protection facilities)
2/ Assumes 13% during 1982, 11% 1983, 10% 1984, 9% 1985, and 8.5% thereafter
3/ Based on 10,275 operating TWs (1982) and 900 to be added in 1983 with assumed individual TW annual O&M of Rs 54,100 (1982), Rs 58,500 (1983), Rs 69,300 (1984), and Rs 82,800 thereafter to achieve increased operating capacity from current 35% to 60% in 1985 and thereafter
4/ Assumes 12% annual divesting rate of TWs in FGW beginnig in 1984
5/ Based on 1,300 operating TWs (1981) in SGW and same assumptions as in 3/
6/ Assumes addition of 340 TWs annually in SGW beginning in 1983, with a total of 4700 TWs (WAPDA's estimate) to be installed through 1992
7/ Same as 2/ with 3% annual real increment added for increased cost of electricity
8/ Assumes SGW O&M financed through drainage assessments with water charges increasing at a normal rate of 25% through 1985 and 10% thereafter
9/ Assumes all irrigation system O&M to be eventually financed through water charges with nominal rate of increase of 25% through 1985, 20% in 1986, and 15% thereafter
10/ Additional cost of Rs 2,683 M in 1992 if TWs in FGW are not divested -- increase in annual water charges at 25% nominal rate would be required to give positive cash flow for surface and FGW supplies in 1991 and entire system in 1992.

Source: IDA SAR, "Irrigation Systems Rehabilitation Project" Annex 5, Table 9.

Table B.13

PAKISTAN

Ex-Ante and Ex-Post Economic Rate of Return for Selected SCARPs

Project	Type of Area 1/	ERR %
A. Ex-Ante		
1. Shorkot Kamalia	FGW	4
2. SCARP VI (on-going)	FGW	19
3. Fordwah-Sadqia	FGW	9
4. Fordwah-Sadqia	SGW	13
5. Bahwal Qaim	SGW	25
6. Jampur/D.G.Khan	FGW	8
7. Jampur/D.G. Khan	SGW	13
B. Ex-Post		
1. SCARP I	FGW	6

Source: WAPDA, "RAP Supporting Report on Project Evaluations," 1979.

1/ FGW - refers to fresh or usable groundwater areas.
SGW - refers to saline or non-usable groundwater areas.

ANNEX B

TECHNICAL SUMMARY NOTE ON
WATERTABLE DEPTH FOR OPTIMAL CROP PRODUCTION

1. To specify an optimum watertable depth, it is necessary to know the requirement of the crop species, soil characteristics, watering procedure, and climatological conditions. It is difficult to transfer the results from one country to another, since the relation between yield and watertable depth depends largely on the climatic conditions. However, the results of research conducted in The Netherlands, USA, and Egypt are summarized below for comparative purposes.

2. Visser (1958) described the intensive survey over 5.5 million acres of agricultural land during a 3-year period of observation. The intensity used was one observation/250 acres. The soils were divided into seven classes; the average relation between watertable depth and relative yield in a normal year is shown below:

Type of Soil	Optimal Depth (CM)	Watertable Depth At which Yield is Decreased by 10%	20%	30%
Heavy clay	130	75	60	45
Loamy humus-rich sand	100	65	50	38
Light clay	80	58	40	35
Coarse sandy reclaimed heath	65	45	35	30
Coarse sand	55	38	30	25
Clay overlying peat	40	30	25	20
Peat	30	25	20	15

However, in dry years, the optimum occurred at more shallow watertable levels.

3. Under such conditions most crops are dominant during the periods of high watertables, so that their effect will not be important provided that drainage conditions are such that excessively high watertables or period of flooding do not occur. Wesling (1969) found that the watertable can be expected to be higher than 25 cm below surface once per year. No permanent harm is done when watertables of short duration remain below the plowed layer. The US Bureau of Reclamation considers a depth to watertable of 3 to 5 feet as generally satisfactory, depending on local conditions, including

type of crop grown. The response of agricultural crops to flooding and to different watertable depths in the U.S.A. experience is of particular interest to Pakistan. The wide range of flexibility, allowing the fluctuating watertable to rise into the root zone with a certain duration. This would allow greater use of the aquifer for seasonal storage. It would also provide wider range of fluctuation as expected with the private operation of tubewells.

4. The results of experiments in upper Egypt, where temperatures are closer to those prevailing in North Punjab, show that the optimal watertable depth for sugarcane and cotton ranges from 4 to 5 feet. The Master Planning soil survey indicated dramatic changes in profile salinity status in Punjab SCARPs within a few years as indicated below:

Project	Affected	Saline	Status, Percent Sodic	Saline Non-GYP	Sodic GYP
SCARP I	70(+36)	2(-3)	9(-4)	12(-13)	5(-11)
SCARP II	84	5(-4)	4(-2)	4(-1)	3(-9)
SCARP III	69	6(0)	7(-1)	9(-12)	7(-10)
SCARP IV	66	1(-3)	13(-5)	15(-10)	5(-9)
All SCARP	72	4(-2)	9(-3)	10(-10)	5(-10)

This is because the majority of profiles designated as saline sodic contain gypsum, and therefore are immediately reclaimed by simple leaching. The criterion used for assessing optimal watertable depth in the reclaimed areas should now be changed to removing surplus water to reach the level of optimal crop production, instead of salinity control as previously designed, particularly in areas where the groundwater has low salt content.

Watertable Depth for Salinity Control

5. Leaching is the basic approach to remote or reduce soil salinity, after providing the land with drainage. In addition to providing the necessary capacity for removing leachate water, the drainage requirement of salt affected soils also requires a minimum depth to watertable. In humid regions where groundwater is low in salts, the permissible depth is largely determined by that required to maintain soil aeration and trafficability, closer to watertable depth for crop production. However, in arid lands with high evapotranspiration rates and with less leaching water applied, greater minimum allowable watertable depths are required. The criterion for establishing the critical depth is the prevention of any upward flow of water from the watertable into the root zone. The drainage requirement for salinity control corresponds to the leaching requirement, salt balance, and capillary rise concepts. The drainage depth also depends on soil physical properties, groundwater salinity, climatic conditions and crop characteristics (moisture withdrawal). Soils of intermediate texture are most liable to soil accumulation and need watertable control to greater depth than either clay soils or

sands. This is coupled with the low water allowance applied in Pakistan (6 cusec per 1,000 acres), which does not produce continual downward flux of water, which requires maintaining the watertable at a greater depth, for avoiding capillary movement of water concentrated salt to upper horizons, particularly in hot spring and summer.

Table C.1
Page 1 of 3

PAKISTAN

Selected References of Major Field Surveys of Private Tubewells

Author of Study	Year	Remarks
1. Pakistan Institute of Development Economics (PIDE), Islamabad (various studies followed)	1963	-
2. Board of Economic Enquiry (Punjab),	1965	-
3. Lower Indus Project of WAPDA	1965	Survey of 94 tubewells in FGW area through Gudu and Rohri Commands
4. HARZA Engineering Co., Consultants to WAPDA, (Reconnaissance Survey of Private Tubewells)	1965	Survey of 63 tubewells in Kasur, Lahore, Okara, Sargodha and Hafizabad areas.
5. Irrigation and Agriculture Consultants Association (IACA), Consultants to World Bank.	1966	Watercourse studies and farm surveys
6. Agricultural Census Organization, GOP (Farm Mechanization Survey)	1968	Detailed survey of 10% selected tubewells.
7. University of Engineering & Tech. Lahore.	1969	Survey of 4,000 tubewells in differ[illegible] areas of Pakistan. For canal command area only.
8. HARZA Engineering Co., Consultant to WAPDA, (Study of Private Tubewells in Gujranwala area)	1969	Study of 59 private tubewells.
9. Pakistan Institute of Development Economics (PIDE), Islamabad	1969	-
10. Review Mission of World Bank	1970	Survey in Bari and Rechna Doab areas. National average based on this survey, various reports and considering other data.
11. Agricultural Census Organization, (Census of Agricultural Machinery)	1975	For Punjab. For Pakistan.
12. Sabasuns Technical Services, Lahore (Planning Report, Panjnad-Abbasia Canal Commands)	1976	Survey by Sabasuns in project area.

Selected References of Major Field Surveys of Private Tubewells

Author of Study	Year	Remarks
13. Republic Engineering Corporation, Lahore (Planning Reports, Shujabad Project)	1976	Survey by REC in Project area.
14. Republic Engineering Corporation, Lahore (Planning Report, Upper Dipalpur Canal Command)	1976	Survey by REC in Project area.
15. Republic Engineering Corporation, Lahore (Planning Report, Shorkot Kamalia Project)	1976	Sample survey by REC in Project area.
16. Ascon Bolan & Associates, Hyderabad (Planning Report, Ghotki FGW Project)	1976	-
17. Project Planning Corganization (Southern Zone), WAPDA, Hyderabad (Planning Report, SCARP South Rohri)	1976	-
18. Project Planning Organization (Northern Zone), WAPDA, Lahore (Planning Report, SCARP Upper Rechna Remaining).	1978	Survey by PPO (N.Z.)
19. National Engineering Services (NESPAK), Lahore, (Planning Report, SCARP D.G. Khan)	1977	Survey by NESPAK.
20. Associated Consulting Engineers, Karachi (Planning Report, SCARP Bahawal Qaim)	1978	-
21. National Engineering Services (NESPAK), Lahore (Planning Report, SCARP Fordwah-Sadiqia)	1978	-
22. Agricultural Research Council, Pakistan (Study conducted by Irrigation Research Institute Punjab)	1979	Data 1970-78 of 685 tubewells in 15 districts of Punjab. Data collected during 1970-78.
23. Project Planning Organization (NZ) WAPDA (Planning Report, Lower Rechna Remaining)	1980	For usable area. For saline area.

Table C.1
Page 3 of 3

Selected References of Major Field Surveys of Private Tubewells

Author of Study		
24. Master Planning & Review Division, WAPDA (Private Tubewells and Factors Affecting Current Rate of Investment)	1978	Surveyed 521 farmers in SCARP and non-SCARP areas.
25. Dr. N.M. Awan, "Technical, Social and Economic Aspects of Water Resources Management in SCARP 1," University of Engineering & Technology, Lahore, Pakistan, December 1981	1980	Surveyed farms in SCARP 1 area and assessed performance of Project.
26. R. Renfro, "Economics of Local Control of Irrigation Water in Pakistan: A Pilot Study," Ph.D thesis, Colorado State University, Summer 1982	1981	Interviewed sample of 130 farmers on 20 watercourses in Faisalabad District, Punjab.

GROWTH OF PRIVATE TUBEWELLS IN PAKISTAN

Year Ending June	NWFP		PUNJAB		SIND		BALUCHISTAN		PAKISTAN		Remarks
	Number	Annual Increase	Number	Annual Increase	Number	Annual Increase	Number	Annual Increase	Number	Annual Increase	
1964	N.A.	-	21,776	-	N.A.	-	N.A.	-	23,140		
1965	331	-	28,746	6,970	2,977	-	470	-	32,524	9,384	
1966	446	115	36,217	7,471	3,069	92	650	180	40,382	7,858	9.858
1967	615	169	44,488	8,271	3,161	92	870	220	49,134	8,752	Average
1968	773	158	53,797	9,309	3,253	92	1,075	205	58,898	9,764	1966-70
1969	966	193	62,034	8,237	3,345	92	1,285	210	67,630	8,732	
1970	1,163	197	75,346	13,312	3,437	92	1,870	585	81,816	14,186	
1971	1,493	320	81,955	6,609	3,531	94	2,278	408	89,247	7,431	
1972	1,645	162	90,758	8,803	4,412*	881	2,521	243	99,336	10,089	12,290
1973	1,695	50	99,674	8,916	5,292	880	3,040	519	109,701	10,365	Average
1974	1,709	14	109,889	10,215	5,582*	290	3,646	606	120,826	11,125	1971-75
1975	2,736	1,027	130,398	20,509	5,871***	289	4,262	616	143,267	22,441	
1976	3,254	518	134,782	4,384	7,675	1,804	4,631	369	150,342	7,075	
1977	3,312	58	140,724	5,942	8,080	405	4,863	232	156,979	6,637	6,536
1978	3,626	314	144,121	3,397	8,590	510	5,143	280	161,480	4,501	Average
1979	4,252	626	147,995	3,874	9,214	624	5,954	811	167,415	5,935	1976-80
1980	4,878	626**	154,468	6,473	9,838	624**	6,765	811**	175,949	8,534	
1981	**N.A.**		**N.A.**		**N.A.**		**N.A.**		**186,000**		

Source: NWFP : 1) 1965-69 World Bank Review Mission Report (1970)
2) 1970-79 Agriculture Department, Government of NWFP, Peshawar.

Punjab : Agriculture Department, Government of Punjab, Lahore.

Sind : 1) 1965 World Bank Review Mission Report (1970)
2) 1966-70 Intermediate Figures obtained by adjustment.
3) 1971-79 Dev. Statistics, Sind (1974, 1978, 1979) and Agri: Statistics of Pakistan (1979).

Baluchistan : 1) 1965-69 World Bank Review Mission Report (1970)
2) 1970-79 Agriculture Department, Government of Baluchistan, Quetta.

* Actual data not available/reliable. Figures have been worked out on the basis of average of the preceding and the following years.

** Figure assumed to be same as in last year.

*** Figure are given for February 1975, which have been proportionally increased to obtained figure for June 1975.

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Table C-2

Table C.3(a)

PUMPAGE OF

PUBLIC TUBEWELLS

FY															
		2069	138	213	163	884	807	2205	542	523	570	1635	935	540	810
76		60[illegible]	468	824	577	3292	3302	8463	2012	2009	2247	6268	3714	1424	2430
	(MAF)	1480	0.115	0.205	0.152	0.831	0.814	2.117	0.486	0.533	0.423	1.442	0.953	0.362	0.560
77		2069	138	213	163	884	807	2205	542	523	570	1635	935	540	1192
		6036	468	824	577	3292	3302	8463	2012	2009	2247	6268	3714	1424	3676
	(MAF)	1.278	0.120	0.199	0.125	0.794	0.685	1.923	0.266	0.447	0.446	1.159	0.870	0.357	0.720
78		2069	138	213	163	884	807	2205	542	523	570	1635	935	540	1192
		6036	468	824	577	3292	3302	8463	2012	2009	2247	6268	3714	1424	3676
	(MAF)	1.391	0.122	0.203	0.106	0.598	0.800	1.829	0.414	0.576	0.553	1.543	0.815	0.436	0.574
79		2069	138	213	163	884	807	2205	542	523	570	1635	935	540	1192
		6036	468	824	577	3292	3302	8463	2012	2009	2247	6268	3714	1424	3676
80	(MAF)	1.355	0.112	0.165	0.127	0.715	0.811	1.930	0.439	0.578	0.468	1.485	0.826	0.137	0.740
		2069	138	213	163	884	807	2205	542	523	570	1635	935	540	1192
		6036	468	824	577	3292	3292	8463	2012	2009	2247	6268	3714	1424	3676
	(MAF)	1.505	0.114	0.173	0.131	0.823	0.826	2.067	0.394	0.581	0.464	1.439	0.834	0.133	0.700
81		2069	138	213	163	884	807	2205	542	523	570	1635	935	540	1192
	Design Capacity (cc ft)	6036	463	824	577	3292	3302	8463	2012	2009	2247	6268	3714	1424	3676
	Actual Pumping (MAF)	1.304	N.A.	N.A.	N.A.	N.A.	N.A.	1.874	N.A.	N.A.	N.A.	1.392	0.911	0.088	0.990

N.A. = Not Available.
Source:- CHO, WAPDA, Lahore.

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PUMPAGE OF
PRIVATE TUBEWELLS

1		SCARP-I 2	SCARP-II 3	SCARP-III 4	SCARP-IV 5	SCARP Khairpur 6	SCARP Rohri 7
1975-76	Number of T/Ws.	8993	4428	5318	5771		
	Design Cap.(cc ft)	10791	4207	5850	6348		
	Actual Pumping (MAF)	2.012	0.608	0.846	1.009		
1976-77	Number of T/ws.	9810	4766	6324	6428	202	800
	Design Cap.(cc ft)	11772	4528	6956	7071		
	Actual Pumping (MAF)	2.195	0.654	1.005	1.124		
1977-78	Number of T/ws.	10225	4966	6068	6553	259	730
	Design Cap.(cc ft)	12270	4718	6675	7208		
	Actual Pumping (MAF)	1.907	0.682	0.965	1.146		
1978-79	Number of T/ws.	10533	4983	6260	6902	252	1034
	Design Cap.(cc ft)	12640	4734	6886	7592		
	Actual Pumping (MAF)	1.964	0.684	0.995	1.207		
1979-80	Number of T/ws.	10580	5178	6621	7074		
	Design Cap.(cc ft)	12696	4919	7283	7781		
	Actual Pumping (MAF)	1.973	0.711	1.053	1.237		
1980-81	Number of T/ws.	10992	5780	6727	7362		
	Design Cap.(cc ft)	13190	5491	7400	8098		
	Actual Pumping (MAF)	2.050	0.794	1.070	1.288		

Source: Groundwater & Drainage Section, Planning Divison, WAPDA, Lahore.

NOTE: These figures are preliminary and need to be verified.

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Table C.3(b)

Table C .4

PAKISTAN

SCARP Transition Subsector Report

Diesel Tubewell Installation Cost and the Amount of Subsidy

Years	Sailaba			Barani Area			Canal Commanded Area		
	Installation Cost (Rs.)	Subsidy (Rs.)	%age of cost	Installation Cost (Rs.)	Subsidy (Rs.)	%age of cost	Installation Cost (Rs.)	Subsidy (Rs.)	%age of cost
1972-73	13500	6000	44	13500	8000	59	13500	4000	30
1973-75	20000	10000	50	20000	12000	60	20000	8000	40
1975-77	25000	10000	40	25000	12000	48	25000	8000	32
1977-78	17500	10000	36	27500	12000	44	27500	8000	29
1978-79	28000	11000	39	28000	13000	46	28000	9000	32

PAKISTAN

SCARP SUBSECTOR REPORT

Groundwater Pumpage in the Indus Plains
(Million Acre Feet)

Year	Public Tubewell			Private Tubewell			Total
	C/Comd	Un-Comd	Total	C/Comd	Un-Comd	Total	Pumpage
1959-60	-	-	-	2.86	0.41	3.27	3.27
1960-61	-	-	-	3.16	0.54	3.70	3.70
1961-62	0.66	-	0.66	3.59	0.80	4.39	5.05
1962-63	2.60	-	2.60	3.91	1.10	5.01	7.61
1983-64	2.64	-	2.64	4.84	1.50	6.34	8.98
1964-65	2.69	-	2.69	5.15	1.64	6.79	9.48
1965-66	2.85	-	2.85	6.39	2.32	8.70	11.55
1966-67	1.96	-	1.96	7.30	2.84	10.14	12.10
1967-68	2.24	-	2.24	7.44	3.36	1.80	13.04
1969-70	4.27	0.02	3.76	8.99	3.45	12.44	16.20
1970-71	4.58	0.03	4.61	11.16	5.06	16.22	20.23
1971-72	4.64	0.03	4.67	1295	4.66	17.61	22.28
1972-73	5.43	0.06	5.49	13.26	5.95	19.21	24.70
1973-74	7.12	0.10	7.22	13.61	6.58	20.19	27.41
1974-75	8.57	0.44	9.01	15.23	7.57	22.80	31.81
1975-76	6.91	0.29	7.20	16.29	8.69	24.98	32.18
1976-77	6.82	0.09	6.91	16.70	9.14	25.84	32.75
1977-78	6.81	0.09/a	6.90	19.23	9.14/a	28.37	35.27

Source: WAPDA

/a Since data was not available, it was assumed to be same as previous year.

Table C.6

PAKISTAN

IRRIGATION WATER SUPPLY, 1960/61-1980/81

(million acre feet)

Year	Rim Station Inflows Kharif	Rim Station Inflows Rabi	Canal Head Withdrawals Kharif	Canal Head Withdrawals Rabi	Net System Loss (-) of Gains (+) Kharif	Net System Loss (-) of Gains (+) Rabi	Surface Availability at Farm Gate Kharif	Surface Availability at Farm Gate Rabi	Public Tubewell Availability Kharif	Public Tubewell Availability Rabi	Private Tubewell Kharif	Private Tubewell Rabi	Total Farm Gate Water Availability Kharif	Total Farm Gate Water Availability Rabi
1960/61	124.59	20.73	54.45	26.14	-9.68	+4.43	32.67	15.68	0.24	0.23	0.71	0.72	33.62	16.63
1961/62	119.14	20.96	55.84	27.22	-10.70	+2.35	33.38	16.34	0.28	0.28	1.05	1.04	34.71	17.66
1962/63	89.51	19.76	57.99	27.78	-9.50	+3.60	34.79	16.67	0.97	0.97	1.45	1.45	37.21	19.09
1963/64	119.20	21.53	62.15	27.17	-10.40	+4.80	37.29	16.30	1.07	1.07	1.97	1.96	40.33	19.33
1964/65	115.84	22.32	60.36	29.55	-15.50	+4.70	36.22	17.73	1.19	1.18	2.59	2.60	40.00	20.51
1965/66	117.16	21.06	65.08	26.17	+3.10	+3.30	39.05	15.70	1.24	1.23	3.32	3.33	43.61	20.26
1966/67	116.47	23.79	66.37	29.59	-4.40	+4.80	39.82	17.75	0.87	0.86	4.12	4.12	44.81	22.73
1967/68	120.00	25.50	61.72	32.98	+1.30	+4.60	37.03	19.79	0.99	0.98	4.87	4.88	42.89	25.65
1968/69	115.48	23.11	66.73	31.58	-3.20	+3.00	40.04	18.95	1.41	1.41	5.40	5.49	46.94	25.85
1969/70	114.15	19.69	69.19	30.66	-12.40	+4.60	41.51	18.40	1.77	1.77	6.03	6.02	49.31	26.19
1970/71	89.59	15.88	60.83	26.53	-8.70	+3.10	36.50	15.92	2.17	2.16	6.60	6.60	45.26	24.69
1971/72	87.94	15.61	60.60	26.05	-11.00	+5.20	36.36	15.63	2.24	2.24	7.32	7.31	45.92	25.18
1972/73	101.52	24.56	68.67	32.23	-10.30	+3.20	41.21	19.33	2.41	2.40	7.91	7.91	51.53	29.64
1973/74	143.90	19.21	63.42	32.65	-1.53	+9.25	38.05	19.59	2.70	2.70	8.51	8.51	49.26	30.80
1974/75	79.46	16.47	62.84	23.59	-10.30	+5.98	37.70	14.16	3.48	3.47	9.10	9.11	50.28	26.74
1975/76	114.35	21.95	62.91	36.00	-16.33	+10.00	37.75	21.60	3.08	3.08	9.71	9.72	51.55	34.39
1976/77	111.17	19.14	58.40	38.80	n.a.	n.a.	35.08	23.32	2.82	2.83	10.26	10.26	48.16	36.41
1977/78/a	100.30	23.10	64.45	37.73	-12.63	+0.91	38.72	22.90	3.11	3.10	10.80	10.81	52.63	36.81
1978/79	137.36	26.39	60.10	36.53	n.a.	n.a.	36.06	21.92	3.31	3.31	11.40	11.39	50.77	36.62
1979/80	108.70	24.87	68.22	37.02	n.a.	n.a.	40.93	22.21	3.52	3.51	11.98	11.99	56.43	37.71
1980/81	109.77	26.38	68.33	36.48	n.a.	n.a.	42.51	22.70	3.70	3.72	12.57	12.57	58.80	38.99

/a Losses have been assumed as 40% up to Nakka as against 30% assumed during the previous years.

n.a. Not Available

Source: Ministry of Finance, Planning and Economic Affairs.
IBRD, Country Economic Report, April 1982

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Table C .7(a)

Selected Findings of Agricultural Benefits Due to Private Tubewells

(a) Changes in Cropping Pattern (Comparison Between non Tubewell and Tubewell Owning Farms).

(Percent Difference)

Areas	Sailaba	Barani	Canal
Wheat	-11.81	10.19	-2.85
Rice	6.07	3.49	2.62
Cotton	1.77	4.71	-2.16
Sugarcane	3.36	1.93	-0.19
Fodder	-	-5.94	-6.47
Others	0.56	-14.38	9.05

(b) Yield Per Acre of Major Crops On the Sample Farms.

Table C.7(b)

Unit	Sailaba			Barani			Canal			Over all		
	With T.W	Non T.W	Diff.	With T.W	Non T.W	Diff.	With T.W	Non T.W	Diff.	With T.W	Non T.W	Diff.
Md.	18.77	14.00	34	18.78	12.14	55	21.52	17.53	23	19.71	15.13	30
"	6.22	-		6.87	11.90	-42	8.55	8.00	7	7.36	11.58	-36
"	14.71	6.00	145	9.00	7.50	20	10.09	9.00	12	10.18	7.00	45
"	17.89	17.40	3	19.51	17.00	15	23.00	16.62	38	20.44	16.86	21
"	7.00	7.00	-	8.00	8.00	-	8.20	8.64	-5	8.00	8.14	-2
"	10.18	12.50	-19	15.00	-	-	15.00	20.00	-25	14.15	15.00	-5
Md. of Gur	25.00	30.00	-17	28.00	32.00	-13	30.00	25.75	17	27.92	27.58	1.0

Siginificant at one percent probability level.

Source: Punjab Economic Research Institute, "Evaluation of Private Diesel Tubewell Subsidy Scheme in the Punjab," 1981.

Table C.8
SUMMARY OF INPUT USAGE AND YIELDS
FOR TUBEWELL USERS AND NON-USERS

Item	Unit	Type	Sugar-cane	Rice Irri.	Rice Basmati	Gardens	Vege-table	Cotton	Wheat	Pulses	Oil-seeds	Others	Total
1. Cropping Pattern	% acres	O*	8	13	8	4	3	8	60	15	8	18	157
		P	5	10	6	2	2	8	36	13	13	19	136
		Nu	3	4	3	1	1	7.5	50	16	11	15	113
2. Per acre use of:													
i. Nitrogen	110 lb bag	O	1.5	1.5		0.5	0.9	0.5	1.0	-	0.2	0.5	
		P	1.0	1.3		0.5	0.5	0.5	0.75	-	0.1	0.4	
		Nu	1.0	1.0		0.4	0.5	0.2	0.5	-	-	0.2	
ii. Phosphorus	-do-	O	0.25	0.5		0.2	1.0	0.25	0.75	0.1	-	0.2	
		P	0.2	0.5		0.2	0.5	0.1	0.6	-	-	-	
		Nu	0.2	0.4		0.1	-	0.1	0.2	0.2	-	0.1	
iii. Seed Rate	Md/Rs	O	67	0.13		130	300	0.15	0.9	0.6	0.1	50	
		P	71	0.12		150	300	0.14	0.8	0.6	0.1	50	
		Nu	53	0.13		150	300	0.11	0.9	0.7	0.1	50	
iv. Insecticide	Rs.	O	14	11.0		50	-	25	1.0	-	-	-	
		P	18	10.5		50	-	13	-	-	-	-	
		Nu	7	11.2		50	-	17	-	-	-	-	
v. Canal water	Acre ft.	O	1.5	1.5		2.0	1.5	0.9	0.6	0.2	0.1	0.4	
		P/Nu	1.2	1.2		1.5	1.2	0.7	0.4	0.2	0.1	0.3	
vi Tubewell Delta	Acre ft.	O	2.0	2.0		1.1	0.7	0.3	0.5	-	-	0.5	
		P	1.0	1.5		1.0	0.6	-	0.3	-	-	0.3	
3. Yield per acre	Md/Rs	O	595.0	32.1	23.6	2450.0	1680.0	9.3	26.3	9.3	9.1	600.0	
		P	485.0	29.3	22.9	2573.0	1595.0	8.5	21.7	10.4	8.9	600.0	
		Nu	315.0	21.4	18.7	2138.0	1030.0	9.2	18.5	10.8	9.7	600.0	

* O = Tubewell owner, P = Tubewell water purchaser and Nu = for Non-user of tubewell water.

Contd...2

Source: WAPDA, "Private Tubewells and Factors Affecting Current Rate of Investment," Annexure IV-3. 1981.

-98-
Table C.8

Table C-9

FINANCING OF TUBEWELL INSTALLATION COST

Years	Area	Total Cost (Rs in million)	Percent of Cost Contributed by 3/				Total
			Own Sources	ADBP	Commercial Bank and Cooperatives	Others	
1978	Pakistan	2,582.6	91*	7	-	2	100
1975 1/	Pakistan	2,075.7	86	7	5	2	100
1968 2/	Pakistan	692.0	72	---------- 28 ----------			100
1975 1/	NWFP	51.2	86	3	1	10	100
	Punjab	173.5	86	8	1	5	100
	Sind	152.4	88	10	1	1	100
	Baluchistan	136.8	89	2	-	9	100

1/ Pakistan Census of Agricultural Machinery 1975 - P.133-134

2/ Farm Mechanization in West Pakistan 1960 - P.77.

3/ Includes friends, relatives and subsidies.

* Includes 3 per cent cost contribution under Government Subsidy Programme.

Table C.10

Summary of Financial Returns to Private Tubewell Users

A. Gross and Net Values for Tubewell Owner and Non-owner Farms (100 ac)

Item		Tubewell Owner	Tubewell Water Purchaser	Tubewell Water Non-user
Cropping Intensity		157	130	113
Gross Value (Rs)		157,698	119,309	86,293
Net Value per acre	1.0 cusec Diesel	785	725	668
Net Value per acre	1.0 cusec Electric	809	734	668
	0.6 cusec Diesel	769	716	668
	0.6 cusec Electric	791	716	668

B. Approximate Financial Rates of Return

	1971 Prices		1980 Prices			
	Canal Areas		Canal Areas		Barani Areas	
	Diesel	Electric	Diesel	Electric	Diesel	Electric
1.0 cusec	30	>50	20	34	12	25
0.6 cusec	19	41	12	31	7	-

Source: WAPDA, "Private Tubewells and Factors Affecting Current Rate of Investment," 1981, pp. 76 and 82.

Table C.11

PAKISTAN

Diesel Tubewell Subsidy Scheme
No. of Tubewells and Amounts
Allocated, 1972 - 1979

	Sailaba	Barani	Irrigated	Total Tubewells	Total Amount of Subsidy (Rs M)	Average Subsidy per Tubewell (Rs)
1972-73	1,451	984	760	3,195	20.1	6,303
1973-74	223	79	142	444	2.5	5,720
1974-75	969	738	868	2,575	27.1	10,522
1975-76	480	610	509	1,599	15.0	9,388
1976-77	1,771	2,144	1,822	5,737	57.4	10,000
1977-78	396	341	454	1,191	10.0	8,396
1978-79	460	369	516	1,345	19.5	14,565
Total	5,750	5,266	5,071	16,086	151.6	-
Percentage	(35.8)	(32.7)	(31.5)	(100.0)	100.0	-

Source: Data obtained from report by M. Malik, "Evaluation of Private Diesel Tubewell Subsidy Scheme in the Punjab", p 6 and 7.

PAKISTAN

(a) Distribution of Tubewells by Farm Size

Farm Category (Acres)	Percent distribution in 1968 Farm No.	1968 Farm area	1968 Tubewells* Installed	1972 Farm No.	1972 Farm area	1972 Tubewells Installed
0 - 5.0	49	10	22	28	5	6
5.1 - 12.5	28	22	24	39	25	21
12.6 - 25.0	15	26	25	21	27	26
Greater than 25.0	8	42	29	12	43	47
Total	100	100	100	100	100	100

Source: Based on Census data.

Table C.12(b)
Tubewell Ownership by Farm Size and Partnership

Ownership	Less than 5.1	Farm Size - Acres 5.1-12.5	12.6-25.0	25.1-50.0	50.1-75.0	Greater than 75	Total
	A. Percent of total of all farms						
Single	3.3	17.4	20.8	18.2	7.4	6.3	73.4
Joint	2.6	7.0	5.9	4.4	1.5	5.2	26.6
Total	5.9	24.4	26.7	22.6	8.9	11.5	100.0
	B. Percent of total by farm size						
Single	56.2	71.2	77.8	80.3	80.3	54.8	73.4
Joint	43.8	28.8	22.2	19.7	16.7	45.2	26.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: WAPDA, "Private Tubewells and Factors Affecting Current Rate of Investment," p. 86 and 87.

ANNEX D

SELECTED FEATURES OF SCARP TUBEWELL TECHNOLOGY 1/

Introduction

1. This annex presents some background information on the SCARP tubewell technology, including: guidelines for planning of well fields and selection of well parameters; past and current design criteria of SCARP tubewells; pumping equipment; construction experience; and screen material.

Guidelines for Planning of Well Fields and Selection of Well Parameters

2. The planning of a tubewell project depends on the purpose of the project. In fresh groundwater zones, for utilizing the pumpage for increasing irrigation supplies, the pumpage of SCARP tubewells is put into the head canals, minors, and watercourses. The canal system is spread throughout the plains but in some cases the distance between the watercourse outlets is too great or too small for even distribution of the tubewells. Under the SCARPs conditions, it was found that the maximum acceptable deviations from a triangular grid are some 1,500 ft for a single well, or alternatively, 750 ft in opposite direction for two adjacent wells, without impairing drainage. The maximum recommended design spacing is in the order of 1.5 mile. The perfect layout for even control of the watertable is the triangular pattern, but this is not usually possible in practice. Shallow tubewells are more effective in controlling the watertable evenly. The quality of water obtained from shallow tubewells generally in the Indus Basin Plains is generally better than water obtained from the larger capacity and deeper SCARP tubewells. On the other hand, the cost of water pumped by shallow tubewells is higher than that of the large capacity wells.

3. In theory, there is no limit to the pump capacity of individual wells and consequently, the design should be based on the most economical pump capacity. If larger pumps are installed, a lower number of pumps is needed resulting in lower investment costs. On the other hand, larger capacity pumps result in higher drawdowns, and consequently, the energy costs would be higher. The effect of the pump capacity on the drawdown is not very significant, due to the high transmissibility values that are found in the SCARP areas. The determination of the pump capacities on a purely economical basis

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1/ This annex is a shortened version of a paper prepared by Anis Youssef, Irrigation Engineer in the Bank's Resident Mission in Pakistan.

could lead to very high pump capacities. However, the pump capacity is limited by the area to be served and the limit of allowable well spacing. The recommended upper limit of tubewell capacity in Pakistan is 3 cusecs, which is currently the most common size for SCARP tubewells.

Design of Tubewells

General

4. The tubewell must be designed for highest efficiency in terms of specific capacity. The optimum design of a tubewell combines the design parameters in such a way that two criteria are satisfied: (i) the economic criterion of finding the minimum costs; and the technical criteria, which do not always coincide with the most economical design. The most important design parameters are the tubewell capacity, the screen length and the screen diameter. The cost of pumped water should be at minimum for a given combination of design parameters. The costs of pumped water reflect the capital costs of the tubewell including installation and electrification, the annual O&M costs and the replacement costs. Capital costs of the tubewell depend upon length and diameter of screen, length of pump housing casing and blank pipe, initial setting of the pump, the capacity and the material of the pumping equipment. The initial setting of the pump and length of pump housing casing depend upon the drawdown, the length and the diameter of the screen and the permeability of the formation.

5. Operation and maintenance costs of a tubewell include the energy costs, costs for repair and spare parts and wages of operating staff. The energy costs depend on the total head of the pump that is related to the drawdown and varies for each capacity and screen length. The life of SCARP tubewell (average 12-15 years) and the total replacement costs should also be considered in the economic evaluation. The result is that for every tubewell capacity there is a combination of screen length and diameter for which the cost of pumped water is at minimum. The capital costs together with the recurring costs are then amortized at the prevailing ratio of interest to calculate the cost of unit of pumped water for tubewells of different screen length and diameter for various capacities and permeabilities. The most economical design parameters are then selected.

6. The optimal design requires that each tubewell should be individually designed, as a separate project on basis of aquifer conditions shown by a test borehole dug at the tubewell site. The above procedure has not been followed in the design of the SCARP tubewells; instead, standard designs were used, therefore assuming similar aquifer conditions. This factor, where the standard design is not consistent with the local environment of the well, provides the main reason for unexpected rapid deterioration of the SCARP wells. It also appears that only simplified technical criteria were used in the SCARP designs without adequate consideration to economic criteria. Little, if any, consideration was given to the interface between fresh and saline water. In some areas this intrusion caused deterioration of the

quality of water, either by lateral flow or by upcoming of saline water. Individual wells drilled in some sites have deteriorated and were abandoned in a short period due to the saline yield. The conventional and latest design criteria are summarized in the next sections. A different approach is followed in designing skimming tubewells in areas with a shallow layer of fresh water underlain by saline water. This approach is discussed in para 4.

Conventional Design for SCARP Tubewells

Well Depth

7. A deep alluvial aquifer was a general design assumption. The depth of the well depends on the length of the housing pipe, length of screen used and the thickness of impermeable layers encountered within the permeable formation penetrated by the well.

Well Diameter

8. Most of the SCARP tubewells were drilled with 22 inches diameter drill bit, which was believed to be adequate to provide proper space around the screen for proper gravel packing. This also allowed for use of up to 16 inches diameter housing pipe for turbine pumps. Although the 22 inch bore is mostly adequate, and theoretically the increase in well diameter has a slight effect on reducing the drawdown, experience indicated that smaller diameters cause operation and maintenance problems and accelerate deterioration. A larger drill hoe is now recommended--24 rather than the 22 inches.

Well Casing

9. The size of the pump (vertical turbine) controls the diameter of the casing, which should allow for adequate clearance. Usually, the housing diameter ranges from 12 to 16 inches for 2 to 5 cusec tubewells. The length of the housing pipe depends on the depth-to-watertable to be maintained and the maximum expected drawdown. Casing should be strong enough to resist stresses and withstand corrosive groundwater environment.

Well Screen

10. The screen is provided to allow sand-free water to enter the well freely and support loose formation. Screen design is based on hydraulic considerations, in addition to selecting adequate well thickness to resist stresses from placement and subsequent production. Enough total area of screen openings is provided so that the entrance velocity of the water will not exceed the designated standard, which usually ranged between 0.2 and 0.03 ft per second. Screen length depends upon thickness of water beaming strata and size of screen opening (slot) depends upon the gradation of the gravel pack, which depends on the critical particle size of the aquifer formation. Similar to the case of the diameter of well bore, experience shows that it is preferable to use larger screens than the diameter calculated from design for

better operation and maintenance. Current well screen recommendations are as follows: 10 inches for 2 to 3 cusec capacity wells, and 12 inch casings for 4 to 5 cusec wells, SCARP tubewells have been designed using 8 to 10 inches, respectively.

Gravel Pack

11. Careful selection of pack is important to prevent the clogging of pack with fine material from the aquifer. The gravel pack is designated to stabilize the finest sand gradation present in the sections selected for screening. The gradation tests should be made for each stratum. Theoretically, a pack thickness of double the grain diameter is sufficient, but practically the minimum thickness is 3 inches. Sections housing more than 20% clay passing 200 mesh screen should have blank screen.

Up-to-date Design Criteria

12. The latest design criteria are based on rigorous computation of the well drawdown using factors obtained from observation of the performance of tubewells in similar areas. The productivity of the well is expressed by the specific capacity of the well (well discharge divided by drawdown). The drawdown in a discharging well consists of two components:

(a) headlosses caused by laminar flow in the aquifer around the well that are called formation losses; and

(b) headlosses by turbulent flow in and near the well that are called well losses.

The formation losses depend on aquifer transmissivity and storage. These losses increase with time until steady state conditions are reached. Well losses depend on various well design parameters, such as well diameter, screen length and slot size. They are constant with time, but increase rapidly with the pumping rate. The general relationship is as follows:

$$\text{Drawdown } SW = BQ+CQ^2]$$

where Q = well discharge
B = formation loss factor
C = well loss factor

B and C are determined by means of a step drawdown test on existing wells at steady state flow condition. In Unit I, SCARP VI Project, well losses were generally between 1 ft and 2 ft up to 2.5 cusec discharge, but exceeded 3 ft for discharges above 3 cusecs. Detailed net rigorous calculations of well drawdown include the breakdown of formation losses into:

(a) drawdown caused by radical flow of an individual well;

(b) drawdown caused by effect of partial penetration; and

(c) drawdown caused by the interference of the wells in a field.

When the recharge to the aquifer and the discharge of the pumps are in balance resulting in a stabilized watertable, the flow regime reaches steady state conditions. Corresponding to the irrigation supplies delivered to the area, the recharge to the aquifer in the project area will vary throughout the year.

13. To maintain a stabilized watertable would require that the system be based on the maximum expected recharge. However, this would result in excessive investment costs. When the system is based on a continuous discharge, the watertable would fluctuate about 2 ft throughout the year. This variation can be further reduced by adjusting the monthly operating factor, i.e., a higher operating factor during the periods with higher recharges and lower operating factors during the periods with lower recharges. Since some fluctuations is permissible, the concept of steady state flow does not strictly apply to the future project conditions. In practice, however, these conditions are sufficiently approached to admit to the use of steady state flow formulae. The effect of interference of wells can be ignored under steady state flow conditions and if the pattern of the tubewells is regular. Well losses consists of the following components:

(a) the resistance of the gravel pack;

(b) the influence of partial performation of the screen;

(c) the entrance resistance; and

(d) the friction loss inside the screen and casing and conversion of static head into velocity head.

The first two of these components are generally very small and are nearly proportional to the discharge of the well and inversely proportional to the screen length and diameter. The entrance resistance through the slots inversely proportional to the screen length and directly proportional to the square of the discharge. The value of this component is small and can be ignored in a semi-conventional tubewell design. The last well loss component is directly proportional to the length of the tubewell casing and the square of the discharge. For deep and high capacity tubewells, this is the major well loss component.

14. Various parameters have an influence on the drawdown calculations:

(a) aquifer characteristics:

- horizontal permeability
- vertical permeability
- thickness of aquifer

(b) tubewell parameters

- discharge
- length of screen
- diameter of screen

(c) factors determining the tubewell layout

- radius of influence of the well
- spacing of tubewell
- distance between open drains

SCARP Pumping Equipment

15. Pumping equipment includes the pump, motor and starter-cum-control of the motor. All SCARP tubewells are provided with open line shaft, water lubricated, vertical deepwell turbine pumps equipped with vertical, hollow shaft, requiring charge induction motors. All the motors are protected by a set of control instruments housed in a cabinet. Components of tubewells in saline groundwater zones are mostly manufactured from corrosion resistant materials. Subsequently, these pumps are not in use due to its higher cost, particularly considering the need for scarce foreign exchange. Most of the turbine pumps have positive heads (e.g., are above the pump).

16. The recommended maximum workable suction lift is 20 ft, with a limiting size of pumps to 2 cusecs, and then only for areas where "the watertable is .... projected to decline only a few feet throughout the life of the pump." Since the drawdown and friction head of a 2 cusec pump approximately 16 ft, such a pump could not be installed at ground level if the static water level was more than 4 ft below land surface. Therefore, 2 cusec centrifugal pumps must be installed below land surface in pits if the watertable is to be lowered significantly below 4 ft. Because of this disadvantage, turbine pumps are preferred for SCARPs located in Sind and Punjab Provinces.

17. The choice of pumps is determined by the anticipated pumping head and the required discharge. For the conditions prevailing in the SCARPs (future depth of watertable, use of the aquifer as a storage reservoir and anticipated discharge) the best choice seemed to be a water-lubricated vertical turbine type powered by an electric motor. The pump efficiency specified was a minimum of 80% at total pump head and 75% at a head of 10 ft less. The

initial wire to water efficiency for the wells in SCARP I was 56%, the low value reflecting the low pumping heads of the early stages of operation.

18. The performance of the vertical turbine pump and its associated auxiliary equipment has been satisfactory and its continued use seems to be justified. In the early stages of the tubewell program, much of the equipment was imported, although turbine pumps manufactured in Pakistan were used in about 700 of the SCARP I tubewells (totalling about _____). By the time the contracts for SCARPs II-B and III were let, all of the turbine pumps, motors (except the very largest) and most of the motor control equipment and transformers were manufactured locally. Accordingly, it does not follow that use of turbine pumps should cease because of importation problems.

Construction of SCARP Tubewells - Borehole Drilling

19. Most of the SCARP tubewells were drilled by reverse circulation rotary method. A few were drilled by percussion method. Tubewells up to 3 cusecs capacity were drilled with a 22 inch bit from top to bottom. In higher capacity, the upper part of the hole was removed to 24 inch. Recently, the WAPDA specification require the use of a 24 inch bit for drilling the borehole for wells that exceed 1.5 cusec capacity. In the early SCARP I tubewells, and in test tubewells in all SCARPs, wells drilled by revers rotary method were electrically logged before lowering the screens to ascertain the change in lithology and water quality at different depth.

20. Wherever sloughing and coring of surface material resulted, conductor casing was installed with diameter 2 inches larger than the drilling bit diameter, from 6 inches above the ground surface to a sufficient depth to encounter firm material. In cases where unstable material was encountered in drilling, either temporary casings or stabilizing fluid additives were used to hold the walls of the hole during drilling operations. Temporary casing was removed in 5 to 10 ft stages as gravel was placed. The gravel was introduced so that each stage of the hole above bottom of the casing was completely filled before the casing was withdrawn to the next stage. Accurate drilling logs including description of all material encountered and their location in the borehold were kept for each borehold. Representative ditch samples or cuttings of the material penetrated at each change in lithology encountered and from each 10 ft (3 meters) of depth of the borehold was also collected in order to determine the thickness and location of each change in material encountered. Samples were placed in cloth bags properly marked for identification, labelled with the depth of the top and bottom section of the bore hold represented.

21. Representative ditch samples or cuttings of the material penetrated were collected by means of a "Cope Sample." A grain size distribution curve was plotted for each sample for selection of type of casing as follows:

(a) blank casing opposite to silt and clay (less than 0.05 mm) formation and also formation containing more than 20% particles passing through 200-mesh sieve (0.074 mm); and

(b) slotted casing or otherwise.

In a few SCARP units, due to lack of sufficient productive aquifer, slotted pump housing sections were provided to utilize the shallow waterbearing formation that were encountered. The bore hole was then reamed to 28 inches in the pump zone.

Installation of Casing

22. The depth of pump housing casing was established for each tubewell depending on the future water levels anticipated. Lengths of the specified diameter of fiberglass casng was to be provided to extend the pump housing casing from the elevation of the top of the pump housing casing to the depth established by the Engineer.

23. The length and sizes of tubewell casing for each tubewell was specified to be sufficient to extend from the bottom of the pump housing casing to the bottom of the tubewell. The bottom of tubewell casing was provided with a bail plug. The tubewell casing consisted for slotted sections opposite water yielding formations and plain pipe sections in the lowest 5 ft (1.5 meters) of the tubewell and opposite non-water yielding formations. Mild steel and stainless steel pipes were plain ended, bevelled for electric welding. Fiberglass casing connectors consisted of a two-part coupling, male and female, factory cemented to the pipe ends in a tapered joint with cement of epoxy resin. The key slot coupling design permitted easy disassembly should it prove necessary to remove the casing from the tubewell during construction. Standard tolerances (1-1/2 inches at the bottom of the pump having casing) were set for the straightness, concentricity and verticality. Use of centralizers was specified. Verticality measurement of the steel pump housing casing performed during placement of gravel prior to placement of gravel and after completion of gravelling.

Gravel Shrouding

24. Gravel shrouding was placed in the annular space between the casing and the casing and the well bore, from the bottom of the drilled hole to the gravel surface. Earlier, the gravel was dumped manually into the well from bags, at a slow and even rate to avoid bridging. The amount of gravel ranged between 40 to 60 tons per well. Recently, tremic pipes and hopers have been used to minimize segregation. Rigid specifications for the general, including cleanliness, water wearing, roundness, carbonite content and gradation were adhered to. After gravel placing, the tubewell was bailed to consolidate the gravel shroud and to clean out excess material within the casng. The well cover is a 1/4 inch steel plate welded over the top of the casing.

Development and Testing

25. Each SCARP tubewell was developed to produce the design capacity of relatively sand free water with a minimum drawdown. Also, each tubewell was tested to determine the effectiveness of the development operations. Development and testing included surging, back-washing, and pumping the tubewell at higher than rated capacity; testing the tubewell for specific capacity, sand content and degree of development; and sterilizing and sealing each tubewell. A minimum development of six hours of pumping was required. In general, the following procedure was followed, but often modified to meet local conditions:

(a) note initial static level;

(b) initial pumping at 50% of design capacity and increase to 150% of design capacity in steps of 75%, 100% and 125%;

(c) at 50% and 75% of design capacity, pumping was continued for 15 to 30 minutes;

(d) at 100% and above, pumping for a minimum of one hour in each step with double back-washing of formation after each 5 or 10 minutes; and

(e) requisite sand contact tolerance prior to test; 100 parts per million at 5 minutes and 30 parts per million at 10 minutes after starting of pump.

The development of the tubewell was performed either (i) with double packer or (ii) by rawhiding. Development with double-packer. Compressed air was used through a compressor capable of developing a maximum pressure necessary at specified discharge rates for each section of the screen. A double packer arrangement, 5 ft long was provided at the bottom of the eductor pipe. All surging and pumping operations were conducted inside the double packer arrangement. Development by rawhiding. The development of the tubewell was performed for a minimum period of six hours by step pumping, back-washing and surging the tubewell with vertical turbine pump. The contractor was to notify the Engineer at any time following the completion of six hour pumping period that the tubewell is ready for testing.

26. After completing the development period and meeting the requisite sand content tolerance, the pump was stopped for one hour for water level recovery. The water level measured after the one hour of recovery, is referred to as the official static water level for future reference. A sounding was performed; if sand in the bottom of the well exceeds 5 percent of the total length of slotted casing, the test pump was to be pulled and the well was to be bailed to within 2 ft of bottom prior to testing. The testing was done following the recovery period. The tubewell was pumped for period of one hour at a test capacity specified, ranging between double the

tubewell capacity for sand test and three-fold the tubewell capacity at the fifth step.

Screen Material

27. The early SCARP I tubewells have suffered from rapid deterioration. The decrease in well discharge was mainly due to severe corrosion and encrustation of the mild steel screens. A few wells in SCARP I were equipped with screen material other than mild steel. These showed lesser deterioration. In the replacement of failure wells, brass screens were used. Subsequently, different screen materials have been used and experimented in the various SCARPs. The general concept was that the metallic screen was susceptible to more corrosion and encrustation and that if screen of some inert material were used, the reduction would be less. SCARP II, comprising 2,205 tubewells, was undertaken during 1962-71. Fiberglass was introduced as a screen material in this project. On the overall project basis, 1,718 tubewells were provided with fiberglass and 487 with mild-steel screens. In SCARP III and IV, 2,475 tubewells were installed during 1965-69. Sufficient data is now available to justify an attempt to examine the performance of various screen materials under the field condition. Stainless steel screens were also tried and installed in SCARP Khairpur.

28. A study was carried out in 1974 regarding the selection of screen material. It recommended that brass and stainless steel strainers are not economical, whereas mild steel appeared to be the best material for tubewell construction in non-corrosive environment. Fiberglass screens are less expensive than brass, but costlier than mild steel.

29. Another study was made by WAPDA (Central Monitoring Organization) and was based on monitoring the average rate of percentage reduction in specific capacity of each tubewell subsequent to acceptance. The study indicated that the behaviors of various screen materials vary from one tubewell to another, from scheme to scheme, and from project to project in respect of changes in hydrological and geo-chemical environments. The results of the study are summarized below according to Project:

(a) SCARP I. Of the total 2,044 tubewells, 1,584 were equipped with mild steel, 407 with brass, 39 with Ghafoor type, 12 with coir rope and 2 with TEJ strainers. The brass screen tubewells were superior to the mild steel tubewells; medium values of rate of percentage reduction in specific capacity were 3.7 and 6.2, respectively. Other screen material including PVC, coir rope, Ghafoor type, aluminum and asbestos showed poorer performance.

(b) SCARP II. Fiberglass screen has been used in majority tubewells in SCARP II. The performance of fiberglass is slightly better than mild steel screens; me........volumes of annual rate of reduction in specific capacity being 2.6 and 3.0, respectively.

(c) SCARP IV. Fiberglass screened wells deteriorated at a rate of 4.7% reduction in specific capacity. On the other hand, the performance of fiberglass services in SCARP Khairpur also had comparable to stainless steel; reduction in specific capacity was about 35% and 32%, respectively.

30. An evaluation performed in 1978 covered five different types of screen material used in SCARP tubewells, mild steel, brass, fiberglass, stainless steel, and PVC. Three criteria were considered, namely: (a) change in the specific capacity in the SCARP contents; (b) screen collapse resistance; and (c) screen suitability for development and rehabilitation. Review of the available reports on the subject in the past 20 years would indicate that no consensus has been reached as to which material is best suited for tubewell screens, nor has adequate information ever been available to fully substantiate an unequivocal selection of screen material for a specific application. The section below summarizes some of the main findings of WAPDA's recent evaluation report according to the principal criteria.

Change in the Specific Capacity in the SCARP Contents

31. Using tubewell specific capacity data collected by CMO during 1973/74, an analysis of the performance of tubewells in SCARPS I, II and Khairpur where more than one screen material was used and the performance of mild steel, brass, fiberglass, and stainless steel could be compared. Adequate data are not available to evaluate the performance of PVC or coir-rope strainers. Only fiberglass screens were used in SCARPS III and IV. The results are as follows:

(a) brass tubewells have consistently performed better than mild steel tubewells in SCARP I;

(b) fiberglass tubewells have performed better than mild steel tubewells in Khadir, Sohawa, and Phalia Schemes of SCARP II;

(c) the performance of fiberglass tubewells was slightly better than stainless steel in the saline groundwater zone of SCARP Khairpur and about the same in the fresh zone; and

(d) considering the overall performance of tubewells in various schemes, brass, fiberglass, and stainless steel have performed better than mild steel. There was no sufficient data to evaluate the performance of PVC screens.

Reduction in tubewell specific capacity may be due to one or more of a number of factors relating to the aquifer and to tubewell design, construction, and development, and can be independent of screen material used in the tubewell. Of the major factors leading to decline in specific capacity -- encrustation, organic clogging, invasion of fines, and corrosion is a factor in only mild steel screens. The other factors are essentially independent of screen material. The analysis based on the assumption that these factors are essentially similar in all the SCARP tubewells.

Screen Collapse Resistance

32. All the screen materials used appear to have sufficient strength to stand the forces normally encountered in a properly designed and constructed tubewell. Although the fiberglass screen is not of the same strength as the metallic screens, it was installed and has been operating successfully in thousands of SCARP tubewells since 1967. The collapse of the fiberglass screens that occurred in a number of North Rohri SCARP tubewells has raised questions about the strength of this material. However, it is reasonably certain that the collapses are at least partially due to abnormal stresses resulting from excessive sand pumping. No similar situation has occurred in any of the other SCARPs.

Screen Suitability for Development and Rehabilitation

33. Pack development and rehabilitation are easier and more complete and require less time in a screen with a high percentage open area. Screen material should also have sufficient strength to withstand vigorous mechanical or air surging, which are associated with all effective tubewell rehabilitation methods. Because of their inherent strength and an open area in excess of 30%, the wire-wound screens would be best suited for effective tubewell development and rehabilitation. Fiberglass screens used in the SCARPs are an open area of only 6% to 8% are the least suitable of all screen materials now under consideration.

ANNEX E

PRIVATE TUBEWELL TECHNOLOGY: FOCUS ON SHALLOW TUBEWELL DESIGN AND COSTS 1/

Introduction

1. Private tubewell development in Pakistan has followed various methods that are briefly described in the following sections. Given the importance of shallow tubewells, particularly in regards to a proposed SCARP Transition Program, most of this Annex concentrates on outlining present practices and potential for shallow tubewells; these contribute most of the current pumpage by private tubewells and offer the greatest potential for future development by the private sector.

Deep Tubewells

2. This category of tubewell is drilled using rotary-mud flush or percussion (cable tool) rigs and is designed to be equipped with either a vertical shaft turbine pump (with electric motor or diesel engine prime mover) or an electric submersible pump. Deep tubewells are constructed in the hill areas where the rocks are consolidated and water levels are deep. Drilling depths typically range from 250 to 400 ft. An exploratory pilot hole is usually drilled to total depth at 6-8 inch diameter, and if successful, is reamed to 16-18 inch diameter. The wells are lined with 8 inch or 10 inch diameter mild steel casing and brass filters and gravel packed. Pumping water levels may exceed 100 ft and well discharges range fro 1/8 to 1 cusec but are typically in the lower part of this range. Surface civil works include a pumphouse and surge chamber.

3. The cost of a fully equipped well is high (in the range of Rs 180,000-220,000) even with Government subsidized drilling. The life of the well is 15-20 years and an electric motor powered vertical shaft turbine or submersible electric pump has a 15-year life. Detailed cost estimates are given in Table 7.

1/ This Annex was based on materials prepared by W. Barber, Hydrologist Consultant for ACE/SGI.

Dug-cum-bored Wells

4. This type of installation is really a variation of a shallow tubewell with sump except that the dug section extends below the watertable. It is typically used for improving the performance of an existing dugwell by extending the yielding section to the well by boring. The technique can be applied in either alluvial or consolidated rock areas. Pumping installations and civil works are similar to private shallow tubewells. Well yields depend on aquifer conditions but should be comparable to shallow tubewells in alluvial areas.

Dugwells with Pumpset

5. This type of installation is typical of the valleys in the mountain zones of NWFP and Baluchistan. A large diameter (15-20 ft) well is dug to 5-10 ft below the water table. The saturated section is usually brick-lined and the entire cut section may be lined if the wall is unstable. Water levels are typically in the range of 40-100 ft. Electric motor-powered centrifugal pumpsets located as a unit in the well are preferred, but surface mounted diesel motors with a belt drive to centrifugal pumps can be used. Sustained well yields vary according to aquifer conditions but temporary high discharges can be obtained from well storage with a period allowed for recovery. Typical pump discharges are ± 1.0 cusec.

6. The cost of the dugwell varies according to diameter, depth, rock type and the amount of brick lining required. Pumping unit costs vary according to installed capacity. Average cost of these installations appears to be about Rs 60,000. A properly constructed well should have an extremely long life if adequately maintained. Electric motor powered centrifugal pumps have a life of 10-15 years.

Dugwells with Traditional Lifting Devices

7. The most common traditional lifting device is the Persian wheel and this is fitted on a hand-dug open well. Such water points have been rapidly replaced by diesel or electric motor powered pumps. They are suitable only for shallow water levels and then can irrigate only a very limited area.

Shallow Tubewell Design and Costs

8. One possible alternative for SCARP Transition is the replacement of the SCARP wells in usable groundwater areas by private sector, small capacity shallow tubewells. The term shallow tubewells refers rather to the methods of construction and pumping rather than the depth of the well. This note reviews the present design criteria and current cost estimates for shallow tubewells. Design and construction modifications which could result in savings in terms of capital, replacement and O and M costs are discussed. Particular attention is paid to design of fractional shallow tubewells (less

than 1 cusec discharge) which could be utilized by small farmers and the cost savings which could be achieved by such facilities.

Present Practices

9. Shallow tubewell facilities are almost exclusively designed to be operated using centrifugal pumps. Thus locating the pump within suction depth of the pumping water level is critical to the design. In areas where the pump cannot be located at land surface (the most common case), a brick-lined, concrete-floored sump (typically 8-12 ft diameter) is first constructed to rear the water table at the well site, the bore is drilled through the floor of the sump and the centrifugal pump is located in the sump delivering through a discharge pipe to a brick-built surge tank with outlet(s) to irrigation water channels. A brick-built pumphouse (over the sump) is provided for security of equipment located at surface.

10. Both diesel engine and electric motor powered pumping units are utilized, the farmer representing about 65% of the present stock of some 180,000 private sector, shallow tubewell facilities in Pakistan. In the case of diesel engine pumps located on wells with sumps, the power unit is located at surface with belt drive to the pumpset in the sump. The most common electric motor powered unit is the mono-block type with either V belt or shaft drive. The electrically energized units are connected to the national grid, the farmer being responsible for payment for the 11 KV line extension, the 11/0.4 KV transformer and the low tension (LT) connection, though a Rs 15,000 subsidy is available for this element of the facility. The present practice is to have an 11/0.4 KV transformer serving a single water point, thus minimizing the length of the LT connection, though a few cases with several pumps supplied through a single transformer have been observed.

11. While diesel engine powered pumping units still outnumber electrically energized units in the total shallow tubewell stock, there is now considerable farmer reluctance to installing diesel engines. This reflects the marked energy price differential which has developed in recent years between electricity and diesel oil, the latter being about three times higher cost to the farmer than the former for equivalent operations. This situation is discussed in detail later in this note (see para 31).

12. The vast majority of the private tubewells are designed and equipped for discharges in the range of 1-1.5 cusecs and the average tubewell discharge for private wells on the Indus plain is reported to be 1.2 cusecs. The tubular components of the wells are usually completed at 6 in diameter and well depths range from 100 ft to more than 200 ft. Mild steel casing with a screen of coir rope wrapping on a mild steel cage is the most common construction. Such tubewell components have a life of 4 to 7 years, the former life being typical of Sind and the latter of Punjab. These relatively short lives reflect both the corrosive and accretionary characteristics of the groundwater.

13. Mild steel casing with brass screens and cement pipes slotted for this screened section have been installed in private tubewells but are less commonly used at present. Use of PVC pipe with slots on the screened section is a relatively recent innovation but it has not found common application. Brass screens and either slotted cement or slotted PVC pipe usually require gravel packing to control sand pumping. Such well construction materials have a longer life than mild steel casing and coir rope wrapped screen. Wells with brass screens in excess of 10 years old have been observed in northern Punjab, though they have suffered some reduction in yield, probably due to encrustation on the screen apertures. The life of a PVC well is believed to be about 15 years. All these materials have higher costs than the mild steel with coir rope wrapped screen. Moreover, the cement pipe and screen requires very careful emplacement if the well is to be successful and few of the drillers have experience of use of PVC pipes and screens.

14. The wells are drilled by baling using a simple tripod and pulley apparatus with working casing to keep the hole open during drilling. Manpower is commonly used by this may be replaced by a winch. The rule of thumb for manpower is one laborer per inch diameter of drilled hole. Bores are opened at 8-10 in diameter for completion with 6 in diameter casing.

Effectiveness of Present Practices

15. The drilling technique is suitable for the relatively soft alluvial sediment consisting principally of sand on the Indus Plain. The technique is well established and there is a strong private sector drilling capacity in Punjab and Sind. In addition, the Agricultural Engineering Departments in these provinces provide custom drilling services to farmers at subsidized rates. The department in Punjab operates 226 sets of hand-drilling equipment plus several winch operated sets and can complete 3,500 tubewells per year -- the Sind government operates 50 hand-drilling equipment with a proportional rate of well completion. It is considered that the drilling technique is most appropriate for the local conditions, does not have a financially competitive alternative, and that there is basically no constraint due to drilling capacity if the availability of both public and private equipment are taken into account.

16. The use of mild steel casing and coir rope wrapped screen provides an effective well though the life is short relative to alternative available tubular materials. Failure may be due to reduced yield resulting from clogging of the filter by accretionary material or rotting of the coir leading to sand pumping. Part of the tubular materials may sometimes be recovered for reuse at least once in the replacement well. Several wells may be constructed in sequence though the same sump and the pumphouse does not require replacement but can be maintained.

17. An analysis has been made to compare the investment decision between a well with mild steel casing with coir rope wrapped screen and one constructed with PVC materials. The analysis computed the present value of the

capital investment and replacement costs of the drilled, cased and screened components of the alternatives. It was assumed that, with a seven year life, the mild steel casing from the coir rope screened alternative could be recovered for reuse in the second of a pair of replacement cycles, whereas all the tubular components were written off and replace with this type of material with a four year life. The PVC well was given a life of 14 years and none of the tubular materials were recovered at replacement. A discount rate of 12% was assumed and the analysis is in financial terms.

18. The results of the analysis is summarized by Table 2 and the basic cost data were abstracted from the cost estimates given in Table 3. The analysis shows that there is only a minimal difference in present. Value between the mild steel-coir rope wrapped screen alternative and the PVC construction so long as the former has a life of seven years and the mild steel casing can be used twice. This is a typical situation in most of Punjab and NWFP. Given the easy availability of mild steel casing and coir screen, the drillers' experience with these materials and some uncertainty about the real life of a PVC well in highly accretionary conditions, the farmers' decision to opt for the lower capital cost unit is generally financially correct. However, in Sind where the coir screened well life may be as short as four years, there could be considerable financial advantage in selecting to construct a well of PVC materials if the life assumptions are correct. It would appear that there are no financially competitive alternatives to mild steel -- coir rope screen materials or PVC pipes.

19. As stated previously, the use of a centrifugal pumping unit usually requires provision of a sump in the upper part of the well to maintain the pump setting within suction depth. The cost of the sump may represent a considerable proportion of the total cost of the well component of the tubewell facility -- ranging from 26% to 45% in the cost estimates shown by Table 3 for mild steel, coir wrapped screen. These would be a considerable cost saving on the well if it was drilled can cased from surface but this would demand installation of a turbine pump, the additional cost o which could outweigh the saving on the well. However, it should be noted that small capacity submersible electric pumps are available of Indian manufacture which are competitive with their locally manufacturized centrifugal units and, moreover, Indian pumps are very competitive against world market prices. The farmer would be essentially independent of water level fluctuations with a submersible electric pump. On the other hand, accessibility of the motor could pose problems given the quality of the power supply and the frequency of burn-outs.

20. Most of the diesel engines installed are low speed units which are robust and easily maintained. High speed engines have been made available in recent years. The exiting units are often over-powered and use of belt drive lowers the efficiency. Over-powered motors are also common with electrical pumping units. This may not involve particularly marked increase in capital cost and the heavier winding provides protection against motor burn-out. However, fitting oversized motor has an operation cost implication due to the

relatively high fixed charges based on connected motor capacity, particularly if the utilization is low. A comparison is given below of the energy cost of fitting a 15 HP motor to perform a 10 HP duty for a range of operation hours using Punjab electricity tariff for agricultural pumping.

Utilization (h/annum)	Installed Motor Capacity 10 HP	15 HP	Cost Increase (%)
	Annual Energy Cost (Rs)		
2,000	5,133	5,983	17
1,500	4,275	5,125	20
1,000	3,417	4,267	25

Note: The energy consumption by the 15 HP unit is taken at the 10 HP rate though it could be somewhat higher

21. Diesel engine pumpsets require replacement after 8 to 10 years, while electric motor sets last 10 to 15 years. Any saving in capital cost of diesel engine powered facility as compared to an electric motor unit due to the high cost of the power connection is discounted with a few years due to the markedly lower energy cost for electrical pumping. Mechanical services are easily available for both diesel engines and electric motors.

22. The suction and delivery pipe work on pumping units is usually properly sized and bends are minimized. However, the delivery is typically taken 5-6 ft above ground level and the water dropped into the surge tank, the farmers being apparently unaware of the energy cost implications of the unnecessary lift.

23. The practice of extending the 11 KV line to the water point, providing an individual transformer and minimizing the length of the LT connection is good for the power distribution system as it avoid the losses on extended 0.4 KV lines. But it can involve high capital expenditure to the farmer. Cost savings would be possible by having a suitably sized 11/0.4 KV transformer serve a group of wells but the decision to like this route should be taken with caution as there is ample evidence that the electrical distribution system is already overloaded in the lower voltage range as evidenced by the existing frequency of motor burn-outs. Care would be necessary to ensure the application of rigorous design criteria for the extended network and, in many cases, some improvement of the existing transmission facilities.

Cost Estimates for Shallow Tubewell Facilities

24. Cost estimates for typical 1 cusec tubewell elements and for complete tubewell facilities are given in Table 2 and 3 respectively. The estimates are based on current. Punjab prices and assume a static water level at 22 ft. depth and a sump of 12 ft diameter to 20 ft depth. The cost of the power connection is taken as Rs 35,000 from which is deducted a Rs 15,000 subsidy.

25. Considering only the well element (sump and bored section), the costs of mild steel casing with coir rope wrapped screen are compared with PVC pipe and screen construction for a range of total depths in the summary below:

Well Type	Total Well Depth (ft)			
	120	150	200	250
	Well Element Cost (Rs)			
Mild steel casing with coir wrapped screen	13,450	16,000	19,150	23,300
PVC casing and screen with gravel pack	16,300	19,000	22,450	26,930
Difference	2,850	3,000	3,300	3,630
% increase	21	19	17	16

26. The total costs of a tubewell facility complete (well, well head civil works, pumping unit and power connection in the case of electric motors) are compared below for 1 cusec wells to a range of depths equipped with either electric motor or diesel engine driven pumps.

Well and Pump Type	Total Well Depth (ft)			
	120	150	200	250
	Tubewell Facility Cost (Rs)			
A. Electric Motor Pump /a				
Mild steel casing with coir wrapped screen	52,450	55,000	58,150	62,300
PVC casing and screen with gravel pack	55,300	58,000	61,450	65,930
B. Diesel Motor Pump				
Mild steel casing with coir wrapped screen	43,800	46,350	49,500	53,650
PVC casing and screen	46,650	49,380	52,800	57,280

/a Includes a power connection cost estimated at Rs 35,000 less a subsidy of Rs 15,000.

Fractional Shallow Tubewells

27. Fractional tubewells are defined at facilities designed and constructed for yields of less than 1 cusec. Such units have application for farmers cultivating less than 20-30 acres who do not have the opportunity of

appreciable water selling. A farmer within a perennial command area of surface water, cultivating 50 acres and operating a 1 cusec tubewell could achieve a high irrigation intensity with either a rice-wheat or cotton-wheat cropping patter with some fodder (160-180% intensity over kharif and rabi). Farm budget analyzes based on current prices have shown that the operation becomes financially non-viable with an electrical power supply of the cultivated area falls below about 20 acres for a rice-wheat cropping pattern with 170% irrigation intensity and 17 acres for a cotton-wheat pattern with a similar intensity if water selling is not available. The cross over acreage to financial non-viability is considerably higher for tubewell facilities equipped with diesel engines due to the markedly higher cost of energy.

28. However, it should be noted that water selling at current prices (Rs 8-14/h for electric motor pumps and Rs 20-25/h for diesel installations with a 1 cusec supply) is relatively profitable to the farmer. For example, the financial rate of return to water selling at a rate of Rs 14/h from a 150 ft deep facility, constructed with mild steel casing and coir wrapped screen and equipped with a 1 cusec electric motor pump, is higher than direct use of the water for irrigating a rice-wheat cropping pattern. This explains why a number of entrepreneurs who are not farmers have found it profitable to invest in a shallow tubewell facility and set up as water masters.

29. Significant capital and replacement cost savings could be made by installing fractional tubewells on small farms. In the case of electric motor powered pumps, there would be also a significant energy cost saving due to the lower fixed charge on the lower installed capacity prime mover. Table 4 gives cost estimates for an 0.5 cusec shallow tubewell equipped with either an electric motor or diesel engine pump. The well is assumed to be 120 ft deep and 20 ft deep sump and a pumphouse is provided. The cost of the power connection is taken as Rs 35,000 from which a subsidy of Rs 15,000 is deducted. The facility is therefore comparable with the 1 cusec facility to 120 ft depth costed in Table 3, and a cost comparison is summarized below:

Pump Unit Type	Facility Capacity (Cusec) 0.5	1.0
	Capital Cost (Rs)	
Electric motor pump	45,300	52,450
Diesel engine pump		

Note: Casing of mild steel with coir wrapped screen.

30. It will be noted from Table 4 that the power connection, which includes an exclusive transformer, represents 44% of the capital cost of the facility if the connection subsidy of Rs 15,000 is deducted. If the total

cost of the power connection is taken into account, this element represents 58% of the capital cost of the facility. It is evident sharing of the 11 KV line extension and 11/0.4 KV transformer between several wells would be advantageous to the farmer and could benefit the GOP if the connection subsidy element could be reduced or eliminated. However, the proviso, stated previously, that strict design criteria for the electricity distribution network must be maintained would still apply.

Diesel Engines versus Electric Motors

31. Despite the fact that diesel engine powered pumps still outnumber pumps with electric motors, there is now a definite farmer preference for main power and an increasing reluctance to install diesel engines. This situation reflects the price differential between diesel oil and main power energy.

32. The price of light diesel oil (LDO) increased only slowly to about Rs 1/liter (ex depot) up to 1979 and was kept constant at a little below this price from 1974 to 1978. The last four years have seen a more than three-fold increase in the price of LDO. The typical price paid by the farmer is now about Rs 3.2/liter. A subsidy of 20% is, in theory, available to the on the cost of diesel used for pumping, but is paid only at the end of year and the application must be supported by purchase receipts. Few farmers apply for the subsidy in the face of the bureaucratic disincentive.

33. In comparison to LDO, agricultural energy from the main power system is subsidized in the actual price charged to the consumer. In 1981-82, the average sale price to all consumers on the WAPDA system (the principal source of agricultural electricity) was Rs 0.52/kwh compared to Rs 0.35/kwh for agricultural energy. Tariffs are increased annually in line with GOP's policy to gradually eliminate subsidies, but it will take years before the agricultural tariff can be expected to cover generation and transmission costs. The long-run marginal cost of electricity (on a system which has a power shortage of about 20% foreseen to continue for the next decade) is estimated to be about Rs 0.58/kwh during peak hours and Rs 0.50/kwh for off-peak hours. The present tariff for agricultural pumping in Punjab and Sind is a fixed monthly charge on installed motor capacity of Rs 19/kw plus a material unit consumption charge of Rs 0.23/kwh.

34. Consider the case of a farmer operating a 10 HP diesel engine pump for 18,000 h/year with a fuel cost of Rs 3.2/liter, compared to a farmer operating a 10 HP electric motor pump with the same utilization and Punjab/Sind energy prices. Their annual energy costs would be about:

diesel motor	-	Rs 12,600
electric motor	-	Rs 4,800

It is evident that, with the above energy cost difference, the higher capital cost of a facility with an electric motor powered pump (see Table 3) would be discounted within a few years.

35. Diesel engines are more difficult to maintain than electric motors and require regular servicing by a skilled mechanic. On the other hand, there is a high incidence of electric motor burn outs, reflecting the poor quality of the energy supply, and a motor rewind costs about Rs 800. Installation of a capacitor and a low voltage regulator in the starter relay (at relatively small extra cost) would provide protection against voltage drops in the electrical distribution system.

Cost Estimate for a Deep Tubewell, 0.5 cusec Capacity

Assumptions: Total Well Depth - 350 ft
Static Water Level Depth - 80 ft
Pumping Water Level Depth - 110 ft

Item	Description	Unit	Unit Cost (Rs)	Number	Total Cost (Rs)
1.	Mobilization	sum	-	-	1,500
2.	Drilling 8" diameter exploratory hole	ft	16	350	5,600
3.	Reaming to 18" diameter	ft	40	350	14,000
4.	Bentonite and water for drilling	sum	-	-	7,000
5.	Supply and installation of 10" MS casing	ft	190	270	51,300
6.	Supply and installation of 10" brass screen	ft	240	80	19,200
7.	Bail plug and specials	sum	-	-	2,000
8.	Gravel packing	sum	-	-	3,500
9.	Well development	sum	-	-	3,000
	Sub-Total				107,100
10.	Well head civil works (pumphouse, surge tank)	sum	-	-	7,000
11.	Deep well turbine pump with electric motor, rising main and delivery pipe	sum	-	-	78,000
12.	Installation and wiring	sum	-	-	3,000
13.	Power connection (less Rs 15,000 subsidy)	sum	-	-	20,000
	Total				215,100

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ANNEX E
Table E/

ANNEX E
Table E.2

PAKISTAN

Present Value of Capital and Replacement Costs for Replaced

Tubewell Elements with Different Construction Materials and Lives 1/

(Discount Rate - 12%)

Well Type	PVC Casing and Screen (14 yr life)	MS Casing Coir Screen (7 yr life)	MS Casing Coir Screen (4 yr life)
Well Depth (M)	Present Value (Rs		
120	11,078	10,908	16,029
	(10,300)	(7,450)	(7,450)
150	13,982	14,015	20,413
	(13,000)	(10,000)	(10,000)
200	17,693	18,060	26,206
	(16,450)	(13,150)	(13,150)
250	22,587	23,239	33,514
	(21,000)	(17,400)	(17,400)

1/ See Table ... for detailed investment cost.

NOTE: Figures in brackets show initial capital cost for tubewell elements; sump, pump house and surge tank are not included. The life of the MS casing and coir screen tubewell is a function of the corrosiveness of the groundwater - the 7 year life is typical of Punjab and the 4 year life represents parts of Sind.

ANNEX E
Table E.3

PAKISTAN

Cost Estimates for Shallow Tubewells to a Range of Depths

Assumptions: Depth to static water level - 22 ft
Depth of sump - 20 ft
Diameter of sump - 12 ft
Design discharge - 1 cusec

Item	Description	Unit	Unit Cost (R)	Total Well Depth (ft) 120		150		200		250	
				No. of Units	Cost (R)	No. of Units	Cost (R)	No. of Units	Cost (R)	No. of Units	Cost (R)
1.	Mobilization	sum	-	-	1,000	-	1,000	-	1,000	-	1,000
2.	Construction of sump (20 ft deep)	sum	-	-	6,000	-	6,000	-	6,000	-	6,000
3.	Drilling (8" diam)	ft	25	100	2,500	130	3,250	180	4,500	230	5,750
4.	Supply and installation of 6" diam, MS casing	ft	60	25	1,500	55	3,300	85	5,100	135	8,100
5.	Supply and installation of coir wrapped screen	ft	30	75	2,250	75	2,250	75	2,250	75	2,250
6.	Well development	sum	-	-	200	-	200	-	200	-	200
	Sub-Totals				13,450		16,000		19,150		23,300
7.	Well head civil works (Pump house, surge box)	sum	-	-	6,000		6,000		6,000		6,000
	Totals				19,450		22,000		25,150		29,300
	Substituting PVC materials for items 4 and 5 plus gravel pack-cost increase				2,850		3,030		3,300		3,630
	Totals for PVC tubewells				22,300		25,030		28,450		32,930

ANNEX E
Table E.4

PAKISTAN

Summary of Costs for Shallow Tubewell Units

Item	Description	Total Well Depth (ft)			
A.	With Electric Motor Pumps	120	150	200	250
		Cost (Rs)			
1.	Well (MS casing, coir wrapped screen)	13,450	16,000	19,150	23,300
2.	Well head civil works	6,000	6,000	6,000	6,000
3.	Pumping unit (1 cusec)	13,000	13,000	13,000	13,000
4.	Power connection (less Rs 15,000 subsidy)1/	20,000	20,000	20,000	20,000
	Total	52,450	55,000	58,150	62,300
	Above with PVC casing and screen	55,300	58,030	61,450	65,930
B.	With diesel motor pumps				
1.	Well (MS casing, coir wrapped screen)	13,450	16,000	19,150	23,300
2.	Well head civil works	6,000	6,000	6,000	6,000
3.	Pumping unit (1 cusec)	24,350	24,350	24,350	24,350
	Total	43,800	46,350	49,500	53,650
	Above with PVC casing and screen	46,650	49,380	52,800	57,280

1/ The power connection cost varies in relation to the location of the well relative to the existing power line - farmers may group together to share the cost of line extension.

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ANNEX E
Table E.5

PAKISTAN

Cost Estimate for 0.5 Cusec Shallow Tubewell Unit (120 ft deep)

Item	Description	Unit	Unit Cost	No. of Units	Total
1.	Mobilization	sum	-	-	1,000
2.	Construction of sump (20 ft deep)	sum	-	-	6,000
3.	Drilling at 6" diameter	ft	16	100	1,600
4.	Supply and installation of 4" diameter, MS casing	ft	40	25	1,000
5.	Supply and installation of 4" diameter coir wrapped screen	ft	20	75	1,500
6.	Well development	sum	-	-	200
7.	Pump house and surge box	sum	-	-	6,000
	Total well cost				17,300
8.	Pumping unit complete (electric motor)	sum	-	-	8,000
9.	Power connection less Rs 15,000 subsidy	sum	-	-	20,000
	Total tubewell unit complete				45,300
	Substituting a diesel engine powered pumping unit - total tubewell unit complete				31,650

ANNEX F

SUBSIDIES FOR PRIVATE TUBEWELL DEVELOPMENT 1/

Cash Subsidies for Tubewell Construction

1. Both Punjab and Sind provide cash subsidies of Rs 16,000 to selected applicants in the tail-ends of perennial command areas and in seasonal areas. Such conditions would be applicable in parts of SCARP I and SCARP N. In both cases, the subsidies are directed to small and marginal farmers (< 25 acres and < 12.5 acres respectively) and in the case of Punjab, preference is given to subsidizing diesel engine facilities. Subsidy applications are subject to rigorous vetting to ensure that the grant conditions are met.

2. In 1981-82, Punjab had budget to finance only 1,100 subsidies out of about 3,000 applicants and a proportion of the grants were directed to applicants farming in barani or riverine lands or where wells encounter hard strata - such areas lay outside the command areas. The wells subsidized represented about 13% of the new wells constructed in Punjab during 1981-82. Similar conditions pertain in Sind which has a much smaller existing stock of private tubewells and in annual growth rate of numbers of new facilities constructed. Both provinces have a large backlog of qualified applicants and the knowledge that few applications will be successful is a disincentive to farmers applying, so these is considerable suppressed demand.

Power Connection Subsidies

3. A subsidy of up to Rs 15,000 is available for tubewell connections to the WAPDA grid, but availability is again subject to budget limitations. WAPDA admit that preference is given to connection applications for which subsidy is not requested.

4. WAPDA has a commitment under the next five-year plan (1983/84-1988/89) to make tubewell connections at the rate of 5,000/year and, in addition, to connect 3,000 villages each year to the rural grid. The tubewell connection target has been historically exceed and WAPDA has actually made connections at the rate of 7,000-8,000/year in recent years. A general complaint in the agricultural sector is the slow rate of making connections and delay periods can range up to 1-1/2 years even for accepted connections.

1/ This Annex was based on materials prepared by W. Barber, Hydrologist Consultant for ACE/SGI.

5. The general practice is to extend the 11 kV line to the well head, provide an individual 11/0.4 transformer and minimize the low tension connection. As the total cost is taken against the tubewell investment, it usually far exceeds the subsidy of Rs 15,000, and the practice is selective towards the richer, larger farmer. On the other hand, the design practice is good for the power supply system which is already over-extended and over-loaded, as evidenced by the frequency of motor burn-oils.

Drilling Subsidies

6. The Agricultural Engineering Departments of Punjab and Sind operate drilling equipments which provide custom service drilling services to farmers at subsidized rates. The Punjab department has 226 sets of hand drilling equipment and 10 winch operated sets; Sind has 60 sets of hand operated equipment and to winch sets. As an indicator of what this capacity means in terms of well completion - the Punjab operation can complete about 3,500 tubewells per year on about 15 wells per year per set of equipment. This represent about 40% of the new tubewells constructed in the Punjab in 1981-82.

7. The actual monetary value of the subsidy is difficult to determine as the farmer commonly provides a labor input for hand drilling with the skilled operator and equipment provided by the department. However, the fact that farmer demand for this custom service exceeds the capacity of the departments to supply indicates that the farmers regard the service as preferable to private drilling which is also available in the provinces.

8. It should be noted that the service only provides for drilling and lowering of the casing and screen, the tubular materials being provided by the farmer. All other well cost are born by the farmer and thus the subsidy can only represent a relatively small proportion of well construction cost and of the cost of the total tubewell facility. The data tabulated below are based on cost estimates for 1 cusec tubewell installations with mild steel casing and a coir wrapped screen, and a 20 ft deep sump; the total tubewell installation includes an electric motor powered pump, brick-built pump house and surge tank and the cost of electricity connection, less Rs 15,000 subsidy, charged to the farmer at Rs 20,000. All costs are at commercial rates.

	Well Depth (ft)			
	120	150	200	250
1. Drilling and pipe lowering (Rs)	2,500	3,250	4,500	5,750
2. Total well cost (Rs)	13,450	16,000	19,150	23,300
3. Item 1 as % of item 2	18.6	20.3	23.5	24.7
4. Total tubewell installation (Rs)	52,450	55,000	58,150	62,300
5. Item 1 as % of item 4	4.8	5.9	7.7	9.2

Electricity Tariff Subsidies

9. Agricultural energy is subsidized in terms of the actual cost to WAPDA of generation, transmission and distribution, the charges made to other consumers on the system, and the long-run marginal cost of electricity on a system which working to its limits, is subject to rationing and on which there is much suppressed demand. In 1981-82, the average sale price to all consumers on the WAPDA system (based on metered units consumed and revenue collected) was Rs 0.52/kwh. This should be compared to an average sale price to agricultural consumers in the same year of Rs 0.35 kwh. In 1981-82, agricultural consumption represented 25% of total consumption on the WAPDA grid which is almost the exclusive source of agricultural power supply (82% of the agricultural consumption was in the Punjab where 73% of the agricultural consumers were located).

10. Using the above figures to determine the weighted average sale price of electricity to non-agricultural consumers in 1981-82 provides the following result

$$25 \times 0.35 + 75 X = 0.52$$

$$X = 0.58$$

where X = sale price to non-agricultural consumers in Rs/kwh

Non-agricultural consumers were paying 66% more than agricultural consumers for energy from the WAPDA grid.

11. The current tariffs for energy for agricultural pumping in the Punjab and Sind are based on a monthly fixed charge of Rs 19/kW of connected load plus a metered consumption charge of Rs. 0.23/kwh. The front and loading of fixed charges is biased in favor of pumping operations involving a high level of facility utilization. Consider an operation using a 10 kva pump operating for 2,000 h/year as compared to operating at 1000 h/year. In the first case, the sale price of energy would be Rs 0.34/kwh; in the second case it would be Rs 0.46/kwh. It is evident that high utilization of facilities must be achieved to maximize on the agricultural pumping energy subsidy. This can, with the present 1 cusec facilities, be most easily achieved by large farmers or by well owners able to sell considerable quantities of water. With traditional tubewells requiring lower capacity prime movers, higher utilization and thus lower energy costs can be achieved which would benefit small farmers.

12. The long-run marginal cost of electricity at the 11 kv level is estimated to be Rs 0.58/kwh during peak hours and Rs 0.50/kwh for off-peak power. As the WAPDA system is now subject to general rationing, it is in reality operating close to peak conditions all the time. Additional agricultural load subsidy should be measured against provision of addition power system capacity.

Diesel Oil Subsidy

13. A subsidy of 20% is theoretically available to the farmer on the cost of LDO used for pumping. Application for the subsidy must be made at the end of the year and must be supported by purchase receipts. Few farmers apply in the face of bureaucratic disincentive.

Agricultural Credit Terms

14. Term credit for tubewell investments are available at 11% interest. A grace period for repayments is not granted. Land is typically used for mortgage. The loans are granted for up to 3 years. By comparison, loans for non-agricultural investments carry interest charges of 14% and land is not normally accepted as security.

ANNEX G

INSTITUTIONAL CREDIT FOR PRIVATE TUBEWELL DEVELOPMENT: ADBP's PAST AND FUTURE LENDING PROGRAM

Introduction

1. Should it be concluded that SCARP Transition can be achieved in whole or in part by replacement of the existing SCARP tubewells by private sector shallow tubewells, it may be foreseen that this would create a demand for institutional credit. The Agricultural Development Bank of Pakistan (ADBP) has been, and it may be foreseen, will be the major source of institutional credit for medium and long term loans to the private agricultural sector. Their loan portfolio has been and will continue to be dominated by loans for agricultural machinery, mainly tractors. However, it is ADBP policy to diversify their lending program, and an element of the program, and an element of the program which it is aimed to strengthen is categorized as minor irrigation an actually consists mainly of lending for shallow tubewells on the Indus Plain. This note reviews the past performance of ADBP in lending for minor irrigation and their future lending program and policies for this sub-sector. Research is also required into the activities of other institutional credit sources - commercial banks and cooperatives - in medium and long term lending for shallow tubewell facilities.

ADBP Historical Lending for Minor Irrigation

2. Historical lending for minor irrigation has been dominated by investments in tubewells. About 88% of the existing private tubewells are in the Punjab and this province has absorbed a similar proportion of ADBP disbursement under this head. This trend may be expected to persist into future because Punjab has the major portion of the unexploited resource. The availability of groundwater resource for development should not become a constraint on investment during the next 5-10 years except in limited localities. The rate at which development will proceed will therefore depend on the enthusiasm for participation by the private sector, the availability of subsidy, the availability of well construction capacity (probably not a major constraint in Punjab when there appears to be a well established private sector capacity), and the availability of power connections or the degree to which farmers can be encouraged to accept the diesel alternative. Recent history has shown that the price margin between poer system energy and diesel oil is now a marked disincentive to the installation of diesel units by the private sector.

1/ This Annex was based on materials prepared by W. Barber, Hydrologist Consultant for ACE/SGI.

3. The historical growth in number of private tubewells and ADBP participation from 1964/65 to 1981/82 is tabulated by years in Table 1. The total number of tubewell units increased from 23,000 to some 186,000 in that period. Average increase in number of tubewells was 9,500/year with a range of 4,000 (1978-79) to 22,000 (1975-79). ADBP participation has been, on average, an investment in about 20% of the units installed each year (assuming the recorded disbursements were mainly against new units) with a range of 6% (1980-1) to 44% (1966-67). In 1981-82, ADBP provided funds for 745 minor irrigation investments, representing only about 7% of the annual increase in units installed in that year.

4. The average disbursement against tubewell investments in 1981-82 was Rs 27,650. The bulk of the investment was in the Punjab. The cost of a new tubewell facility including power connection charge less subsidy was then on the range of Rs 50,000 - 60,000. Allowing 10% for the farmer's contribution, the additional funds required for full financing would have been in the range of Rs 45,000 - 54,000. If most of the loans were for new installations, it is implicit the ADBP provided less than the full investment requirement. However, the consolidated records studied did not categorize within the tubewell loans and it is possible that a significant proportion of the lending was for replacement weeks or pumps.

Future ADBP Lending Program

5. While lending for minor irrigation (tubewell facilities) is expected to remain a relatively small proportion of the ADBP loan portfolio in the period 1982-83 to 1984-85 (increasing from 2% to 7% in that period), the program for this type of investment is, nevertheless, _______ when viewed in terms of past history. The tabulation below attempts to convert the projected ADBP annual disbursement for tubewell investments under two conditions:

(a) Case 1 - the loan amount corresponds to the average loan in 1981-82 with a price escalation of 10% per annum; and

(b) Case 2 - the loan amount corresponds to the full investment less farmers contribution of 10% (assumed to be Rs 56,000 in 1981 including power connection) with a price escalation of 10% per annum.

Base Year	Disbursement in year (Rs M)	Average Loan amount- Case 1 Rs	No. of loans	Average Loan amount- Case 2 Rs	No. of loans
1981-82	20.57	27,650	745	56,000	
Forecast					
1982-83	45.00	30,400	1,480	61,600	730
1983-84	130.00	33,500	3,880	67,800	1,920
1984-85	315.00	36,800	8,560	74,500	4,230

6. It will be noted that Case 1 implies that some 8,560 loans will have to be made in 1984-85 - an eleven-fold increase on 1981-82 and more than twice the number of loans in the best historical year (3,566 in 1974-75). Under the conditions of Case 2, 4,230 individual loan disbursements would have to be made in 1984-85, again a large increase on the recent record.

7. Given the ADBP policy for loan diversification and for expansion in the tubewell subsector, the implication is that there will be no shortage of credit for tubewell investments in future years from this institution. Should SCARP Transition activities in the future generate demamd for credit against tubewell facilities in excess of the ADBP forecast, there can be little doubt that their minor irrigation lending program could be expanded to meet the demand without upsetting the balance of the overall portfolio which is presently weight vary heavily to tractor loans. As mentioned previously, the expanded minor irrigation lending program would, if achieved, form only about 7% of the total ADBP loan portfolio in 1984-85. In fact, it may be stated with considerable certainty that ADBP will experience difficulty in fulfilling their ambitious minor irrigation expanded lending program in the absence of some parallel activity such as SCARP Transition. Moreover, that institution should also welcome the opportunity of large-scale scheme lending which could be planned and could offer the possibility improved technical standards and quality control of private sector tubewell investments which are normally very difficult to achieve.

ADBP Individual Loan Policy

8. ADBP loans for private tubewell installations are made against land mortgages by individuals or several individuals. In the latter case the names of the joint loanees and their mortgaged lands and other institutional debt commitments are recorded on the loan documents. ADBP does not, and presently refuses to consider loans to cooperatives or similar organized groups. Under this category would fall the 'water users associations' for which provincial ordinances have recently been promulgated. Since the successful implementation of a SCARP Transition Program will involve organized farmer groups, it will be important for ADBP to reconsider its current lending policies. Hopefully, ADBP would provide credit to appropriately organized farmer groups who would provide acceptable security (e.g. land, and if not possible, on the tubewell itself).

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Historical Growth of Private Tubewell Units in Pakistan and Participation of ADBP in Terms of Numbers of Units and Loans

Year	No. of Units Pakistan /a	Annual Increase /a	Tubewell Loans ADBP	% of	Total Amount Loaned (RM)	Average Loan Amount (Rs)
1964/65	23,000	-	800	-	10.9	13,650
1965/66	33,000	10,000	2,100	21	29.5	14,050
1966/67	40,000	7,000	3,100	44	31.0	10,000
1967/68	49,000	9,000	2,751	31	30.3	11,000
1968/69	59,000	10,000	2,700	27	24.8	9,200
1969/70	68,000	9,000	2,092	23	19.2	9,200
1970/71	82,000	14,000	1,714	12	18.7	10,900
1971/72	89,000	7,000	1,790	21	18.4	10,300
1972/73	99,000	10,000	2,389	24	26.4	11,050
1973/74	110,000	11,000	2,922	27	45.0	15,400
1974/75	121,000	10,000	3,566	36	74.5	20,900
1975/76	143,000	22,000	2,357	11	47.6	20,200
1976/77	150,000	7,000	1,364	19	25.7	18,850
1977/78	157,000	7,000	500	8	10.8	18,600
1978/79	161,000	4,000	543	16	10.1	18,600
1979/80	167,000	6,000	425	7	9.2	21,900
1980/81	176,000	9,000	565	6	13.6	24,200
1981/82	186,000	10,000	745	7	20.6	27,650
Means		9,500		20		

/a Rounded to nearest thousand.

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Projection of Numbers of Private Tubewell Units to be Financed by ADBP according to the 1982/83 to 1984/85 Loan Program With Alternative Individual Loan Amount Assumptions

Base Year	Disbursement in Year (RM)	No. of Loans	Average Amount of Loan /a (Rs)	Assumed Average Investment Less 10% /b (Rs)	No. of Loans by ADBP if Financed for Full Investment Less 10%
1981/82	20.57	745	27,650	56,000	-
Forecast					
1982/83	45.00	1,480	30,400	61,600	730
1983/84	130.00	3,880	33,500	67,800	1,920
1984/85	315.00	8,560	36,800	74,500	4,230

/a Average loan amount for 1981/82 has been given a price escalation of 10% per annum.

/b The assumed average investment is an approximate weighted average allowing for dominance of Punjab type units, includes an electrical connection charge or a proportion of diesel units, deducts 10% of total cost for farmer's contribution and is escalated at 10% per annum.

ANNEX H

POWER SUPPLY FOR TUBEWELL DEVELOPMENT 1/

Introduction

Generation

1. Pakistan's total installed generating capacity in June, 1982 was 4,035 MW of which 1,847 MW (46%) was hydro, 1,395 MW (35%) steam, 656 MW (16%) gas turbines and 137 MW (3%) nuclear. The effective maximum capacity is 3,790 MW due to derailing of old fossil fuel plants. Hydro developments are located on the Indus river and its tributaries in the northern part of the country. Thermal installations are mainly concentrated in three generation poles - Multan, Guddu and Karachi - along a narrow, north-south corridor. The generation centers are interconnected by 500 kv and 220 kv lines, and the intensity of the former VHT network is being strengthened.

2. The operation of the generation system is determined by the season. Most of the hydro electricity is generated from July to December when discharges on the rivers are high. The bulk of the thermal generation occurs during the rest of the year. This generation pattern poses transmission problems given the large distance between the sources of the two types of power supply.

3. No new hydro power projects are planned before 1990 but the addition of additional turbine units at Tarbela (2,674 MW) and at Mangla (200 MW) is scheduled during that period. Any extension of thermal generation in the next ten years has to be based, at least temporarily, on imported coal or furnace oil. Subsequently, additional home produced primary energy sources may be available. The search for additional fossil fuel reserves, principally gas, is being actively pursued.

Generation Demand Forecast

4. The most recent demand prediction by WAPDA indicates a growth rate of 12.3% for 1982-88, 11.3% for 1989-93 and 8.8% thereafter. This implies that the peak demand will increase from about 3,720 MW in 1982-83 to 9,140 MW in 1990-91. Assuming a system loan factor of 60%, the need for additional

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1/ This Annex was based on materials prepared by W. Barber, Hydrologist Consultant for ACE/SGI.

generating capacity would amount to about 7,000 MW in eight years plus the required transmission and distribution. Forecast power shortages in the WAPDA system, which supplies at least 95% of Pakistan's agricultural demand, are summarized below through 1986-87.

Estimated Power Shortages - WAPDA System

Year	Deficit in MW	Deficit % of Total Demand
1982-83	550	18
1983-84	940	27
1984-85	1,100	28
1985-86	1,040	20
1986-87	780	14

Transmission and Distribution

5. The transmission/transformation capacity of the WAPDA system has been upgraded in recent years, particularly by provision of 500 kv lines linking main generation centers. In 1980-81, the length of transmission lines (500,200, 132 and 66 kv) was 15,294 miles with 358 grid stations with a transformation capacity of 8,916 MVA. The distribution system (33, 11 and 0.4 kv) is at present overloaded. Transmission/distribution system losses amount to about 30% of total generation.

6. The transmission and distribution system requires major extension and rehabilitation to meet the country-wide objectives set by GOP. The next five year plan sets a target of 3,000 village connections per year and 5,000 well connections per year to the rural grid. There is evidence that the incoming energy for transformation to 11 kv is often of poor quality, being subject to low voltages which are not totally smoothed at transformation. The quality of the energy in the 11 kv network is also often poor with marked voltage fluctuations, as evidenced by a high incidence of motor burn-oils on pumps (all of which cannot be attributed to former misuse of equipment).

7. The SCARP power supplies were originally designed with dedicated power lines are switch gear at the 33/11 kv substations, and appropriate individual transformers to LT voltage at the wells. The pump motors were equipped with proper starter relays in which were incorporated pump motor protection devices (low voltage cut-outs and capacitors). Taking SCARP 1 as an example, up to two thirds of the wells (originally some 2000) have down-time every year due to motor repairs-mainly burn-outs. It may be argued that the motor failures are due to breakdown of low voltage cutouts or similar protection devices, but the ultimate cause of such a high incidence of motor failure must rest with the quality of the incoming energy in the 11 kv lines. It is also noteworthy that WAPDA has not been able to maintain the energy consumption meeting system at the individual wells in SCARP 1 (as an example). Energy charges are now made by a complex formulaa starting from

metered bulk consumption at the 33/11 kv substation, though there are many private consumers and losses below this point.

8. While the SCARP systems were originally designed (presumably properly) with dedicated power supply, many additional (private) connections have been made, may be a critical cost to the efficiency of the distribution network. Such action could reflect WAPDA's attempt to meet connection targets and demands in the face of limited budgets for capital development. A policy to replace SCARP wells by low capacity, private wells would naturally increase demand for connections (a 3 cusec SCARP well with a design utilization of 4000 h/yr would require 12 x 1.0 cusec wells operating for 2000 h/yr for replacement equivalence). The load factor of the private wells could never be as high as the SCARP well as the farmers would tend to demand water, and therefore power, simultaneously. An attempt to reduce expenditure by connecting several private wells to a single 11/0.4 kv transformer would, at best, only increase system losses, and could be easily abused.

Consumption

9. Agricultural energy consumption (mainly for pumping represented 23% of total consumption in 1980-81, and 80% of agricultural consumption was in the Punjab. A similar pattern holds true today. In June 1981, there were about 104,000 classified agricultural consumers of whom 73% were located in the Punjab. This energy consumption per average agricultural consumer was 1.5 times higher in the Punjab than in the rest of the country. Energy consumption by sector groups in 1980-81 is summarized below.

Energy Consumption by Sector Groups (1980-81)

Category	Punjab	Sind	Rest	Total
	Gigawatt hours			
Domestic	1,294	216	348	1,858
Commercial	306	70	70	446
Industrial	2,625	458	399	3,482
Public lighting and bulk supply	806	70	237	1,113
Traction	44	-	-	44
Agricultural	1,693	194	237	2,124
Totals	6,768	1,008	1,291	9,067
Agric. as % of Totals	25	19	18	23

10. The energy consumption resulting from replacing SCARP wells by an equivalent annual abstraction by private well could involve higher energy consumption. The work to water efficiency of the private sector pumps should not be higher and could prove lower than SCARP pumps. The specific capacity of private wells is probably lower than SCARP wells. Thus the private facility could demand a higher energy input per unit volume of water delivered to surface than a SCARP well. Consider the following situation:

1. Static water level - 15 ft.
2. SCARP well discharge 3 cusecs, drawdown 10 ft, w/w efficiency 60%
3. Private well discharge 1 cusec, drawdown 15 ft, w/w efficiency 50%

The energy consumed by the private well is 1.44 times higher than the SCARP well to deliver unit volume of water to surface.

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Table 1 : PROJECTIONS OF POWER DEMAND AND GENERATING CAPACITY, FY83-FY90

Fiscal Year	Peak Demand	High Water Months: Total Installed Capacity	High Water Months: Firm Generating Capacity	High Water Months: Surplus Deficit (+/-)	Low Water Months: Total Installed Capacity	Low Water Months: Firm Generating Capacity	Low Water Months: Surplus Deficit (+/-)	Planned Additional Generation Facilities
1983	2,990	3,200	2,692	-298	2,400	2,175	-815	Tarbela units 5 to 8 (700 MW) and Quetta Gas (25 MW)
1984	3,378	4,024	3,500	+122	2,750	2,485	-893	
1985	3,818	4,024	3,500	-318	3,100	2,800	-1,018	Tarbela units 9 and 10 (350 MW), Guddu 4 (210 MW), Gas Turbine (300 MW), KESC interlink (1165 MW)
1986	4,314	6,000	5,200	+886	4,400	4,100	-214	
1987	4,875	6,000	5,200	+325	5,750	5,236	+361	Pipri D-3 Steam (200 MW), Mangla 9 and 10 (200 MW), Combined Cycle Steam (150 MW), Jamshoro (800 MW).
1988	5,508	7,380	6,200	+692	6,350	5,836	+328	Mid country Thermal (400 MW), Pipri D-4 Steam (200 MW).
1989	6,225	8,350	7,000	+775	6,965	6,450	+225	
1990	7,034	9,490	8,000	+966	7,600	7,031	- 3	Tarbela 11,12,13 (1218 MW), Pipri D-5 Steam (200 MW), Additional Gas Turbine (200 MW).

Source: WAPDA Annual Report 1981/82, Tables 26, 27, Press reports and RMP.

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Table H.1

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SCARP TRANSITION PROJECT PREPARATION STUDY

Terms of Reference

Background

1. In order to control the wide spread menace of waterlogging and salinity in the irrigated areas of the Indus Plain, WAPDA started the construction of Salinity Control and Reclamation Projects (SCARPS) in 1959. The SCARPS tubewells are installed for pumping groundwater that is used for irrigation purposes in fresh groundwater (FGW) areas and is drained out of the area in saline groundwater (SGW) areas. Until now WAPDA has taken up the construction of 30 such projects, for which summary features are presented below:

Province	No of Proj.	No of T/Ws Installed FGW	SGW	Expend. upto June 1981	O&M Expenditure 76/77	77/73	78/79	79/80	80/81
				--------Rs M--------					
Punjab	13	8,065	1,031	2,827.8	124	123	186	197	320
Sind	9	2,376	365	1,244.8	2	2	2	72	73
NWFP	8	612	-	387.2	N.A.	N.A.	N.A.	N.A.	N.A.
Total	30	11,053	1,396	4,459.8					

Out of the total CCA of 34.5 million acres, the CCA covered by the completed and on-going SCARPS is about 14.2 million acres, or 41% of total CCA. After the construction of the SCARPS, which have been financed by the Federal Government from the federally arranged resources, these tubewells are transferred (including operaton and maintenance responsibility) to the respective Provincial Government. In addition to the public sector tubewells, there are approximately 180,000 small capacity tubewells in the Indus Plains that are owned and operated by private farmers. It has been estimated that out of 34 MAF of groundwater pumped annually in the Indus Plains, about 80% (or 27 MAF) are pumped by the private tubewells.

2. Waterlogging is still quite wide-spread in the Indus Plain. In June 1981, about 13% of the area had watertable depth of less than 5 ft; about 52% of the area had a watertable depth between 5 and 10 ft. One of the main factors for the recent increase in waterlogging is the use of Tarbela water in the non-perennial areas during Rabi while these canals continue to get irrigation supplies on the old pattern, which traditionally has high water allowances during flood months.

Need for Study

3. SCARP evaluations have highlighted the following findings:

i. operation and maintenance of SCARPS in the public sector have been costly and inefficient.

ii. little attention was paid to cost recovery policies in the SCARPS, such that the extra Abiana collected in the SCARP areas was limited to Punjab Province only, and is not sufficient even to meet the O&M costs of the SCARPS.

iii. in the past, O&M funding for the SCARPS has been inadequate, with the result that the tubewells are under utilized.

iv. because of the construction of more SCARPS in saline groundwater areas and increase in energy costs, the future requirements of SCARP O&M funding will increase very rapidly.

v. there is a general scarcity of resource in the public sector in Pakistan and the position of availability of funds for SCARP O&M is not likely to improve in the near future.

vi. by transferring SCARPS to the private sector, not only the burden of SCARP O&M shall be shifted from the public to the private sector, but the operaton of SCARPS shall become more efficient thereby fulfilling the purposes behind the SCARPS in a more effective way.

4. In the light of the above assessment, the Revised Action Programme (RAP prepared by WAPDA in 1979), recommended that the FGW SCARPS may be divested and/or gradually phased out of the public sector and be replaced by smaller capacity and privately-owned tubewells. Tubewells in SGW areas, however, will continue to be installed, operated and maintained in the public sector. This study is being taken up in response to the above RAP recommendations, which are reflected in GOP's National Agricultural Policy of 1980.

Purpose of Project Preparation Study

5. The main purpose of the project preparation study is to prepare a feasibility level report, comprising of a reconnaissance report and SCARP Transition feasibility reports for SCARP 1 and N. Rohri, to the level of detail required for World Bank appraisal. As part of this overall objective, the report would devote special emphasis to:

a. assessing the various problems/issues affecting the current arrangements of SCARP tubewells in FGW areas; based on this assessment, the study would formulate the necessary arrangements and measures (including alternative approaches, if appropriate) for transferring management of groundwater in the selected FGW areas from public to private sector, while at the same time ensuring that: (i) resulting pumpage would adequately control waterlogging and salinity; and (ii) groundwater pumpage would be available at appropriate costs to all interested farmers.

b. proposing appropriate project-related actions and measures that would contribute to incremental agricultural production, and would also help provide sufficient incentives for farmer participation in project; and

c. assessing the scope for cost recovery of the operation and maintenance and capital costs of SCARP tubewells. The SCARP Transition proposals should account for Government's intention of eliminating any future public investments or subsidies, and of recovering, if possible, all or part of public investments in the FGW SCARP areas.

Scope

6. The project preparation study will prepare a summary report that will be based on the following related reports (or volumes):

a. General Reconnaissance Report

b. Feasibility Report SCARP I Transition

c. Feasibility Report SCARP North Rohri Transition

d. PC I Proforma SCARP I Transition

e. PC I Proforma SCARP North Rohri Transition

General Reconnaissance Report

7. The General Reconnaissance Report will review and analyze the broad issues associated with the program of transfering groundwater pumpage in FGW areas from public to private sector. Although this review should consider all SCARPS in FGW areas, the analysis should be closely interrelated with the findings obtained in SCARP I and SCARP North Rohri areas. Such a transfer should consider the various possible arrangements/measures (which are not necessarily mutually exclusive) for divesting and/or phasing out of SCARP tubewells to private sector and replacement with small capacity private tubewells. The Reconnaissance Report will include:

a. review and evaluation of SCARP and private Tubewell Development Programs and experiences (installation, O&M, replacement, fiscal impact and agricultural production); this review should be based primarily on existing information and studies, and where necessary, should be supplemented with updated analysis, including projections (up to 1995) of capital (e.g. replacement) and O&M expenditures and of revenues for SCARP tubewells "without" and and "with" SCARP Transition;

b. establishment of criteria leading to categorization of tubewell divesting (transfer, rehabilitation, termination, or replacement);

c. identifying legal and institutional issues related to the transfer and termination of SCARP tubewells; such a review should include recommended measures.

d. assessment and recommendation of appropriate small capacity (1 cusec or less) tubewell technology (e.g. pumping capacities, pump type, energy source, and availabilities, well construction, and material for pipe and screens for replacement wells);

e. reviewing tubewell subsidy program and the adequacy of present credit programs as main source for financing private tubewell installation; such a review should also consider other possible financial sources and arrangements for the installation of private replacement tubewells;

f. studying availability of well digging capacity as well as sale and service facilities for pumps (large and small capacity), and role of the private sector in providing these services;

g. reviewing pricing and other policies (e.g., water charges, tubewell replacement, subsidies, water scheduling, groundwater legislation) with view to recommending measures required to encourage sound approach to SCARP transition, including adequate conjunctive use of groundwater and surface water and groundwater pumpage by private sector;

h. problems of electrification of the SCARP tubewells and small capacity private tubewells installed as replacement to the present SCARP tubewells; and

i. for the interim period, the report should recommend arrangements that would improve the efficiency of existing SCARPs. In the event the transfer arrangements are clearly demonstrated as not being feasible, the study should recommend improved and feasible policies and measures for improving the efficiency of SCARPs and of lessening the O&M burden on the public sector.

j. reviewing and proposing appropriate institutional arrangements for implementing a SCARP Transition Program, considering management of: (i) tubewell development (including SCARP Transition) at Provincial level; (ii) tubewell management at local levels.

Feasibility Reports

8. Separate feasibility reports for transition, comprising the core of the study, will be prepared for SCARP I and SCARP North Rohri, and will serve as basis of appraisal for external financing. This approach recognizes the importance of demonstrating the feasibility of SCARP Transition. Each report will consider and contribute to the findings of the Reconnaissance Report and will include the following:

a. assessment of existing conditions in the proposed SCARP areas, including.

   i. condition of SCARP tubewells and their classification according to following main categories: transfer, rehabilitation, and termination. (based on data provided by CMO and spot checking by consultants),

   ii. soil and aquifer conditions, quality of groundwater, status and trends of waterlogging and salinity (based on existing data and spot checks by consultants), and

   iii. assessment of the SCARP and private tubewell experience in the SCARP and surrounding area including comparision of water use, yields, cropping intensities and patterns between SCARP and private tubewells, using existing data and necessary supplemental data collected by consultants (including data for 1982/83 rabi season and preliminary estimates of 1983 kharif season);

b. detailed formulation of recommended approach and arrangements for the rehabilitation, transfer, and/or replacement of SCARP tubewells in terms of sub-areas, focusing on those having the greatest prospect of success. For the interim period, the report should recommend arrangements that would improve the efficiency of existing SCARPs.

In the event the transfer arrangements are clearly demonstrated as not being feasible, the study should recommend improved and feasible policies and measures of improving the efficiency of SCARPs and of lessening the O&M burden on the public sector;

c. based on the recommended approach and arrangement as cited in (b), the report will formulate appropriate legal, technical, financial, organizational, and institutional measures that would facilitate SCARP transition. These measures should also include the recommendation of appropriate small capacity tubewell technology;

d. in the proposals recommending transfer and/or replacement of SCARP tubewells by small capacity wells, report should indicate investment requirements and availability of: (i) electrification network; (ii) credit and subsidy (if any) involved for the replacement of tubewells; and (iii) training, technical assistance, and other possible assistance by public sector;

e. based on data provided by WAPDA, to review the basis of the present power supply tariff for the agricultural sector in the SCARP area; if a subsidy is recommended to act as incentive to private sector, such a proposal should assess rationale and estimate government liability of such subsidies;

f. arrangements, or SCARP facilities that shall be retained, for providing beneficiaries with efficient and economical repairs and maintenance of SCARP tubewells transferred to private owners; financial impact of these arrangements on government should be assessed;

g. disposal of redundant or deteriorated SCARP tubewells and their components, including recommended criteria and arrangements for their disposal;

h. assess feasibility of rehabilitating SCARP tubewells including cost estimates of such rehabilitation;

i. assess the effects of recommended transition arrangements on subsurface drainage;

j. proposing appropriate institutional arrangements for implementing SCARP Transition program (see para 7-j) and proposed project, considering management of: (i) tubewell development and SCARP Transition at Provincial level (i.e. arrangements to promote appropriate policies and programs and to implement SCARP Transition program by Provincial Departments of Irrigation and Power, and Agriculture, including: monitoring, siting policies and "protection" of aquifer, water management and improved conjunctive use of surface and groundwater supplies) and (ii) Tubewell O&M at local levels, (e.g. Water Users Associations, Cooperative Society, private entrepreneurs, and individual farmers). The proposed local institutional arrangements would be based on field surveys and consultations to account for social and cultural considerations, particularly to ensure the continued and equitable use of tubewell water (both large and small capacity tubewells);

k. estimation of project costs and investment/phasing schedule for proposed project. The rationale for various project components should be presented, including consideration of investments provided by other on-going projects. Also, project-related costs in the public and private sectors should be shown separately;

l. financial and economic analysis, based on representative farm budgets that account for the recommended approach, project components, and policies to implement SCARP Transition: this section should include proposed project impact on farm incomes, employment, and agricultural production and cost recovery;

m. availability of tubewell water to all interested farmers according to the recommended approach to transition. Based on such an assessment, the report should formulate measures that would help ensure small farmer access to tubewell water at a reasonable cost; impact on small farmers should be estimated;

n. program for monitoring and evaluation in a manner that accounts for the recommended transition arrangements; the role and effectiveness of WAPDA's Central Monitoring Organization (CMO) should be reviewed. The study should recommend improved arrangements for monitoring and evaluation of groundwater management in the project area; such arrangements should also be generally applicable to all SCARP (FGW) areas;

o. project implementation schedule (physical works and other project actions), elaborating the requirements for implementing the proposed project in its first year;

p. the proposed project size and implementation program should be presented in a manner that would accommodate varying levels of available financing;

q. consultation with farmers and farmer organizations, based on appropriately designed and implemented field surveys and informal discussions. This consultation should obtain their views and suggestions regarding the existing and proposed arrangements for transferring the SCARP tubewells. The survey should emphasize those points related to: operation and maintenance arrangements; sharing of tubewell water; management of groundwater; and the institutional arrangements and improvements that could enhance the returns to tubewell water under recommended transition arrangements;

r. consultation at appropriate periods with concerned officials from WAPDA, Provincial Agriculture and Irrigation and Power Departments, and other concerned parties, regarding the recommended approach to transition: it is expected that these consultations would be arranged through and under aegis of WAPDA Planning Division;

s. review the potential and rationale for including project components and/or measures that would contribute toward incremental agricultural production and farm incomes, such as canal rehabilitation, on-farm water management, extension services, input supplies, and marketing. Based on such a review and justification, recommend those components for inclusion in the project; these measures should build on the existing Provincial institutional arrangements; and

t. analyze potential for improving conjunctive ground and surface water utilization and improvements in canal water scheduling as appropriate. Based on such assessment, recommend appropriate measures for improving conjunctive water use in a manner that could be supported by the proposed project.

PC I Proformas

9. Preparation of PC I proforma is the requirement of Government of Pakistan (GOP) and this form is to be filled for all projects presented for review by Central Development Working Party (CDWP) and ECNEC. Separate PC I's shall be prepared for the SCARP Transition Feasibility Reports for SCARP I and SCARP North Rohri.

Schedule of Study and Reports

10. It is expected that the preparation study would be initiated by about November 15, 1982 and would take about 12 months to complete. It is expected that the consultants would devote the majority of their efforts in preparing the proposed SCARP Transition project feasibility reports for SCARP 1 and SCARP North Rohri. The draft Final Report, comprising of summary, reconnaissance, and two project feasibility reports, would be prepared in an acceptable form for World Bank appraisal and would be submitted to the Bank by September 15, 1983. The PC 1 proformas would be prepared by October 15, 1983. The Final Report would be prepared within 30 days after receipt of comments from World Bank. The report would become the property of GOP. In addition, the consulting firm would prepare an inception report and a six-month progress report. All reports would be in English, with 30 copies to GOP (through WAPDA), 15 copies to the World Bank (through the Resident Mission), and 5 copies to the UNDP Resident Representative. Reports would cover the following:

a. Inception Report. This report would be submitted for review and comment within six weeks of the study's starting date and would: (1) present the major problems and issues in carrying out the agreed TOR; (2) present a detailed outline of the Reconnaissance Report and would focus on identifying the main issues and information gaps that need to be addressed in the remaining period of the study; and (3) present the detailed work plans (especially field surveys during rabi 1982/83 and kharif 1983 seasons) for carrying out the study's agreed TOR.

b. Six Month Progress Report. This report would follow UNDP format and would be submitted to World Bank within six months of the study's starting date. This progress report would include a detailed outline of the final report (summary, reconnaissance and feasibility reports), a proposed program to resolve previously identified issues or problems, recommendation of main approach to SCARP transition, preliminary project components, and working papers as may be necessary. The six-month progress report would serve as a basis for a review/decision meeting, comprising of concerned officials from GOP, WAPDA, GOPunjab, GOSind, UNDP, and World Bank.

c. Draft Final Report. The general outline of the draft Final Report should follow the format that is in accord with World Bank appraisal reports. The summary report, or Volume 1, should include:

i. Sector Background

ii. Project Area

iii. Project (components, costs, financing)

iv. Organization and Management

v. Project Benefits and Justification

The summary report should be based on three accompanying Volumes, which consist of the Reconnaissance Report and the SCARP 1 and SCARP North Rohri Transition feasibility reports. These volumes should provide the detailed information used in preparing the summary report and should be organized in a topical manner that would enable integration of the reconnaissance and project feasibility reports. These topics, or report sections, may include, <u>inter alia</u>:

i. SCARP and Private Tubewell Performance, Emerging Issues, and Rationale for SCARP Transition (technical, physical, management, legal, financial/economic, policy; the effects on drainage agricultural production and farm incomes, and public expenditures should be highlighted);

ii. Related Agricultural Support Services (input supplies, marketing, credit, research/extension/ water management, tubewell repair facilities);

iii. Electrical Infrastructure and Adequacy for Tubewell Requirements;

iv. Tubewell Technology (SCARP and Small Capacity Tubewells);

v. SCARP Transition Approach and Arrangements (according to classification of SCARP wells-- termination, replacement, transfer, rehabilitation);

vi. Project Components, Cost Estimates, Financing, and Implementation Schedule;

vii. Sociological Considerations in SCARP Transition;

viii. Institutional Arrangements for SCARP Transition Program and Project Implementation,

ix. Assessment of and Recommended Policies for SCARP Transition (pricing, water charges, cost recovery, tubewell replacement, water scheduling, power tariffs, credit);

x. Agricultural Production, Financial and Economic Analysis (includes details of agricultural, farm budget, cost recovery, and economic analyses used for the two proposed project feasibility reports);

xi. Conjunctive Surface and Groundwater Use; and

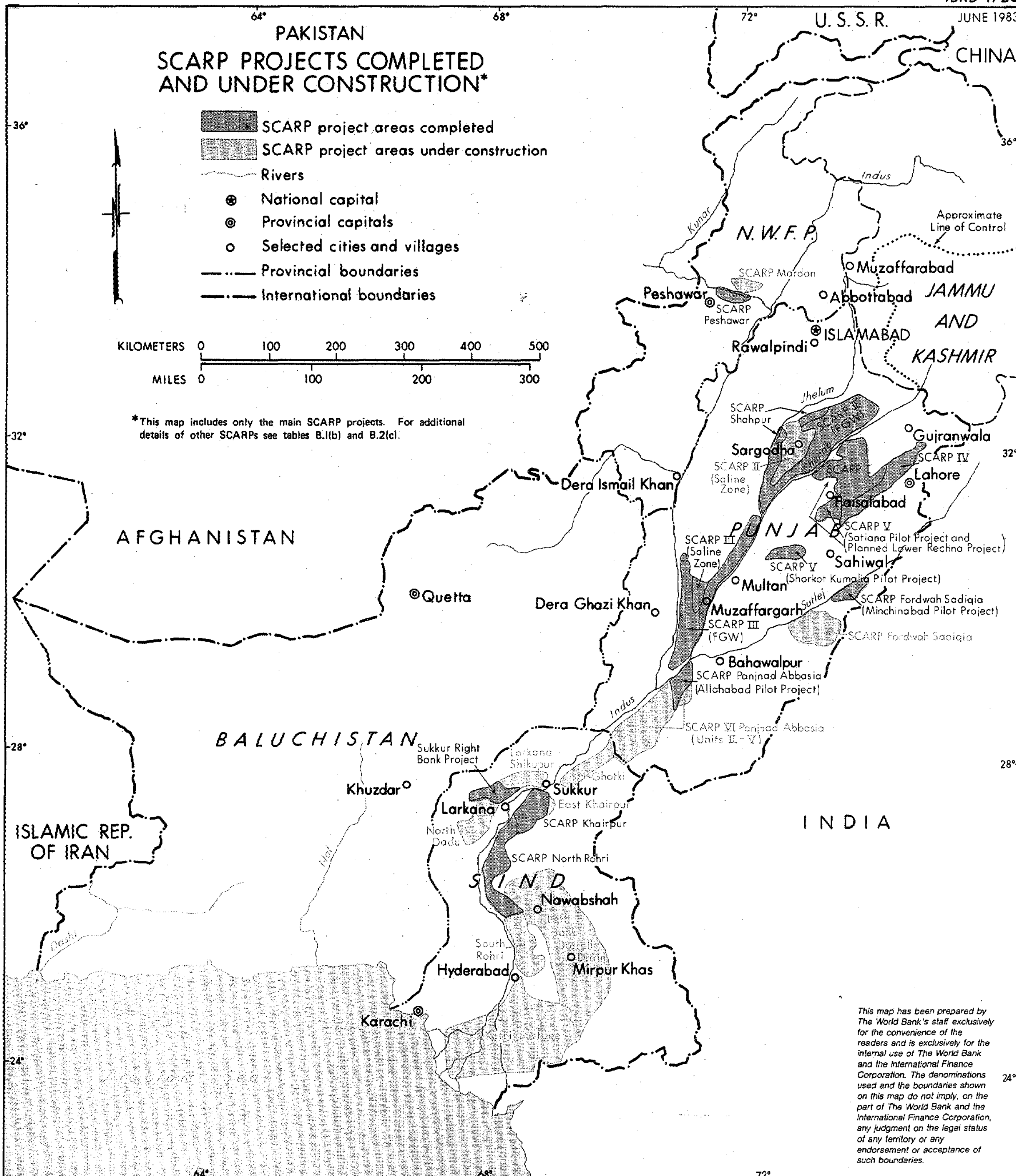
xii. Monitoring and Evaluation of SCARP Transition.

d. Final Report and PC I Proforma. The Final Report would incorporate the Bank's comments, which would also include GOP/GOPunjab/GOSind views.

Institutional Arrangements

11. As Executing Agency for UNDP, the Bank would provide overall supervision. WAPDA's Planning Division will provide day to day supervision and coordination of the various aspects of the work on behalf of GOP. In this capacity, WAPDA Planning Division will ensure coordination with GOPunjab, GOSind, and other concerned government organizations. The consultants shall maintain constant liaison with Planning Division of WAPDA, who has agreed to assist consultants in obtaining the relevant reports and data from WAPDA, GOP, and GOPunjab and GOSind in a timely manner.

IBRD 17261


JUNE 1983
PAKISTAN
SCARP PROJECTS COMPLETED AND UNDER CONSTRUCTION*
SCARP project areas completed
SCARP project areas under construction
Rivers
National capital
Provincial capitals
Selected cities and villages
Provincial boundaries
International boundaries
KILOMETERS 0 100 200 300 400 500
MILES 0 100 200 300
*This map includes only the main SCARP projects. For additional details of other SCARPs see tables B.1(b) and B.2(c).
U. S. S. R.
CHINA
AFGHANISTAN
ISLAMIC REP. OF IRAN
INDIA
N.W.F.P.
PUNJAB
BALUCHISTAN
SIND
JAMMU AND KASHMIR
Approximate Line of Control
Indus
Kunar
Jhelum
Chenab
Sutlej
Nal
Dasht
Peshawar
SCARP Mardan
SCARP Peshawar
Muzaffarabad
Abbottabad
ISLAMABAD
Rawalpindi
SCARP Shahpur
SCARP II (FGW)
Sargodha
SCARP II (Saline Zone)
Gujranwala
SCARP IV
Lahore
SCARP I
Faisalabad
SCARP V (Satiana Pilot Project and Planned Lower Rechna Project)
SCARP III (Saline Zone)
SCARP V (Shorkot Kumalia Pilot Project)
Sahiwal
Multan
Dera Ismail Khan
Quetta
Dera Ghazi Khan
Muzaffargarh
SCARP III (FGW)
SCARP Fordwah Sadiqia (Minchinabad Pilot Project)
SCARP Fordwah Sadiqia
Bahawalpur
SCARP Panjnad Abbasia (Allahabad Pilot Project)
SCARP VI Panjnad Abbasia (Units II - V)
Sukkur Right Bank Project
Larkana Shikarpur
Ghotki
Khuzdar
Sukkur
Larkana
East Khairpur
SCARP Khairpur
North Dadu
SCARP North Rohri
Nawabshah
South Rohri
Mirpur Khas
Hyderabad
Karachi
36°
32°
28°
24°
64°
68°
72°
This map has been prepared by The World Bank's staff exclusively for the convenience of the readers and is exclusively for the internal use of The World Bank and the International Finance Corporation. The denominations used and the boundaries shown on this map do not imply, on the part of The World Bank and the International Finance Corporation, any judgment on the legal status of any territory or any endorsement or acceptance of such boundaries.