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Planning and Implementation Framework for Salinity Control in the Indus River Basin

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WATERLOGGING AND SALINITY PROBLEM

About 62 percent of the Indus Basin lies in Pakistan. The mean annual rainfall varies from 50 to 1000 mm. Approximately two-thirds of the total area receives less than 250 mm of rainfall. The Indus River basin plains start below the Salt Range about 800 miles from the sea. It is a vast land of about 21 million hectares with very flat topography having an average slope of 0.0002. The total irrigated area in the region is 15 million ha.

The Indus irrigation system is shown in Figure 1. Its history began with agricultural practices being carried out on the banks of rivers made moist by swollen and overflown streams, which evolved into the construction of "Inundation Canals." By the middle of the 19th century many such inundation systems existed. The British initiated a massive development program about the turn of the century which gave Pakistan the world's largest contiguous irrigation system. After independence in 1947, the historic struggle of the people resulted in major dams such as Tarbela and Mangla, barrages, large canals linking rivers, irrigation canals, more than 200,000 tubewells and 80,000 watercourses which deliver water to the farmers' fields. There are about 3 million farmers with a median farm size of 2.1 ha. An average watercourse serves about 40 farmers and a normal village of 100 to 120 farms will have approximately three watercourses.

The irrigation system is constructed to that water flows from minor canals through turnouts (moghas) supplying water to a village area. The farmers themselves operate and maintain their distribution system. There are no headgates at the moghas and if a particular canal has a water in it, there is water in every watercourse (khal) along that canal. The farmers on the watercourse use the entire flow on turn (based

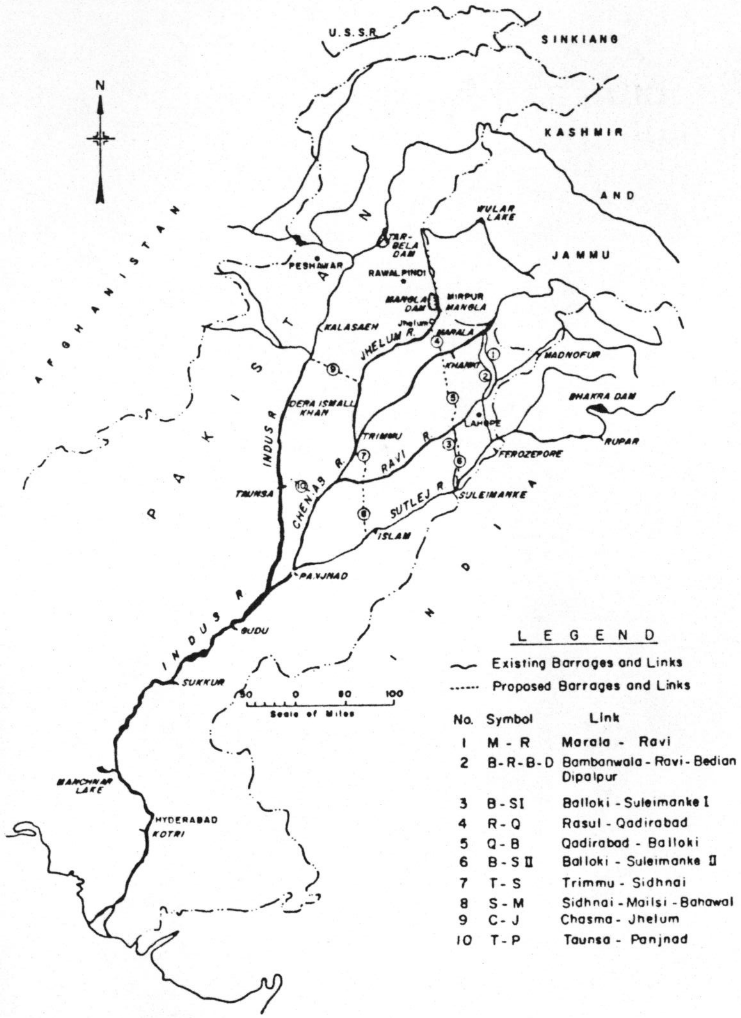

Figure I. Indus River Basin.

on farm size) and there is a fixed time each week, ten days or two weeks to use this water. The system of rotation is called "warabundi." The level basin method of irrigation is used extensively.

Natural drainage ways are not readily apparent. A few artificial drains have been constructed; therefore, surface drainage for irrigation water is virtually non-existent either from artificial or natural drains. Irrigation water passing through each "mogha", as well as surface runoff during the monsoon season, is therefore utilized on that particular watercourse area as there is no provision to let it pass to an area of lower elevation.

In this arid and semi-arid region, the salts were deposited in varying degrees when the alluvium was laid down. Prior to the major conversion of inundation canals to weir control canals, the water table in the center of the "doabs" (land between two rivers) and in other portions of the Indus was eighty feet or more below the surface (1). The water table has gradually risen over a large area. A 1975 survey indicated 6.9 million ha of canal culturable commanded area (CCA) underlain by a water table within 3 m and nearly 80,000 ha had become unculturable due to high water table (2). Because of the high water table and lack of drainage infrastructure, hundreds of thousands of hectares have become saline. Many thousands of hectares are going out of cultivation each year due to waterlogging and increased salinity. The average rise of the groundwater table has been estimated between 15 to 60 cm per year.

The latest survey also reveals that out of 14 million ha of CCA, nearly 5.2 million ha of land is severely saline and sodic (2). According to another survey supported by laboratory analysis, this badly salt affected area is more than 5.8 million ha. Estimates prepared by FAO and UNESCO report 80 percent of the irrigated area of this region is affected by this problem to varying degrees.

Waterlogging has been recognized as a problem in the region since 1841. However, no practical solution was applied at that time. A serious consideration to waterlogging was given in 1851, when malaria became a serious problem in the Western Jamna Canal (now in India). After irrigation began on a significant magnitude in 1856, and particularly as the irrigated area increased, the intensified problem of waterlogging became of major concern. The sequence of activities are listed below:

- 1870, Systematic observation of ground water levels was initiated.
- 1892-1904, Western Jamna Canal--measures were taken to prevent canals from obstructing surface flows.
- 1908-1918, Lower Chenab Canal--surface drains were constructed and some lining of channels was done.

- 1917, serious discussions took place and comprehensive schemes were prepared to combat the waterlogging dangers.
- 1918-1926, Financial conditions after World War I did not permit significant improvement works.
- 1926-1933, Upper Chenab Canal--some seepage drains were placed along the main line, tubewells were installed, and pumping of large ponds was initiated.
- 1933-1941, Rechna Doab--drains were excavated.
- 1941-1947, comprehensive tubewell schemes were prepared and many surface drains excavated.
- 1952-1958, The Government of Pakistan in cooperation with the Government of Canada completed an air photography survey of the Indus Plains, which showed that out of 29 million ha surveyed, 4.9 million ha were severely saline and 4.6 million ha were covered with saline patches.
- 1954, a detailed investigation was initiated by the Punjab Department of Irrigation and later by the West Pakistan Water and Power Development Authority (WAPDA) with the help of the International Cooperation Administration (now USAID).
- 1959, in order to develop a detailed program for alleviating waterlogging and salinity throughout the Indus Basin, WAPDA engaged two well reputed foreign firms of consultants; Hunting Technical Services, Ltd. and Tipton and Kalmbach, Inc.
- 1961, a master plan for the control of waterlogging and salinity was formulated by WAPDA, which called for the installation of 31,000 tubewells, 12,000 km of major drainage channels, and 40,000 km of supplementary drains; however, all such ambitious programs suffered a serious setback because of later political developments.

Following is a brief description of the results achieved:

- In the Northern Zone of the Indus Basin (mainly the Punjab Province), under the regional plan, WAPDA has so far completed the detail planning of seven salinity control and reclamation projects (SCARP's) with an aggregate area of 4.8 million ha, of which four projects have been completed.
- In the Southern Zone of the Indus Basin (mainly the Sind Province), WAPDA has completed the detailed planning of eight SCARP's with gross area of 3.6 million ha, of which three projects have been approved and are being implemented.
- Under SCARP and Public Irrigation programs there are now about 18,000 tubewells in addition to the estimated 190,000 tubewells installed by the private sector.

- WAPDA has undertaken a tile drainage program in the Sind Province near Kahirpur.
- Provincial governments in the Punjab and Sind Provinces are undertaking a surface drainage program but progress is not encouraging and surface drains are not being maintained.

The development of irrigated agriculture in the past has remained focused almost entirely upon the construction of water delivery systems. This preoccupation with the installation of "hardware" results from the naive single-discipline approach to water management. Moreover, in the past, even the increased water availability has not been matched by the expansion in acreage. As a matter of fact, increased water supplies have resulted in increased recharge to the ground water aquifer because of increased system losses. In order to assess the magnitude of deep percolation from the root zone and seepage from conveyance systems, a schematic water balance of the Indus Basin irrigation system is given in Figure 2. This shows that more than 60 percent of the ground water recharge takes place from watercourse seepage losses beyond the canal outlet and deep percolation from croplands. At present, recharge to the aquifer is at least two times greater than the water being pumped by tubewells. The on-farm water losses along with canal seepage losses are directly responsible for rising ground water levels and degradation of return flows. This problem is steadily getting worse simply because of an inordinate focus on developing more and more water supplies and the almost complete neglect of improved soil-plant-water management practices.

Achieving high levels of water use efficiency in order to minimize canal deliveries and prevent or control waterlogging and salinity due to return flow is both difficult and expensive. Potential solutions and control measures involve physical changes in the system, which can be brought about by constructing sufficient improvements to the existing system, or placing new institutional influences on the system, or a combination of both.

The most significant improvements in controlling waterlogging and salinity will potentially come from watercourse improvement and improved on-farm water management practices. Pilot programs have been undertaken since 1975, primarily to increase crop production, that involve watercourse improvement, precision land leveling and some emphasis on water management. According to the 1977-1978 benchmark survey, about 40 watercourses were improved and more than 11,000 acres were precisely leveled. The planning targets are 8,700 improved watercourses and more than 170,000 ha of precisely leveled cropland by mid-1983 (3).

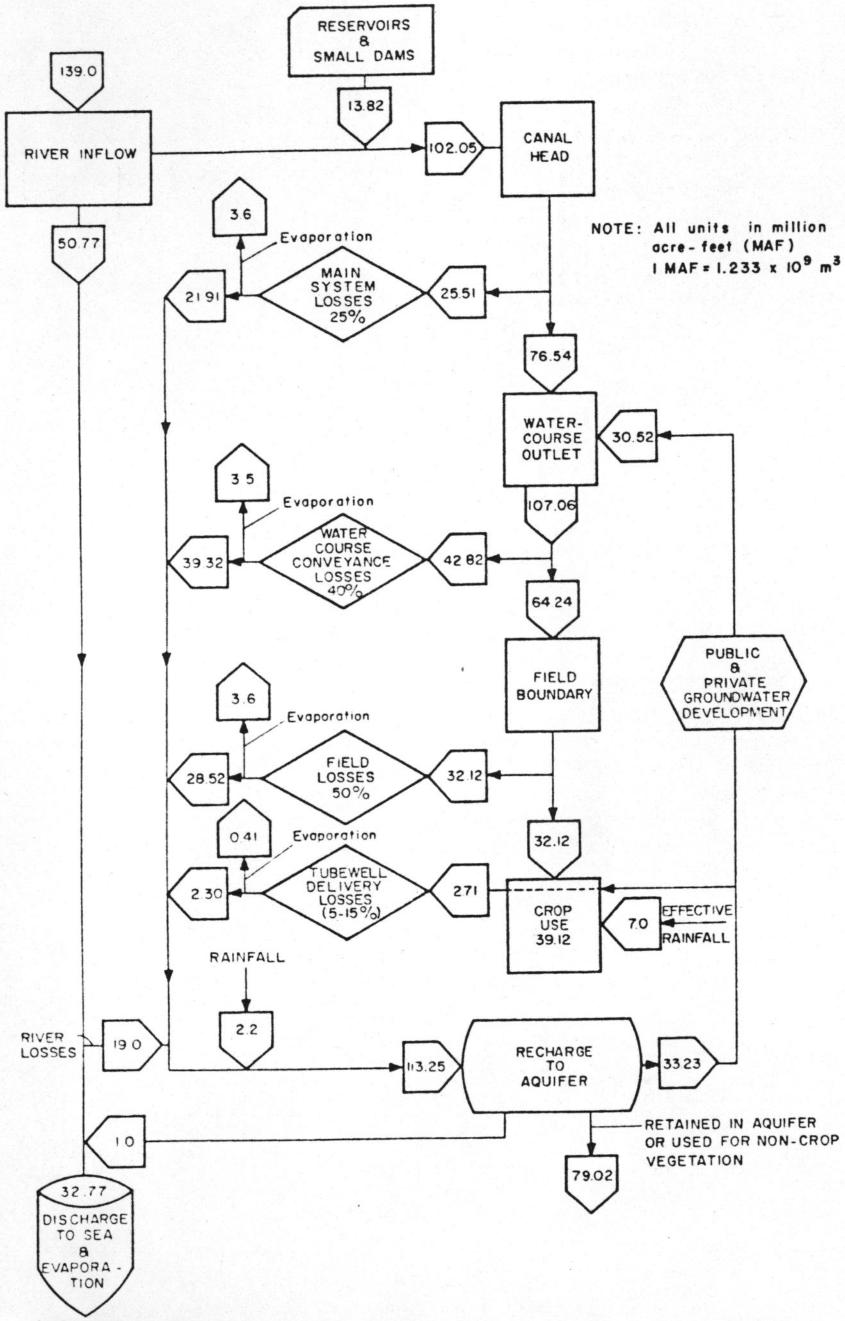

Figure 2. Schematic water balance for the Indus River Basin.

SALINITY PLANNING FOR INDUS RIVER BASIN

The majority of salinity control planning for irrigated agriculture in Pakistan has been directed toward identifying measures in individually irrigated areas called SCARP's. However, plans must also be developed for the entire Indus River Basin. First, evaluation of alternatives for each area leads to practices that can effectively control salinity from use of irrigation water. These plans should indicate optimal policies for reducing salinity by amounts ranging from the maximum potential control achievable to no control. The relationship between salinity control policies and their resulting effectiveness is usually expressed as a cost-effectiveness relationship for each area under examination.

In each subarea, the magnitude of the problem must be determined and the salinity sources delineated. This should include the magnitude of subsurface irrigation return flows resulting from seepage losses and deep percolation losses, along with changes in chemical composition of these flows enroute to the groundwater reservoir and subsequently the Indus River. Appropriate solutions should be demonstrated and evaluated on farmers' fields to develop alternatives that are both acceptable to the farmers and the implementing agencies. In addition, cost-effectiveness analyses must be established.

The second step is to define the best management practices by optimizing the cost-effectiveness relationships from individual areas into a single strategy. This planning function delineates the level of salinity control required in each individual subbasin to achieve the overall goal for waterlogging and salinity control with the least cost. Relative levels of implementation among the areas are also determined.

Finally, the third step assigns the required level of salinity control that should be implemented in each subbasin or irrigated area. The basin planning process for salinity control involves integration of planning studies at the local level into the total basin framework to define the best management practices on the basin-wide scale. By integrating the results outlined in the first step, the best management practices for salinity control in each area are identified. A summary of this process is shown schematically in Figure 3 (4).

Much of the future emphasis in Pakistan will have to be on improving existing croplands. In other words, water management will have to be improved, waterlogging and salinity problems alleviated, and crop production increased on existing irrigated lands. Technology alone will not usually bring about the necessary improvements. Instead, a combination of technological changes and institutional modifications will be required.

A "Development Process for Improving Irrigation Water Management on Farms," which is directed toward improving the

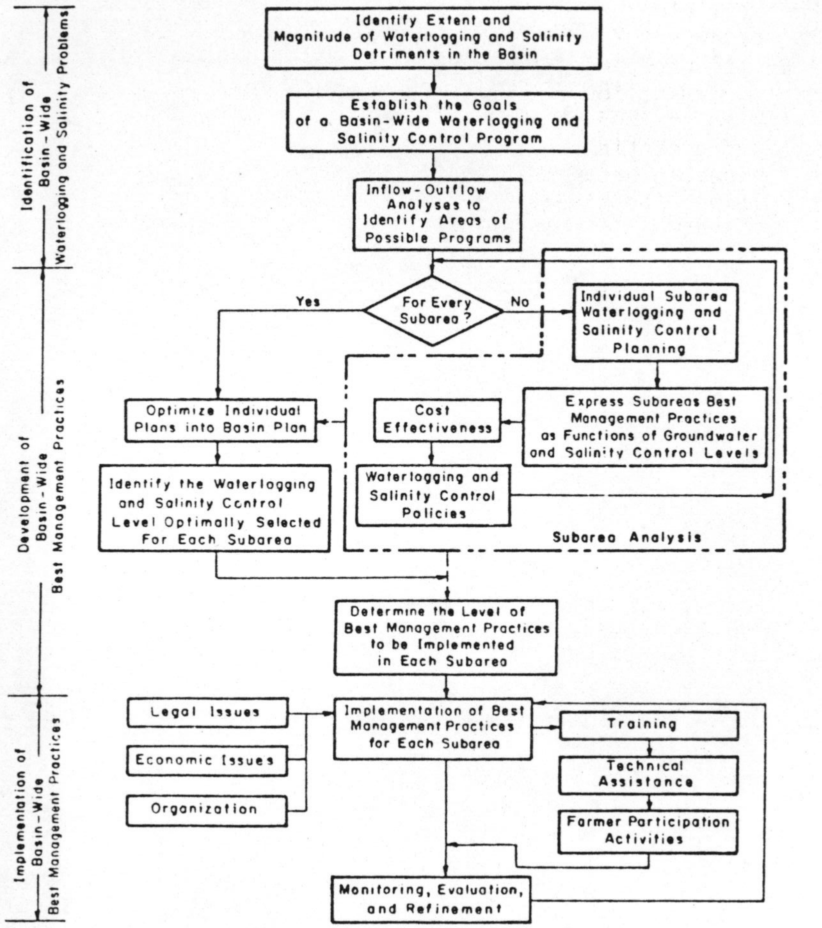

Figure 3. Planning framework for waterlogging and salinity control in a river basin.

productivity of existing irrigated lands, has recently been reported (5). This process has two important themes: (a) an interdisciplinary approach; and (b) farmer client involvement. Physical scientists and social scientists work together with farmers in identifying major constraints to increasing agricultural productivity and conserving natural resources. Acceptable solutions are developed for priority problems in collaboration with farmers. Finally, acceptable solutions are implemented that utilize both the resources of the farmers and the government. This process consists of three phases: (1) Problem identification; (2) Development of solutions; and (3) Project implementation. The three phases have also been subdivided into subphases as listed in Table 1.

Table 1. Phases and subphases of the development process for improving irrigation water management on farms.

Phase	Subphase
Problem Identification	Reconnaissance Problem Diagnosis
Development of Solutions	Identification of Plausible Solutions Testing and Adaption of Solutions Assessment of Solution Package
Project Implementation	Project Authorization Project Organization Project Operation

CONCLUSIONS

Too much emphasis on developing more water supplies and total neglect of efficient water use has resulted in waterlogging and salinity problems in the Indus River Basin.

Drainage is lacking in most of the Indus Basin. Water is being lost by seepage from canals and watercourses and deep percolation from croplands which results in high ground water levels, degradation of downstream water supplies and salt accumulation on the ground surface.

One of the important elements in the new strategy for waterlogging and salinity control in the Indus River Basin is attention toward efficient water utilization and its proper management on croplands.

Integration of the "waterlogging and salinity control planning framework" with the "development process for improving irrigation water management on farms" provides a framework for both planning and implementing an effective waterlogging and salinity control program.

Public tubewells having a discharge capacity of 30 to 150 ℓps have proven too large because of: (1) drawing upon deeper, more saline, ground water; and (2) even poorer water management practices.

Seepage losses from the farm watercourses range from 30 to 50 percent. Watercourse improvement programs within the entire basin can reduce these losses by 50 to 90 percent.

Another important salinity-control measure is reducing deep percolation losses from the irrigated lands by providing precision land leveling, conversion to better irrigation methods, irrigation scheduling, etc.

In order to make the ongoing water management program in the Indus Basin effective, the role of farmer organizations needs special consideration. The planners are acutely aware of the fact that without such organization the program is likely to fail.

Finally, a monitoring and evaluation program is needed for continuous reassessment or "tuning up" of project implementation.

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Part 3

Salinity Sources and Problems