IIMI Country **Paper** - Pakistan **No.1**

Private Tube Well Development in Pakistan's Punjab

Private Tube Well Development in Pakistan's Punjab: Review of Past Public Programs/Policies and Relevant Research

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Country **Paper - Pakistan No.** 1

Johnson, R. 1989. Private tube well development in Pakistan's Punjab: Review of past public programs/policies and relevant research. Colombo, Sri Lanka. xx 36p.

/ tube well irrigation / agricultural production / economic aspects / environmental aspects / equity / governmental interrelations I policy / research / Pakistan / Punjab.

DDC 631.7

ISBN. 92-9090-151-9

Summary: Although Pakistan's surface irrigation development has a long history. it is only about 30 years ago that the development of groundwater resources was begun. During the past decade. government policy has been reoriented towards private. instead of public, tube well development in fresh groundwater areas. This paper examines the policies that have affected tube well development, and reviews past literature on the subject.

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Foreword

Agricultural production in Pakistan is based almost solely on irrigation. Pakistan's public surface water supply system has a long history, dating back to the 1800s. Extensive public development of Pakistan's abundant groundwater reserves, however, has taken place in only the past 30 years. Even more recent has been the remarkable expansion in the number of private tube wells installed by farmers. Currently groundwater plays a major role in Pakistan's agricultural production system. Conservative estimates place its contribution to the total water supply for irrigated agriculture at 30 percent

Since the late 1970s the Government of Pakistan has adopted an official policy that emphasizes private instead of public tube well development in fresh groundwater areas. The test vehicle for implementing this policy is the Transition Pilot Project of the Salinity Control and Reclamation Project. By the end of fiscal year 1990 this project will either terminate or transfer the control of 213 of its wells to farmers in the Khanqah Dogran block of the Salinity Control and Reclamation Project-1 area. In addition, the project plans to encourage the installation of 2,100 private wells in the Khanqah Dogran block to ensure that vertical drainage still takes place, and that small farmers retain access to groundwater supplies.

A proper analysis of the potential impacts of projects aimed at private tube well development, such as the Transition Pilot Project of the Salinity Control and Reclamation Project, is impossible without a proper historical understanding of that development process to date. This paper is one effort to provide such an understanding through a review of past literature on private tube well development in Pakistan, as well as previous public programs and policies that have directly or indirectly affected the pace and character of this development

Acknowledgements

The author would like to acknowledge the comments received from Dr. Edward Vander Velde and Mr. Mohammad Badruddin, IIMI Pakistan, on the initial draft of this paper. The financial support provided by the Irrigation Support Project for Asia and the Near East is gratefully acknowledged. This paper is one product of a joint Cornell University/IIMI Pakistan research project focused on the irrigation management implications of private tube well development in Punjab, Pakistan.

Private Tube Well Development in Pakistan's Punjab: Review of Past Public Programs/Policies and Relevant Research

INTRODUCTION

IRRIGATED AGRICULTURE HAS a long history in the Indus Basin. Since the British constructed their first surface delivery system in 1859, surface irrigation has expanded enormously. Today, an estimated 16.47 million hectares (ha) (40.7 million acres) are commanded by surface water supplies in Pakistan. The origins of groundwater development in the country, however, are comparatively much more recent. Public development of groundwater started originally with 20 tube wells installed for irrigation purposes near Shaliiar Gardens between 1938 and 1953 (Mohammad, 1965:2). Between 1944 and 1953, 1,500 wells were installed as part of the Rasul and Central Tube Well Projects in Rechna and Chaj Doabs to lower the water table by intercepting canal seepage and to provide supplemental irrigation water. In addition, the Provincial Irrigation Department, Punjab Province, also began installing tube wells for supplemental irrigation purposes. Public groundwater development began on a large scale and in a comprehensive manner with the initiation of the Salinity Control and Reclamation Projects (SCARPs) in the early 1960s.

While private groundwater development in the form of Persian wells has a long history in Pakistan's Punjab Province, the installation of private tube wells initially lagged far behind public tube well development. In 1950, the Department of Agriculture reported only 177 private wells, all installed with its help since 1939. Although private drillers were certainly installing wells before 1950, the number is not known, and probably was not significant. It was

not until the early 1960s when public intervention in groundwater development gained momentum that private well development blossomed.

Interest in groundwater supplies in what is now Pakistan arose originally out of a desire to control the adverse effects of the "twin menaces": waterlogging and soil salinity. By 1964, an estimated 22 percent of the 9.31 million ha (23 million acres) supplied by canal irrigation suffered waterlogging and/or salinity damage (White House Department of Interior Panel Report, 1964:62). Starting first with the Rasul Project, a series of attempts was made to control waterlogging problems via vertical drainage. The results of these were inconclusive, perhaps due to the limited extent of each individual project.

In 1961, the Government of Pakistan, with US financial and technical support, began an ambitious program to alleviate waterlogging/salinity problems by lowering the water table on a regional basis. The program relied on vertical drainage via deep tube wells spaced at appropriate distances. The intent was to manage water table levels by controlled pumping. Where groundwater was not too brackish, it was added to surface supplies and used as a supplemental source of irrigation. Provincial Irrigation Departments were given the responsibility for the Salinity Control and Reclamation Project well operation and maintenance (O&M); O&M costs were only partially recovered from fanners,

Since 1961, both the number of individual salinity control and reclamation projects and the total number of wells have steadily expanded, until by 1987 there was a total of eight full and pilot projects in Pakistan's Punjab Province, originally comprising 8,087 wells (not all are still operational) (Water and Power Development Authority [WAPDA], 1988). In 1975. the United States Geological Survey pronounced the Salinity Control and Reclamation Project program an unequivocal success in lowering groundwater levels. While most would agree that the Salinity Control and Reclamation Project wells have partially attained one of their original goals - water table control' - it has been so attained at a substantial cost. In many areas the useful life of the Salinity Control and Reclamation Project wells was much shorter than expected. Continuing the Salinity Control and Reclamation Project program in older project areas will require enormous capital investments to replace aging wells, pumps, and motors. Operation and maintenance costs are a burden to provincial governments, and a serious drain on funds that could be used for

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[1] *See* Anson (1983:8), Lowdermilk et al (1978:40), and Mundorff et al, (1976:Q27). For a dissenting view, see Johnson (1982162).

other purposes. In 1982. O&M for the Salinity Control and Reclamation Project wells consumed 60 percent of the country's total irrigation O&M budget (Anson, 1983:iii). Evaluators claim that, for a variety of reasons[2], the Salinity Control and Reclamation Project wells provide only a portion of potential supplemental irrigation benefits. In fact, the Salinity Control and Reclamation Project program was never meant to be a permanent solution to Pakistan's problems of water table control.

Meanwhile, private tube well development for irrigation has blossomed in areas where groundwater quality is good. Their numbers expanded from approximately 6,000 at the start of the Salinity Control and Reclamation Project program to more than 190,000 in 1985. Their estimated total yearly groundwater pumpage surpasses that of the Salinity Control and Reclamation Project wells in many areas where they coexist - suggesting that private wells have a greater impact on water table levels than do public wells. In addition, evidence suggests that private tube wells result in cropping intensities and yields that exceed those attributed to the Salinity Control and Reclamation Project wells (Lowdermilk et al., 1978:21,25,46; Anson, 1983:29). The Water and Power Development Authority (1980,xiii) estimated that more than 91 percent of these private wells were located in Pakistan's Punjab Province.

Faced with crippling Salinity Control and Reclamation Project costs, and realizing the apparent benefits of private well development, the Water and Power Development Authority of Pakistan, the agency responsible for planning and executing the Salinity Control and Reclamation Projects, proposed a shift in policy in 1979. In its *Revised Programme* for *Irrigated Agriculture Report*, the Water and Power Development Authority called for a gradual divesting of public responsibilities for groundwater management in fresh groundwater areas, and for an increasing reliance on the private sector to both maintain proper water table levels and provide additional water for irrigation use. The government's draft of the Sixth Five Year Plan (FY84-FY88) reflected this policy change: "...the Government would like to leave the development of other sweet water areas (of those having depth-to-water-table greater than 5 feet) to the private sector; in fact it would seek to transfer some of the public sector tubewells already existing in certain SCARPs to the private sector." One outcome of this policy change is the Transition Pilot Project of the Salinity Control and Reclamation Project, funded by the World Bank. On 1 November

[2] For a complete list. see Johnson, 1982

1987, the Pilot Project began terminating the operation of the Salinity Control and Reclamation Project wells in parts of the Khanqah Dogran subproject area of the Salinity Control and Reclamation Project-I, while encouraging further private development through a variety of methods.

The transfer of responsibility for groundwater management from the public to the private sector in Pakistan reflects a broader trend that is current across Asia and the Near East. Within the irrigation sector throughout this region, there is a movement to shift specific responsibilities from government agencies to users or user groups. However, the Water and Power Development Authority's policy change in 1979 also was the product of an at times intense debate within Pakistan over the merits of public versus private control of fresh groundwater supplies. Beginning with Ghulam Mohammad's work with private tube wells in the early 1960s (Mohammad, 1965), researchers in Pakistan have repeatedly questioned the validity of the Salinity Control and Reclamation Project program in fresh groundwater areas when so much potential existed for private tube well development.

PAST GOVERNMENT POLICIES AND PROGRAMS AIMED AT PRIVATE TUBE WELLS

While the Salinity Control and Reclamation Project program since 1961 has consumed by far the largest share of the public resources allocated to groundwater development, the government has also had other programs and policies aimed at encouraging private tube well development. As the government begins to step away from the salinity control and reclamation projects in fresh groundwater areas, these past programs gain new significance. They can serve as the basis for extended programs. They offer lessons from their accumulated experiences. A careful analysis of their successes, failures, potentials and limitations can provide insights as the government approaches groundwater development with a new perspective: that of guiding equitable and environmentally sustainable groundwater development through the private sector rather than diiectly through agency control over pumping facilities.

This paper is not intended to provide detailed analyses of the programs it

describes. For many, there have been published evaluations; where these exist they are noted. Our purpose is to give a brief overview of the type and variety of past government programs and policies aimed at private tube well development, along with some of the conclusions others have reached regarding their efficacy.

The agency with the longest history of promoting private tube well development is the Department of Agriculture. Through its Agriculture Engineering Section, it has offered subsidized drilling services to farmers. In 1939. the Agriculture Engineering Section began installing wells at the rate of approximately 10-20 a year (Mohammad, 1965:3). In 1950. the pace was quickened; between June 1961 and June 1964, more than 1,000 wells were installed by this program. By the fiscal year 1981/82 the Agricultural Engineering Department had the capability and the equipment to complete 3,500 wells per year, or roughly 40 percent of the wells reported installed in the Punjab that year (Anson. 1983:131). Usually, the Department of Agriculture does the drilling and it lowers the casing, while fanners are expected to provide material and labor. Anson (1983:131) estimates that in actual terms this subsidy is only a fraction of the total boring cost, amounting to less than 25 percent of the total cost of sinking a well, if one includes the cost of constructing a pump-house, digging a sump pit, and installing a concrete stilling tank. For farmers with just a bore-point, however, the savings can be significant

The net impact of the Department of Agriculture's drilling services over the years is hard to estimate. The Water and Power Development Authority (1980:19) concluded that almost all private wells (92%) are installed by private drillers because private drilling facilities and the services of these drillers are readily available when farmers need them, without their having to follow bureaucratic procedures to obtain public assistance. However, the demand of farmers for this service reportedly exceeds the ability of the Department to supply it

The next government institution to become directly involved with private tube well development was the Agricultural Development Bank of Pakistan (ADBP). Beginning in the early 1960s, this bank began supplying credit to fanners installing tube wells as part of its minor irrigation development program. A review of its lending activity for private tube wells was published by the bank in 1985. The bank reports that between 1964 and 1982, it participated in financing about 20 percent of the units installed during that period, with a range from 6 percent (1980/81) to 44 percent (1966/67). Over

the years, the number of loans extended has fluctuated considerably. Both in terms of the absolute number of loans and the percentage of newly installed wells that used the Agricultural Development Bank of Pakistan financing, its loans towards private tube wells reached their low around 1980. Since that time they have steadily increased.

In 1983/84, the average disbursement of the Agricultural Development Bank of Pakistan is against tube wells was Rs 35,675 per well with the bulk of the investment in the Punjab.[3] The weighted average cost of a new tube well in this same period was estimated to be Rs 45,000, implying that farmers had to also either find additional sources of financing, or use their own resources. However, it is difficult to draw general conclusions as to the sufficiency of lending by the Agricultural Development Bank of Pakistan on a per tube well basis, since included in this Rs 37,675 average were loans for maintenance, repair, and replacement for existing tube wells where the total costs involved were certainly less than the Rs 45,000 required to install a new well. Also it is not clear how much of the financing of this bank has gone to electrically-operated wells and how much to diesel-powered wells - whose installation costs differ significantly.

According to the 1985 review of the Agricultural Development Bank of Pakistan lending to minor irrigation, loans for private tube wells were described as disappointingly small, both in terms of the bank's total lending portfolio and in terms of the total number of private wells being installed annually. Despite the bank's claim that it helped finance 20 percent of the wells between 1964 and 1982, the Water and Power Development Authority reported in 1980 that 91 percent of the wells it had surveyed were installed entirely with fanners' own resources. The bank appears to be attempting to expand its lending for private tube wells: the 1985 review notes: "The means of achieving these increased figures are mainly internal to the ADBP in the removal of restrictions placed on loaning to small (sic) farmers: in steps taken at Regional and Bank level to achieve sufficient incentive and management drive for tubewell loaning; and in the manning, organization and technical support provided for the programme," (Agricultural Development Bank of Pakistan, 1985:3.08).

As a financial institution, lending policies of the Agricultural Development Bank of Pakistan have been selective. The Water and Power Development Authority's 1980 study found that no tube well owners with holdings totaling

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[3] In 1984, US$1 = PRs 15.36

less than 2.024 ha (5 acres) received financing from this bank because holdings of this size represented less than the minimum value of land required by it for mortgages. Anson (1983, 136) reports that as of 1983 the bank still refused to consider loans to cooperatives or similarly organized groups, such as "water users' associations". These two realities have severely curtailed the access of small-scale farmers to the bank's credit facilities.

In 1972, the third major govemment program aimed at encouraging private tube well development was started. Known as the "Diesel Subsidy Program", its original purpose was to encourage the development of diesel-powered private tube wells in "disadvantaged" areas such as the tail ends of canal systems, lands not reached by surface supplies (*barani* lands), non-perennial command areas, and riverine areas (*sailaba* lands). In the Punjab Province this program has been implemented by the Agricultural Engineering Section of the Department of Agriculture. The program was evaluated by the Punjab Economic Research Institute in 1980; the conclusions of this evaluation were published in 1981 (Malik, 1981). Farmers who satisfied program requirements could apply the subsidy against the cost of government approved diesel-powered pumps. Program requirements were substantial; they included regulations on the size of holdings allowed, timetables for completion of approved wells, and proof that the groundwater was fit for irrigation purposes.

The amount of subsidy varied substantially with the particular year, size, and location of the wells. Between 1972 and 1979, the percentage of the total installation cost provided by the subsidy ranged between 15 and SO percent. The number of wells installed each year as part of the program also varied considerably in this time period, from 444 wells in 1973/74 to 5,737 in 1976/77 (Malik, 1981:6). By June 1979, 16,086 subsidies had been sanctioned under this program, representing 20 percent of the total number of wells installed in this period, at an expense to the government that was equal to only 3 percent of the total expenditures up to that time on the Salinity Control and Reclamation Project wells. Demand For subsidies outstrips supply - in 1981/82 only 1,100 out of 3,000 applicants were funded in the Punjab. comprising a mere 13 percent of the total number of wells installed in the Punjab during that fiscal year (Anson, 1983:130).

The Diesel Subsidy Program has had its difficulties; Malik (1981) provides a complete list. A few particular shortcomings that Malik highlighted in his review were: 1) The subsidy program initially favored large-scale farmers by requiring compact landholdings of at least 10.12 ha (25 acres). In 1979, this

restriction was eased so that small-scale farmers had access to subsidies for tube wells with capacities less than 28.32 liters/sec (1 cusec). 2) The administration of the program laid it open to manipulation by farmers with political contacts. 3) The program has been subject to sudden and abrupt changes in requirements, subsidy sizes, and number of subsidies available in any given year. 4) The majority of the wells installed as part of the program probably would have been installed anyway, even without the subsidy. 5) Many farmers exploited the program by selling their diesel-powered motors and connecting their wells to electrically-operated pumps.

The most recent, and probably the most expensive and far-reaching attempt of the government to encourage private tube well development, is the Transition Pilot Project of the Salinity Control and Reclamation Project. It grew directly out of the government's desire to transfer groundwater development responsibility in fresh groundwater areas from public to private hands. The Transition Pilot Project of the Salinity Control and Reclamation Project will eventually either terminate or transfer the control of 213 of its wells to farmers in the Khanqah Dogran block of the SCARP-1 project area. The original timetable was fiscal year 1987 through fiscal year 1990. Total project costs amounted to Rs 383.6 million, or approximately Rs 19,000 per private well the project proposed to install (2,100 wells in all).[4] These additional private wells are to ensure that drainage requirements will be met, and that small-scale farmers retain access to groundwater supplies once the control of the Salinity Control and Reclamation Project wells is transferred.

The project included funds for: improving electricity supply infrastructure, installing private wells, lining of minors, watercourse improvements, and institutional development. In fact, the actual amount of money earmarked for the installation of private wells is only a small portion of the total project cost. As originally conceived, the Transition Pilot Project of the Salinity Control and Reclamation Project was to be based on cooperation between the Water and Power Development Authority, the Agricultural Development Bank of Pakistan and the Department of Agriculture. Emphasis was to be placed on electrically-operated wells. As a pilot project, it was expected that the lessons learned would be transferred to similar projects as the government attempts to phase out some 7,500 Salinity Control and Reclamation Project wells in the future,

[4] In 1987 and 1988, US$1 = PRs 17.84 and PRs 17.43, respectively.

affecting 1.62 million ha (4 million acres) of land. This project has been controversial from the start because of its size and because many of the assumptions upon which it has been based.

Besides these programs, several agencies have had programs of their own with more specific goals and specialized constituencies. One example is the Integrated Rural Development Programme, partially described by Yasin (1975,4), under which 600 new tubewells in 1972/73 and 200 in 1973/74 were installed. More recently, the Punjab Land Utilization Authority has begun its own limited effort. Established in 1980, its mandate was to provide incentives to farmers who could reclaim waste land by providing electrical connections for tube wells free of cost, subsidizing the purchase of transformers, providing a rebate for two years on the fixed charge portion of the electricity bill, extending easy credit, and hiring bulldozers for land-levelling. Between 1980 and 1984,470 wells were installed under this program. Its progress has been reviewed by Shah, in a report published in 1986.

To encourage the installation of private elecuically-operated wells, the Water and Power Development Authority has had a tube well power connection subsidy. Anson (1983:130) reports that a subsidy of up to Rs 15,000 has been available for tube well connections to the Water and Power Development Authority grid, but availability was subject to budget restrictions. "WAPDA admit (sic) that preference is given to connection applications for which subsidy is not required." Since farmers are expected to pay for the installation of a feeder line and a transformer, the subsidy was originally only a fraction of the cost involved with installing an electrically-operated tube well. This fact has meant that the subsidy "is selective towards the richer, larger (sic) farmers" (Anson, 1983:131). Since 1983, the subsidy has been increased to Rs 30,000 per connection. Anson (1983:133) also reports that a subsidy of 20 percent is theoretically available to farmers who purchase diesel for pumping purposes. "Few farmers apply in the face of bureaucratic disincentive." There also have been indirect subsidies for private tube wells. Starting in the mid-1960s, the government began to encburage private tube well development via "liberal imports of pipe and accessories. credit and electrical connections, etc." (Water and Power Development Authority, 1980107).

The one policy that has had probably the most profound impact on farmers' technology choices and usage rates has been an electricity tariff subsidy for agricultural consumers of electrical power. Anson (1983:132) claims that in 1981/82, the average sale price of the Water and Power Development Authority

electricity to all consumers was Rs 0.52 per kilo watt hour (kwh). Comparing this to an average sale price of Rs 0.35 kwh for agricultural consumers demonstrates the subsidy inherent in electricity supplies for agricultural production. Assuming that agricultural consumers used 25 percent of the available power supplies in 1981/82, the implication is that nonagricultural consumers paid 66 percent per unit more for their supplies (about Rs 0.58 kwh). The traditional tariff includes a fixed monthly charge, plus a metered consumption charge. In 1981/82, the fixed monthly portion of the charge was equal to approximately 83 hours worth of the metered consumption charge.

Based on 1981/82 prices, Anson (1983:123) estimated that diesel-powered tube well owners paid approximately 3 times more per unit of water pumped than owners of electrically-operated wells. This finding is nothing new. In 1980, the Water and Power Development Authority estimated that the operating costs of diesel-powered wells were 57 percent higher than those for electrically-operated wells. A significant portion of these price differentials was due to the subsidy inherent in electricity tariffs for agricultural consumers. The result has been a marked preference for electrically-operated wells among farmers, and an observed difference in utilization rates between owners of diesel-powered wells and owners of electrically-operated wells (Water and Power Development Authority, 1980). In recent years, the Water and Power Development Authority has allowed electrically-operated tube well owners to switch from a mixed tariff (composed of both fixed monthly connection charges and metered charges) to one entirely based on a fixed monthly charge. On an operating cost basis, this policy change will increase the differential that currently exists between operating costs for diesel-powered and electrically-operated wells. Technology choice and utilization rates have special significance in Pakistan, where the electric power supply grid is already overburdened.

In conclusion, public programs aimed at encouraging the development of private wells in Pakistan's Punjab can be characterized in the following way: 1) There have been a variety of such government programs that included most of the available options for public interventions (i.e., credit. direct power and installation subsidies, direct technical support through drilling, indirect subsidies for hardware). 2) These involved most of the government agencies that could have claimed any interest in groundwater development (i.e., the Water and Power Development Authority, the Department of Agriculture, the Agricultural Development Bank of Pakistan, the Land Reclamation Departments, etc.). 3) Except in the case of the Transition Pilot Project of the Salinity Control and

Reclamation Project, the programs/policies supported by various agencies have been relatively uncoordinated. 4) The cumulative impact of these programs/policies on the number of private tube wells installed has been small. although they may have had a substantial impact on choice of power source, and total pumpage. 5) Finally, these programs/policies represented a relatively small portion of public expenditures on groundwater development.

PAST RESEARCH

There have been many important field studies of various aspects of private tube wells that have been conducted since Ghulam Mohammad's initial work in the middle of the 1960s.[5] Taken together, these comprise a body of knowledge that the government can use as a reference point in its attempts to promote equitable and environmentally sustainable groundwater development through the private sector for fresh groundwater areas. Some of the more important conclusions found in this body of knowledge are outlined in this section.

The way data has been collected in the past on private tube wells has greatly influenced the kinds of information that are currently available. Without exception, past studies of private wells relied on one time cross-sectional interview data to reach conclusions. Typically, samples were constructed based on official records of private tube wells and drawn from political units (i.e., districts), rather than hydrological units (i.e., canal command areas). As a result, past studies focused on issues that lent themselves to cross-sectional data collection, such as the total number of wells installed, the types of technology used, installation and operating costs, owner characteristics, and impacts on agricultural production (i.e., cropping patterns, intensities, and yields). Hence, there have been some aspects of private tube well development that have been established repeatedly, and can now be accepted without doubt, but there are other aspects of that same development that are not understood.

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[5] The conclusions presented in this section were drawn from the following studies: Ghulam Mohammad, 19655; Yasin, 1975; Pakistan Agricultural Research Council, 1979; Water and Power Authority, 1980.

Relative Importance of Private Tube Wells in the Agricultural Production System

The Water and Power Development Authority (1983) estimated that in 1977/78 private wells accounted for more than 90 percent of the total pumpage (with 75 percent of this occurring in canal command areas) and supplied 30 percent of the total amount of irrigation supplies available at the farm gate. The effect of this 30 percent on total productivity is even larger than the number suggests since private tube well water is water supplied on demand, versus public supplies whose availability bears no relationship to farmer requirements. Although the rate of increase in the number of private wells has slowed in recent years, current growth in the number of private wells suggests that private groundwater development will play an even more important role in the agricultural production system of Pakistan in the future.

Private Tube Well Technologies

Private tube well development in Pakistan has centered almost exclusively on low-lift centrifugal pumps that are placed as close to the water table as possible. Most studies agree that about two-thirds of the wells installed are driven by some form of diesel-powered engine (originally slow-speed, locally produced diesel-powered engines, and more recently tractors and high-speed Chinese-made diesel-powered engines), and the remaining one-third by electrically-operated motors. Most tube well components are locally available, including the casing and strainer for the well, the low-lift pump itself, and many of the engines/motors that are in use. Replacement parts are also readily available from local markets. Farmers can face a variety of technical difficulties with their wells, including reduction in discharge over time, failure of centrifugal pump impeller blades and valves, and burned-out electrically-operated motors.

Ownership Patterns

Research to date has shown conclusively that it is the wealthier farmers in Pakistan's Punjab who have had the greatest access to private tube wells. In every study, the distribution of tube wells among farmers with different sized holdings is skewed towards large-scale landholders. There are a number of reasons for this. First, large-scale farmers have had a comparative advantage procuring assistance from past government programs. For example, the Agricultural Development Bank of Pakistan requires a farmer seeking credit for installing a private well to have at least 2.024 ha (5 acres) that he can mortgage. In its early years, the diesel subsidy program required that applicants have at least 10.12 ha (25 acres) in compact holdings. With the Water and Power Development Authority's electrical connection subsidy, farmers are usually expected to pay the entire cost of connection, including the cost of the connecting line and transformer. These costs were usually much more than the subsidy of Rs 15,000, discouraging its utilization by small-scale farmers. Even without formal program restrictions on small-scale farmer access to public programs, local political influence wielded by large-scale farmers has often been enough to guarantee access to scarce public resources.

The second reason for the concentration of private wells in large-scale landowners' hands is that technologies available to date become financially unattractive when holding sizes fall below a minimum level. While water selling in the Punjab is common, the Water and Power Development Authority (1980) claims that the amount of water sold in Pakistan compared to the amounts pumped is very small, providing little incentive by itself for installing a well. The implications are that the primary source of returns to a farmer installing a private well must come from his own land. Also, while fractional cusec technologies are available, costs are relatively inelastic when compared to capacities. Hence, cutting a well's capacity in half does not reduce its installation cost by a corresponding amount.

Finally, the wells owned jointly by several farmers are a relatively small fraction of the total number of private wells. The estimate of the number of wells owned by groups range from 11 percent (Yasin, 1975) to 25 percent (Water and Power Development Authority, 1980). Again, this is partly due to the fact the public programs have done little to encourage joint ownership of private wells; in fact, some discourage such arrangements. For example, in the past the Agricultural Development Bank of Pakistan's tube well credit program

has refused to consider loans to cooperatives or similarly organized groups. Anson (1983) explains the small number of joint owners in terms of: available technology, financing restrictions, farmers' distrust of cooperatives, and the lack of efforts by the government to organize farmers based on local customs.

Economics of Private Tube Wells

The economics of private tube well investments, at least from the owner's perspective, has been included in almost every field study of private wells. Based on the work to date, four conclusions can be drawn. First, the installation costs for private wells have risen enormously over the past 20 years. For example, the Water and Power Development Authority (1980) estimated capital investment costs as Rs 35,600 for a diesel-powered well and Rs 25,100 for an electrically-operated well; this is reported to be 3040 percent more than in 1977. This authority also reported that in 1969 these costs were only Rs 6,848 for an electrically-operated well and Rs 9,103 for a diesel-powered well. After adjusting these values for inflation, this authority estimated that installation costs had increased by as much as 300 percent in this period.

The second conclusion is that, despite these costs, the returns to a private well can still be substantial. The Water and Power Development Authority (1980) calculated benefit/cost ratios with 1978 data that ranged between 1.28 and 3.18, depending on the assumptions. Yasin (1975) claimed that owners of electrically-operated wells in some districts of the Punjab could expect to recover their investment in less than a year. Mohammad (1965) estimated that diesel-powered well owners would reclaim their investment in 3 years, and electrically-operated well owners in 2 years. Obviously, such estimates are highly dependent on the size of landholdings and the quantity and reliability of alternative water supplies such as rainfall, public canal water and the Salinity Control and Reclamation Project pumpage. But. the Water and Power Development Authority (1980) concluded that it was these high financial returns that have escalated private tube well development since the 1960s.

The third conclusion is that operational costs are substantially higher than installation costs. In 1980, the Water and Power Development Authority estimated that operational costs totaled to almost 3 times the initial installation costs of a tube well during its lifetime. The Pakistan Agricultural Research

Council's studies in the 1970s, and Mohammad's work in the 1960s reached similar conclusions. Related to this, the fourth conclusion is that there is a dramatic difference in operational costs between diesel-powered and electrically-operated wells. The Water and Power Development Authority (1980) claimed that diesel-powered well operating costs were 156 percent higher than those for electrically-operated wells in 1969, and 57 percent higher in 1978. The Pakistan Agricultural Research Council (1978) reported differences that ranged from 50 percent to 100 percent or higher, depending on the district. In 1965. Mohammad claimed diesel-powered wells cost 60 percent more to operate than did electrically-operated wells. Such cost considerations become extremely important in farmers' choice of technologies.

Impacts on Production

In a review of several field studies conducted in Pakistan, Anson (1983:29) concludes that "farms served by private tubewells have achieved significantly higher production levels than farms that are not." These increases are reflected in these parameters: yields increased by 15 to 30 percent; cropping intensities increased from 120 to 140 percent; and cropping pattern shifted to higher value crops. In 1980. the Water and Power Development Authority reported cropping intensity comparisons of 157 percent for owners of tube wells versus 136 percent for non-owners of tube wells who purchased water versus 113 percent for non-owners with no access to private water supplies. In addition, the Water and Power Development Authority reported marked differences in cropping patterns between owners and non-owners, especially with regard to high value crops (*basmati* rice, sugarcane, etc.). It also reported yield increases that almost reached 100 percent in the case of sugarcane. The effects of private tube wells on owner income have also been remarkable, especially when a combination of holding size and pumping technologies allowed the original capital investment to be recovered in a years' time.

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CONCLUSIONS AND AREAS FOR FURTHER WORK

Private tube wells have played a crucial role in theadvancement of agricultural production in Pakistan's Punjab. As the government enters a new era in groundwater management, with an emphasis on private rather than public control of pumping facilities in fresh groundwater areas, the key issue arises: how can the government and donors encourage equitable and environmentally sustainable development of groundwaterresources via the private sector? Past research has been thorough in describing the importance of private wells to Punjab's agricultural production, to the economics of private wells, to the technologies in use. and to some primary characteristics **of** private tube well ownership. However, little insight has been gained to date into the more subtle questions of the long-term sustainability of private tube well development, the distribution of its benefits among different groups, and the links between the public surface irrigation system, and its underground private counterpart.

Environmental Sustainability

To date, for obvious reasons, private tube well development has taken place almost entirely in areas of the Punjab overlying "fresh" groundwater. In the context of Pakistan's Punjab, however, water is never absolutely fresh or saline; groundwater quality in fact varies over a wide range of values for standard water quality indicators. Vertical drainage, as practiced directly by the Salinity Control and Reclamation Project wells and indirectly by private tube wells, is not a long-term solution to the accumulation of salts in the groundwater, since these salts are not removed from the system when water is applied to farmers' fields. One may expect that groundwater quality will deteriorate in Pakistan's Punjab over time, although the rate of deterioration is open to debate.

One of the conclusions from the Water and Power Development Authority's private tube well study in the late 1970s was that "...by and large, the water developed by private tube wells does not pose any hazards according to the generally advocatedcriteria of waterquality" (Water and Power Development Authority, 198011). However, recent work by the Pakistan Division of the

International Irrigation Management Institute (IIMI Pakistan) in thecommand area of one distributary located in the heart of a ''fresh" groundwater area found a very mixed situation with regard to groundwater quality, with the majority of water sampled from private wells rated as "unfit" for long-term use as irrigation water. Past researchers have hypothesized that fanners treat their groundwater supplies differently as water quality worsens.[6] With the government's current commitment to relying on the private sector for the development of groundwaterin "fresh" areas, it is essential that detailed work be done on how water quality affects installation and usage pattemsforprivate wells, and on what the long-term implications of private groundwater use are for overall groundwater quality and the productivity of agriculture.

Anson (1983:32) claims that "With the exceptionof 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." With the transfer of responsibility for groundwater development from the public to the private sector in fresh groundwater areas, there is uncertainty as to whether private tube well pumpage will indeed be sufficient to maintain water tables at satisfactory levels, or, on the other hand, whether further encouragement of private tube wells will lead to overextraction, with adverse effects on water quality and water tablelevels. To answer these questions, accurate information is required on total installed capacity in the private sector. and on the utilization of that capacity.

As long ago as 1965, Ghulam Mohammad questioned the accuracy of official estimates of installed capacity for private wells. At the time he estimated that actual numbers of private wells were 76 percent more. than what the Revenue Department reported. In 1980, the Water and Power Development Authority reported tube well densities of 4 tube wells per405 ha (1,000 acres) in the Gugera command area of Rechna Doab. IIMI Pakistan's intensive field survey, in 1988, of the Lagar distributary, one of Gugera's many distributaries, showed a tube well density closer to 15 wells per 405 ha (1,000 acres). This figure is higher than any reported by the Water and Power Development Authority for any part of the Punjab in 1980, even though the Lagar distributary

[6] See, for example, Mohammad. 1965

is part of the Salinity Control and Reclamation Project. While part of the discrepancy is certainly due to a natural increase in the last eight years, it highlights the danger of estimating numbers based on official records alone.

Estimates of utilization have traditionally been made based on one-time cross-sectional surveys, relying on farmer recall (and honesty) to determine yearly utilization rates. They have ranged from 7 percent (the Salinity Control and Reclamation Project Monitoring, **1988)** to **29** percent (Water and Power Development Authority, **1980). IIMI** Pakistan's experiences in the Lagar distributary have pointed out the general unreliability of such data. Accurate estimates of farmer utilization, and what affects it, are essential if one is to begin to understand to what extent groundwater resources have been developed, and how much potential remains to be exploited.

Equity

Past research has highlighted the concentration of private pumping facilities in hands of relatively large-scale landowners. Anson (1983:31) concludes:

> First, **the greatest scope for future development of private tubewells** lies in extending their use to smaller farmers **(less** than 5.06 ha **[12.5** acres]) through promoting appropriate fractional tubewell 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.

While ensuring equal access to pumping facilities is one way to guarantee equitable distribution of groundwater resources, it is unrealistic to assume that each farmer in Pakistan's Punjab will one day at least partially own a private tube well. For those farmers who are not owners, access to the benefits of groundwater development can only be guaranteed through some form of water markets. Past studies in Pakistan's Punjab have shown that groundwater is commonly sold, although most conclude that such sales represent only a fraction of the total amount pumped in a given year, that they are seasonal, and

that wells are not installed primarily to sell water. Work in other parts of the Indian subcontinent have identified locations where relatively sophisticated groundwater markets have naturally developed (see for example Shah, 1987). A closer look at incipient markets in Pakistan's Punjab is necessary to identify obstacles preventing more extensive water selling arrangements. Such work may also suggest ways in which water markets can be encouraged, and the forms such markers might take.

The diverse array of past and present government programs and policies that affect or have affected private tube well development provides a rich source of information on the potential impacts of planned governmental programs. What is required is an assessment of those programs/policies in terms less gross than simply the number of wells installed. While in many cases there have been program evaluations that provide useful information, they invariably rely on simple cross-sectional surveys. The type of information required for a complete understanding of a given program's impacts requires baseline information and monitoring through time. In the case of the Salinity Control and Reclamation Project program, there has been some success in instituting this kind of evaluation process (for an example of one product, see Water and Power Development Authority, 1988). Programs and policies aimed at private tube well development, however, have lacked even rudimentary arrangements for this type of evaluation process.

The groundwater problems and potentials that Pakistan's Punjab Province experiences are a direct prcduct of the existing surface water system. Programs aimed at improving the surface system will *also* have profound impacts on the availability of groundwater supplies on the one hand, and farmers' demand for those supplies on the other. To date, there has been no analysis in Pakistan whatsoever that adequately addresses these linkages, or that attempts to explore the implications of surface water programs for groundwater development, and vice versa.

While it is true that private wells have become a crucial part of Pakistan's agriculture system with little attention from the government, the track that development has taken has been largely determined, consciously or unconsciously, by government policies. Now that the government has explicitly decided to turn over groundwater management in fresh groundwater areas to the private sector, it is essential that future government policies and programs be built on a thorough understanding of the private tube well development process, and of how the groundwater system is linked to public surface supplies.

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