however, a few exceptions to this general classification.

ii) Majority of the soils are heterogeneous so that horizontal permeability is much higher than vertical permeability. The permeability is low only in case of highly alkaline soils where Ph is 9.5 or above.

iii) But for a few clay lenses here and there, the water bearing aquifers are generally continuous bounded in most cases by rivers, canals or other water bodies. At places where clay lenses are found, the soils are impermeable or less permeable.

iv) At some places calcium carbonate is present in high percentage in the form of nudules known as 'kankars'.

v) Potassium and magnesium is present also in small quantities in the exchange complex of clay in the southern parts of the Indus Basin.

vi) A pronounced difference can be noticed between the soils in the upper, middle and lower parts of the Indus Basin. The soils in the upper and middle portions contain lower percentage of sodium and sufficient soluble calcium and magnesium in the exchange complex of its clay contents. The soils in the southern parts of the basin are usually sodic in nature and consequently less permeable. They have a black crusty surface which becomes sticky when wet. Within this overall pattern, there are a number of exceptions both in the north and south as can be seen from the variation in the permeability from place to place and changes in the quality of ground water both along the vertical and horizontal directions.

APPENDIX-II

CONCLUSIONS AND RECOMMENDATIONS ON THE CONTROL OF SALINITY AND WATERLOGGING BY PAKISTAN DELEGATION TO MOSCOW DURING 1963

A high powered Pakistani delegation visited USSR in May 1963 to study the Russian methods for waterlogging and salinity control. On their return, this delegation submitted a comprehensive report to the Government of Pakistan. The conclusions and recommendations of this report are reproduced below:

1. CONCLUSIONS

1. Most of the agricultural lands in the Uzbek and Azerbaijan Republics are highly salinized and have mineralized ground waters, which are quite close to the surface. Extension of Irrigation has resulted in serious problems of waterlogging and accumulation of salts in the arable soil.

2. Both preventive and corrective measures are adopted to improve the situation. Preventive measures comprise containment within and diversion of flood waters through improved flood channels, reduction of water losses by such means as use of lined channels and precast cement concrete troughs, efficiency in water application and creation of tree belts to establish biological drainage. Corrective measures comprise desalinization of soils in the root zone, depressing the water table to an optimum depth, demineralization of the ground waters to contain a low percentage of salts in solution and subsequently creating a sweet water stratum overlying the mineralized waters.

3. The criteria used are:

   i) Optimum depth of ground water below the land surface varies with the climatic and soil conditions, crops grown and the stage of plant growth and is of the order of 1 to 2.5 m.

   ii) Total salt content in the root zone(about 1-1.5 m depth)should not exceed 0.3 gm/lit., chloride content should be less than 0.01 per cent and sulphates present should be below 0.15 per cent.

   iii) Mineral content of ground waters for cotton should not be higher than 2 to 3 gm/lit.

4. A high water table is as likely to be damaging as helpful, depending upon how it is regulated. It has long been known that plants take water from the ground water storage and this is of great practical importance inasmuch as the plants can satisfy from this storage their partial evapotranspiration needs and thus expenditure, both capital and recurring, on irrigation works and labour charges can be greatly reduced. The system is vastly practised in "The Netherlands", where by regulation of the water table higher yields are harvested. The Imperial Valley in the U.S.A. has a water table ranging between 1.7 to 3 m and yet here not only cash crops of all kinds are grown successfully but the agricultural yields per unit area are some of the highest in the world.

5. The result in the USSR is secured through two measures:

i) The sub-soil water is refreshed so as to make available to the plant what it can readily assimilate; and

ii) the water-table, through regulation of drains, of any type, is maintained at an optimum depth so that resalinization is eliminated.

6. Leaching to remove soluble salts and displaced exchangeable sodium is essential for reclamation. Lands are desalinized by ponding and leaching out and evacuating the leachate through a system of deep drains, supplemented by shallow drains, the general methods being:

   i) Continuous flooding without a crop.

   ii) continuous flooding with a rice crop, and

   iii) continuous application of excess water during irrigation of a crop.

   Method(i) is most frequently employed.

7. In the case of alkaline lands, complementary measures including deep ploughing, loosening, temporary shallow drains and use of chemicals such as gypsum, are employed.

8. Ground waters are demineralized by heavy application of water to dilute and displace mineralized waters and progressively export them through the permanent drains.

9. Reclamation(desalinization of soils, demineralization of ground waters and depression of water table to the optimum depth is achieved by two stages:

   a) Temporary stage, when a temporary network of open drains

is built and through leaching the soils in the root zone are desalinized to contain approximately 0.2 -0.3 per cent total salts and not more than 0.01 per cent chlorides. Further the ground waters are depressed to an optimum depth and demineralized as far as possible to a concentration of 2-3 gm/lit, when despite the proximity of the subsoil water table the continued fertility of the irrigated soils can be ensured.

b) Permanent stage, when a permanent drainage network, more often tile drains in combination with surface drains, is provided and through repeated applications of fresh water when the land lies fallow, generally a good quality water layer is built over the salinized ground water table.

10. Judging from the high yields of crops, the system of open drains and tile drains could be regarded as a proven success. And it cannot be otherwise as is also recognized by the US President's Science Advisory Committee on Waterlogging and Salinity in West Pakistan, vide pp. 102-103 of their draft report.

11. While the above system is in general use on the Soviet Union, the Soviet workers continue to test other methods such as 'vertical' drainage by tubewells in areas with a sweet water aquifer, mostly in varying degree of combination with open drains. Even where the water table is successfully lowered by pumpage, emphasis is placed on maintaing the water table at the optimum depth.

12. Tile drains of baked earth have been found chemically inert, capable of sustaining heavy loads, virtually having an infinite life, a depenable and economic material for desalting salt impregnated soils and easy to maintain.

13. While the drainage tubewell operation experience in the USSR is limited, this cannot be said of tubewells for potable water supply. The life of a tubewell is reckoned at 15 to 20 years under those conditions. Corrosion is absent but incrustations are generally formed. Ground water of poor quality is likely to further reduce the life of tubewells and create more complicated maintenance problems.

14. Considerable theory on the depth and spacing of tile drains, etc., has been developed. But the solution of any drainage and reclamation problem is mostly sought through experience on a field test station. The final layout is determined from experience gained through operation of a temporary drainage system on individual land parcels during the first two to three years of reclamation.

15. There is close cooperation between research and field workers with the result that the results of research find ready application in the field and with satisfactory results and considerable economics.

2. RECOMMENDATIONS

In view of the above findings our recommendations are as follows:

1. Heavey accretations to ground water table from any source are in most cases economically dealt with by their prevention or by direct disposal through improved natural or artificial open drains.
2. In lands with a high water table if the sub-soil water is of good quality, it is uneconomic to depress the water table at the beginning of the season beyond about 2.5 m, the exact depth being a function of climatic conditions and the crop variety.
3. Where the sub-soil water is salinized, it may be depressed gradually to a depth of 10 to 15 m, while concurrently building up a sweet water buffer zone through high water applications to check resalinization and to serve as a reservoir to meet part of the water requirements of crops.
4. Where the soils are salinized they should be simultaneously leached to reduce the salt content to a permissible limit. The methods adopted for this purpose in the Soviet Union are similar to those adopted in Pakistan and elsewhere, although it appears that some refinements suiting the local conditions of a specific situation have been introduced.
5. Tile drains or shallow tubewells in varying combinations with open drains would appear to satisfactorily solve the problems of land drainage in West Pakistan.
6. Where deep tubewells are employed to secure additional water for irrigation, in determining the economics of tubewells, allowance, hitherto completely ignored, needs to be made for water 30 to 50 per cent in the case of cotton- that the plant normally derives from the sub-storage. As a result of mining of ground waters by depressing the water table, to the extent that the plant no longer can draw upon this storage for meeting part of its evaportranspirtion requirements, the net benefit from tubewells pumpage is obviously the total quantity reduced by such loss.

7. In determining the relative merits of the horizontal and ' vertical' drainage by tubewells, the following aspects need to be considered:

   i) Tile drains have been tried and found successful not only in the Soviet Union but also in the USA., The Netherlands, UAR (Egypt) and many European countries.

   ii) Tile drains have almost an unlimited life and even for purposes of financial calculations, a life of 40 to 50 years is adopted.

   iii) Tiles are manufactured from indigenous materials, and so also filter material is locally available. Further tile laying could be made greatly labour intensive. For under-developed countries with unemployment and under-employment this aspect has obvious importance.

   iv) Maintenance of tile systems is simple and inexpensive.

   v) World experience in tubewell drainage is limited with risk of failure being comparatively greater.

   vi) Tubewells have a much shorter life and under the most favourable conditions in Pakistan it may be about 20 years. In adverse condition it could be as low as 5 years and instances of life lower than this are not wanting.

   vii) Tubewells; cost has and will continue to have a heavy component of foreign exchange which is of a periodically recurring nature.

   viii) The operation and maintenance cost of tubewells forms a sizeable annual bill.

8. Field reclamation stations in representative areas all over West Pakistan need to be established not only to determine the various variables in a drainage system and the norms of water application to leach out salts, etc., but to run as model farms and to innovate new methods and techniques of agricultural production. Such stations in order that they should furnish dependable guidelines must be located in the worst possible area.

9. Arrangements should be made for an exchange of scientific literature with the USSR. Most of the papers carry abstracts in English. Articles of special interest should be rendered into English, and circulated through a central organization.

10. It is in the national interest that the Pakistani engineers and technicians, who in achievements and dedication are next to none, should be afforded better and greater opportunity to widen their knowledge and serve the country on a befitting manner.

AUTHOR'S COMMENTS

1. Although some members of this delegation were actively engaged alongwith foreign consultants in the planning, designing and implementation of salinity control and reclamation programme of WAPDA, most of the above recommendations did not find their place in the projects implemented in Pakistan during 1960s.

2. The above situation can only be explained by relying the statement that the local engineers and planners had no say in the matter and the foreign consultants neither studied the local problems in depth nor they examined the most appropriate methodologies to tackle the twin menance of waterlogging and salinity. Instead they applied the capital intensive technology involving mass scale import of foreign equipment, material, technical know-how and even implementation capabilities.

APPENDIX-III

Observations made by Professor Victor Kovda of UNESCO on the Waterlogging and Salinity Problems in Pakistan during his visit in August,1964

Following general ideas were given by Prof. Victor Kovda during his visit to Pakistan:

1. Importance of Preventing Measures in Anti-Salinity and Anti-Waterlogging Struggle

Before any measures for reclamation of soils are started(So expensive as horizontal or vertical drainage) designers should make sure that all existing preventive measures have been applied and their effectiveness utilized.

2. Areas of West Pakistan Affected with Positive Influence of Natural Drainage

Tremendous reserves of previously accumulated toxic soluble salts must be exported by artificial means outside the irrigated land. Existing balance of growing accumulation of soluble salts must be destructed and replaced by new type of balance of desalinization with permanent out-flow of any excess of soluble salts. This task could be accomplished most effectively through construction of a network of horizontal deep drainage and heavey leachings and washing out of soluble toxic salts from both saline soils and saline ground water.

3. Ground Water of Punjab

Many aspects of ground water hydrology of Punjab have not been studied as yet, which considerably complicates opportunities to recommend one or other system of measures for preventive and reclamation of alkalinity, salinity and waterlogging.

It is, therefore, recommended that before mass scale introduction of irrigation application of alkaline water through tubewells pumping, comprehensive studies of the long term consequences of this practice for soil in laboratories and in fields must be conducted. There are other specific aspects of chemistry of ground water of Punjab complicating the possibilities of tubewells pumping of this water for irrigation. It was firmly established that salinity of ground water in Indus Valley increases with the depths. There are certain ranges which can be quoted in this context. One could describe

four types of increase in the salinity of ground water with depths in Punjab. These are from depths of 15 to 30 ft.; between 200 to 400 ft.; between 500 to 600 ft. and between 1000 to 2000 ft. Regionalization and mapping of these four types of increasing salinity with depths has not yet been done. This is why one would not be sure of the real resources of fresh and not alkalined ground water in deep vertical strata of territories. The hydrological and chemical relationship of the fresh ground water with deep basic stratum of mineralized ground water both in the horizontal and vertical directions is also not clear. For the time being, therefore, it would be difficult to predict long term consequences of pumping of fresh ground water. There is no doubt that long term pumping of alkaline and saline ground water would add to the total salt concentration both in the soil as well as ground water, due to recycling.

4. Possible Means of Reclamation of Saline Irrigated Soils

There are two internationally accepted systems; one is based on redistribution and cyclic circulation of soluble salts and the second is based on change in the existing natural balance of soluble salts and evacuation of the soluble salts from the irrigated territory occuped with saline salts.

Considering the merits and demerits of the two systems, one reaches the following conclusions:

> "In conclusion of consideration of both concepts of reclamation of saline soils one could see that the concept of redistribution in fact recommended to keep existing balance and budget of soluble salt in soil ground water strata unaffected. Tremendous network of pumping tubewells could even accelerate the process of a general increase in the toxic components in system soil to ground waters. The concept of evacuation of soluble salts from irrigated land based on sound idea of earliest possible liquidation of main sources of saline salts as well as establishment of new type of budget of soluble salts based on permanent run-off and evacuation of any newly formed solutions of soluble salts. After effective reclamation of saline soils and saline upper strata of ground water is completed, pumping of brackish ground water by tubewells could be permitted(to a limited extent).

5. Importance of Utilization of Fresh Ground Water by Plants

In USSR, it was established that fregh ground water could be utilized by growing cultural vegetation in very high degree

namely,depending on their depths; 50 to 60 per cent of water consumption if ground water is shallow, i.e., 5 to 6 ft. 30 to 20 per cent if ground water is 7-10', and even deep located fresh ground waters between 12 to 15 ft. are also being partly utilized by roots of vegetation through capillary action.

From this point of view the tendency to remove fresh ground water eveywhere and to reduce the level very deep could not be accepted as universally desireable. Evacuation of fresh ground water followed to this reducing of level shall utlimately provoke additional water requirements of growing cultural vegetation and additional irrigation. The deeper the reduced level of fresh ground water level, the more will be requirements for additional irrigation. Considerable amount of cautiousness is required before big practical measures for pumping and over-pumping of fresh ground water would be introduced in a big territory(Punjab). If in spite of our recommendations, vertical drainage would be choosen as main mechanism of reclamation of saline soils the pumping in tubewells and leaching must be organized in such a way that fresh sub-soil ground water will be kept on level of 5 to 6 ft. (Unfortunately this recommendation was totally ignored by Project Consultants during 1960s.

6. Deep horizontal Drainage and Leaching as Main Tools of Reclamation of Irrigation Soils

As shown by the experience of USSR, USA, UAR, Australia, Chinese Peoples Republic, the best method of reclamation of saline and alkaline soils is the simultaneous application of deep horizontal, drainage and leaching of soluble salts from soil and ground water. Network of horizontal drainage depends on the degree of soils, soil salinity as well as of ground water and can be considerably variable. The salinity and alkalinity is the results of many factors such as natural, economical as well as historical in origin. The leaching arrangements and application of gypsum, etc., must be based on special design in accordance with established reclamation practices required for different types of lands.

7. Vertical Drainage and Supplementary Methods

If after deep hydrological studies existence of real artisan waters of high quality is found in deep underlying strata of Indus Valley Plains, the pumping of these waters shall be an additional source of fresh irrigation water for the area. The drilling done for the time being is relatively shallow and not deeper than 2000 ft.

By Dr.S.M.H.Bokhari

If the artesian basin of fresh water is found in West Pakistan it will open a new realistic era for tubewell water supply for irrigation lands of West Pakistan. For the time being, tubewell pumping is very limited with zones of fresh water formed for sub-irrigation. Over pumping of these limited resources of water can in the future reduce productivity of soils of these fresh water belts. Additional sinking of tubewells to expedite the reclamation and increase the effect of both horizontal drainage and of leaching could be effective but combination of joint action of horizontal and vertical drainage must be previously experimentally studied.

APPENDIX-IV

EVALUATION OF ALTERNATIVE
SYSTEMS FOR LAND RECLAMATION

(Prices - 1972 Level)

Item	Alternative-I SCARP I	Alternative-II: Shallow private tube-wells
(1) Capital Investment on tubewells (United State $)	1880 per Cu.ft/Sec capacity(Public funds).	(a) Electric tubewells 600-900 (b) Diesel tubewells 900-1200 (farmer's own funds)
(2) Percentage of total capital investment in foreign currency	56	15-20 on imports of some raw materials only.
(3) Cost per acre foot of water(recurring cost; U.S.dollars	2.5	(a) Electric tube-well:1.1 (b) Diesel tubewells:2.1
(4) Operation period during a year(as percentage of one year)	30-37	25-35(even 50 in some cases)
(5) Utilization efficiency, excluding wastefull operation (percentage)	20-30	20-30(higher in some cases)
(6) Economic life of tubewells.	10-15 years compared with 10 years assumed in the project feasibility	8-10 years
(7) Land Reclamation	62 per cent of affected land has been reclaimed in 10 yrs, against 100 per cent the process after coming to a halt, has reversed.	62 per cent in 7 years process is progressing.
(8) Cropping intensities.	Maximum of 109 percent compared with 150 percent propoed in design.	140-183 per cent

(9)	Crop yields (pound per acre)	(a) Wheat :1,450-1,900 (b) Rice:1500-1800 (c) Cotton:650-700 (d) Sugar-cane(gur)4900 Most of this increase is noticeable on those large farms where, in addition to public tube-wells, private tubewells have been installed.	(a) 1230-2100 (b) 2200 (c) 500-800 (d) 2700-4000
(10)	Net average farm income per acre (U.S.dollars)	22-39	(a) Electric tube-wells:83 (b) Diesel Tube-wells:48
(11)	Annual financial return to investor	Negative-annual cost is subsidized to extent of US$ 2,750,000	60-100 per cent of total investment.
(12)	Prospects for improved land and water management	Not favourable for obvious reasons: (a)Quantity and quality of tubewell water available to the farmer are variable. Any amount of advance planning and, consequently, investment to improve cultivation practices is full of risks and uncertainties; (b) Of the farms,65 percent are very small and barely operating at the subsistence level; whatever little increase takes place in their net income is offset by paying reclamation fee and enhanced water-rates at twice the normal canal rates, which leaves few financial resources for them to invest on imporvement of their land management;	Very good.

		(c) The situation is worsend by the rapid decline in the yield of public tubewells and the deterioration of water and soil quality through recirculation of highly saline water, without exporting any salt from the project area. Farmers who initiated land imporvement have therefore been discouraged.	
(13)	Operator attitude.	The public tubewell is operated by a young matriculate who receives a fixed salary from the government department. He is therefore more interested in protecting his interests than those of the farmers, as he is not accountable to them. Those who are the most seriously affected are the small landowners and tenants whose access to the operator or his organization is limited	The tubewells are operated either by the owner himself or under his direct supervision. He makes sure that the tubewell is operated strictly according to his water needs.
(14)	Local Participation.	The project was both engineered and constructed by foreigners. Hence, local participation was low, at least up to the commissioning stage. Most of the materials and machinery also were of foreign origin.	Participation is full, as all operations are carried out by local population. All the materials and machinery also are locally manufactured. As all finances are provided by the farmers themselves, public funds thus saved can be diverted to other competing developments.
(15)	Area affected by a damaged tubewell	500-800 acres	50-100 acres
(16)	Managerial Problems	(a) A single tubewell serves from two to four watercourses, which involves long link watercourses connecting these tubewells to different watercourses. For rendering poor-quality tubewells water fit for irrigation uses, it was proposed that it be mixed with	Non-existent

	canal water in specified proportions. In practice, the link watercourses could not be constructed and maintained by the farmers, nor was it possible to arrange adequate canal supplies for mixing. Even where adequate canal supplies were available, mixing arrangements were not adequate. Thus, there were numerous technical and administrative problems which were almost insurmountabe. (b) Tubewells were installed hastily without incorporating necessary changes in the distribution system.Farmers' ditches with a capacity of 1-2 cu.ft./sec. had to cope with a water volume from two to three times their capacity, which inevitably resulted in frequent breakdowns and wasteful spillage of water. (c) Due to excessive tubewell water in the farmers" distches, most of the outlets became non-modular and could not draw their designed share of water from the canal. Therefore, the resulting mixture of tubewell and canal waters remained poorer that planned. The combined effect of these and a large number of other similar discrepancies gave rise to complex managerial problems, which were further complicated by reduction in the discharges of a large number of tubewells and deterioration of their water qualities.	
(17) Environmental qualtity	There was considerable improvement at the early stages, when waterlogging & salinity began to disappear rapidly. Subsequently, however, due to reasons listed above, the salinity problems reappeared. And unless effective remedial measures are provided in the form of horizontal drains and replacement wells, salt intrusion is likely to proceed unchecked, gradually replicating the conditions obtaining at wellton Mohawk (United States of America) during 1951-52.	Shallow-water quality being less saline, the environmental qualtity is improved by this alternative, through effective control over the water-table.However, horizontal drains will eventually become necessary in areas with private tubewell concentration, in order to save these areas from harmful salt concentrations.

International Experience

a) India: Mellor, et al (1971) compared public tubewells with private tubewells in India. According to their analysis the cost of state tubewells is 7 1/2 times that of private tubewells. Although the state tubewells operate much closure to engineering capacity than do the private tubewells, the higher utilization rates of public wells usually result in increased breakdowns and consequent unreliability of water supplies as compared to private wells.

b) India : Given the importance of tubewells in India's programme of irrigation expansion, the ways in which tubewells are provided and managed are critical factors. Great differences are observed between private and state tubewells. Moorti (1971) is of the views that farms irrigated with private tubewells are operated in a more profitable manner than those with state tubewells. Farms with private tubewells have more intensive cropping patterns, grow greater proportions of highy yielding varieties and operate at much higher levels of input use.

c) World Bank: Explaining the World Bank experience in water resource developments, Kirpich(1972) stated:

> In Punjab the "green revolution" in a way perplexed the planners because almost spontaneously tens of thousands of shallow wells were installed by private farmers in the space of a few years. Mostly electric driven low-capacity centrifugal pumps are used which in physical terms are far less efficient than large capacity turbine pumps; yet the former are clearly superior in economic and human terms as events have proved.

References:

1. Mellor, et at, 1971, Economic and Political Weekly Review of Agriculture. Vol. VI, No.13, New Delhi, India, March.

2. Moorti, T.V., 1971. A Comparative Study of Well Irrigation in Aligarh District of India. Cornell International Agricultural Development Bulletin 19, Ithaca, New York.

3. Kirpich, P.Z., 1972. Some World Bank Experiences in Water Resource Planning. Paper presented at the International Symposium on Water Resources Planning held in Mexico, September.

By Dr.S.M.H.Bokhari

APPENDIX-V

REVIEW OF WATER QUALITY CRITERIA

Water Quality Standards

Considering the chemical character of ground water of the region and the contemplated future water management practices and conditions of use, the restriction on development and use of ground water, in the opinion of Messrs. Tipton & Kalmbach(WAPDA Consultants) for reclamation programme can be defined by a single parameter-mineral concentration, or salinity index of water expressed in parts per million(ppm) of total dissolved soild salts. Without providing any scientific explanation, the internationally recognized water quality standards were rejected to adopt extremely liberal standards in the salinity control and reclamation projects to be implemented in Pakistan. Table VI below contains these relaxed standards:

TABLE-VI

Salinity (ppm)	Classification	Restriction on Use
i) Less than 1500	Non Saline	None
ii) 1500-4000	Intermediate	May be used in conjuction with canal supplies under prescribed management practices which ensure supplemental leaching commensurate with the salinity of applied water.(Unfortunately this can be achieved on an experimental scale only and that too in well-equipped soil salinity laboratories- but impossible under field conditions obtainable at the farm level even in developed countries let alone Pakistan or any other less industrialized developing country).
iii) 4000 and above	Saline	Unsuitable for development as an economic supply under present conditions for water management and use.

It is not understood what prompted consultants to advocate use of highly mineralized ground water in Indus Basin for Irrigation purposes on long term basis when the following factors were very well known:

i) Majority of the farmers were illiterate and poor. They could not take any innovative measures to revolutionalize their land and water management on their own.

ii) Most of the farm sizes were smaller than internationally recognized economic units which could sustain agricultural activities at the subsistence level only.

iii) Land holdings were fragmented and land tenures not conducive to extraordinary investment of time and money.

iv) Surface irrigation system not capable of full regulation of the available river supplies due to lack of storage dams.

v) Existing surface water distribution facilities based on an unscientific fixed 7-day roster for supplying of water for a fixed period of time irresepctive of the quantity of water available for distribution and without any reference to the crop needs at the time of the fixed turn of the farmer.

vi) Most of the farms not levelled precisely and the irrigation lay out at the farm based on the outmoded concepts.

vii) Farm drainage totally absent.

Without planning or proposing any improvement in the above parameters the water qualtity standards were so relaxed that even under the best possible environment and farm management, the chemistry and the physiology of the irrigated lands would have been spoiled. This has been well demonstrated in the Welton Mohawk Irrigation District of Arizona, U.S.A. where despite best environmental conditions and top class farm management, all the irrigation tubewells had to be converted into drainage tubewells within a short span of 20 to 30 years.

Another question which is equally disturbing is regarding the total neglect of other parameters such as Residual Sodium Carbonate (RSC), Sodium Adsorption Ratio(SAR), Soluble Sodium Percentage(SSP) and the concentration of toxic ions principally boron. No doubt a mention of these parameters was made under the secondary criterion for water quality, in practice they were ignored while designing the project facilities in the SCARP areas.

By Dr.S.M.H.Bokhari

It may be of interest to mention very briefly the broad classification of water qualtity recommended by various consultants:

i) Dr. Revelle Group and Mr. Fireman suggested to fix 5000 ppm as the limit for possible mixing between the surface and ground water for Indus Basin.

ii) HARZA suggested that 3000 ppm should be the upper limit for northern zone and 2000 ppm for the southern zone.

Although WAPDA did not accept these recommendations in full and instread adopted slightly lower values, still the difference between the adopted standards and the international standards was very big as can be seen from Table-VII given below:

TABLE-VII

Classification	Relaxed WAPDA Standards			U.S. D.A. Handbook Standards			Remarks
	E.C.	S.A.R.	R.S.C.	E.C.	S.A.R.	R.S.C.	
Useable(low salinity/alkalinity hazard)	1500 m.mhos	10	2.5 m.eq/L	750	6	1.25	It may be pointed that U.S. D.A. Handbook does not use the terms 'safe'/'useable'/ 'marginal' or 'hazardous" for irrigation waters. Instead the waters are classified as of low,medium or high salinity/alkalinity hazards, depending on the value of E.C., S.A.R. and R.S.C. etc.
Marginal/Medium salinity/ alkalinity hazard	1501- 3000 m.mhos (M/S.T&K go upto 4000 ppm)	10- 18	2.5 to 5.00 m.eq/L	750 to 1200	6 to 10	1.26 to 25 m.eq/L	
Hazardous	Beyond 3000 m/mhos	Beyond 18	Beyond 5	Beyond limits for marginal.			

As a result of the above relaxed standards, secondary salinization has taken place at a number of places in the project areas. In effect, even the so called good quality tubewell water has deteriorated large areas particularly when its characteristics were slightly alkaline. In a study carried out by Directorate of Soil Survey of Pakistan, it was discovered that alkali formed on the surface through evaporation of water having carbonates and bicarbonates of sodium. The pH of alkali (papri) was found to range between 9.5 to 10 in the fields under the crop. In other areas, the pH was between 8.5 to 8.8. Following general conclusions were drawn from the result of this field investigation(1973):

(a) In marginal and hazardous quality zones porous permeable-, clay loamy soils have been effected generally upto 3½" and in few cases upto 36". The clayey soils were affected upto 3" or 4" and occassionally to 15" depth. However, the intensity of deterioration was more severe in the latter possibly due to lesser permeability of the soil and higher cation exchange capacity.

(b) The tubewell water of all the three qualities have brought no improvement in the saline alkali soils. Most of these had remained as before.

(c) Soil deterioration had also been observed in areas receiving good quality tubewell water.

Although a number of concerted research efforts have been made in the recent past in U.S.A. and elsewhere to devise ways and means whereby water having higher salt concentration could be utilized for irrigation purposes on long term basis. A new approach is under close observation whereby instead of leaching down the salts from the root zone, these could be precipitated out, so that soil moisture remains within acceptable levels of salt concentration. For such concepts to be viable, systems are needed that provide for closely controlled and metered application rates, uniformly distributed and with minimal system losses. Clearly, in view of current practices, even in the developed countries and irrigation efficiencies commonly observed-both system and farm- the improvements suggested cannot be realized without serious complications. In the opinion of Schilfgaarde and others, numerous organizational, institutional and legal restraints can be cited in the practical application of these concepts. Investments in established water delivery and farm irrigation systems present powerful forces against the change. The uniformity of application obtainable with currently available systems is limited all over the world. The need to satisfy daily evaporative demand plus a prescribed leaching fraction would demand an unattainable accuracy in estimating short-term consumptive use, if the irrigation were to be scheduled on a consumptive use basis. The expected limited range in matric potentials in the root zone preclude control based solely on tension-meters or similar water potential censors(1974).

To fulfil some of the requirements under which the new concepts can theoretically operate, all the existing designs of sprinkler system drip irrigation and gravity irrigation will have to undergo modifications and changes. It, therefore, logically follows that the new concepts are not applicable to even the most modern irrigated agriculture

in the world let alone most primitive farming practices in Pakistan.

References:

1. Soil Survey of Pakistan, 1973, Effects of Tubewell Water on the Lands of the Salinity Control and Reclamation Project I.

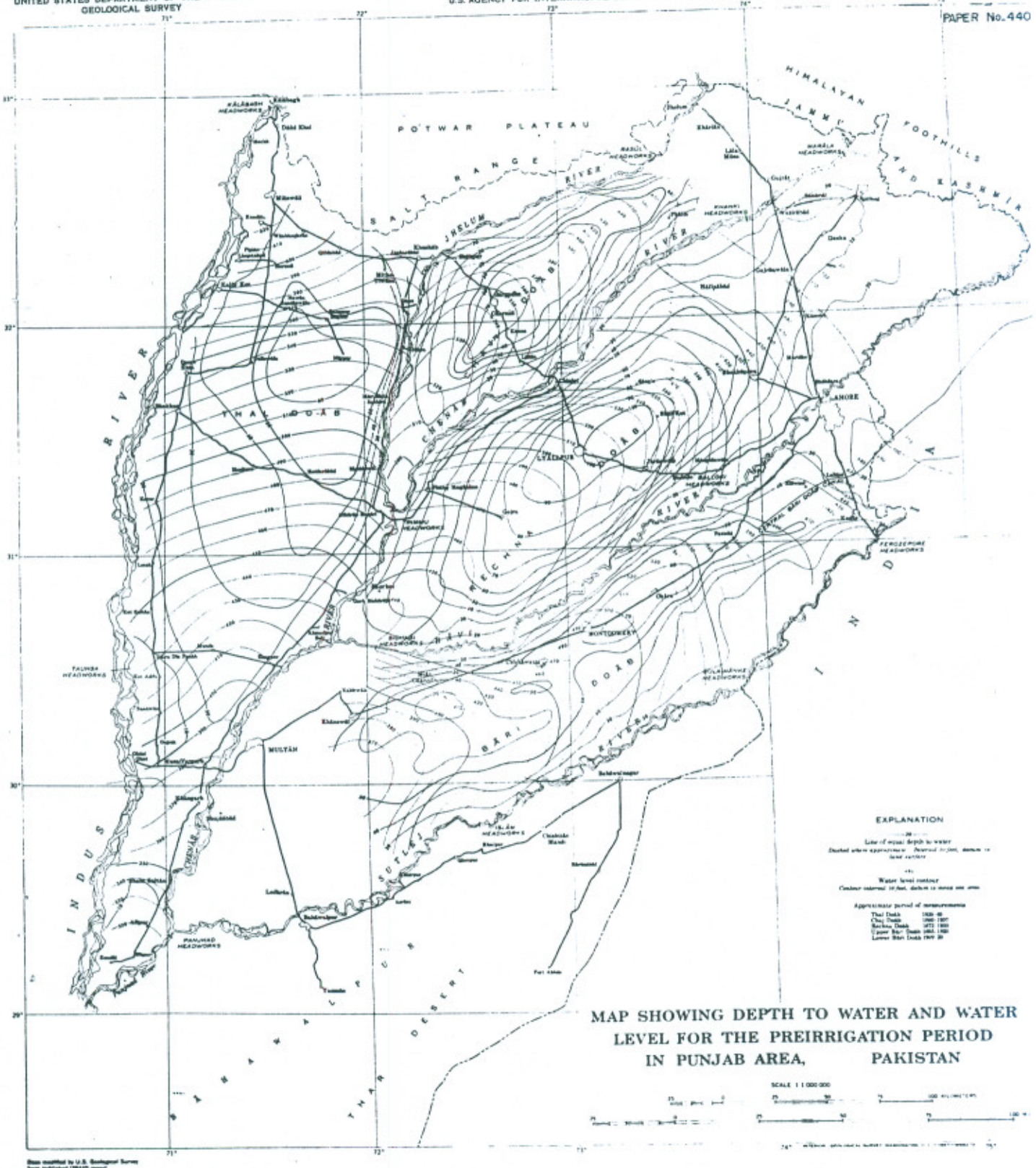
2. Schilfgaarde -.et al., 1974, Irrigation Management for Salt Control- Journal of the Irrigation and Drainage Division. Presented at the August 22-24, 1973, American Society of Civil Engineers Specialty Conference on Agricultural and Urban Considerations in Irrigation and Drainage, held at Fort Collins, Colorado, U.S.A.

COURTESY
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY
UNDER THE AUSPICES OF THE
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

WATER-SUPPLY PAPER 1608-J
PLATE-1

PAPER No. 440



MAP SHOWING DEPTH TO WATER AND WATER LEVEL FOR THE PREIRRIGATION PERIOD IN PUNJAB AREA, PAKISTAN

SCALE 1:1 000 000

Base modified by U.S. Geological Survey
from published USAID report

COURTESY
ITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY
UNDER THE AUSPICES OF THE
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

WATER-SUPPLY PAPER 1608-H
PLATE-II

PAPER No. 440



MAP SHOWING DEPTH TO WATER AND WATER LEVEL FOR 1960 IN PUNJAB AREA, PAKISTAN

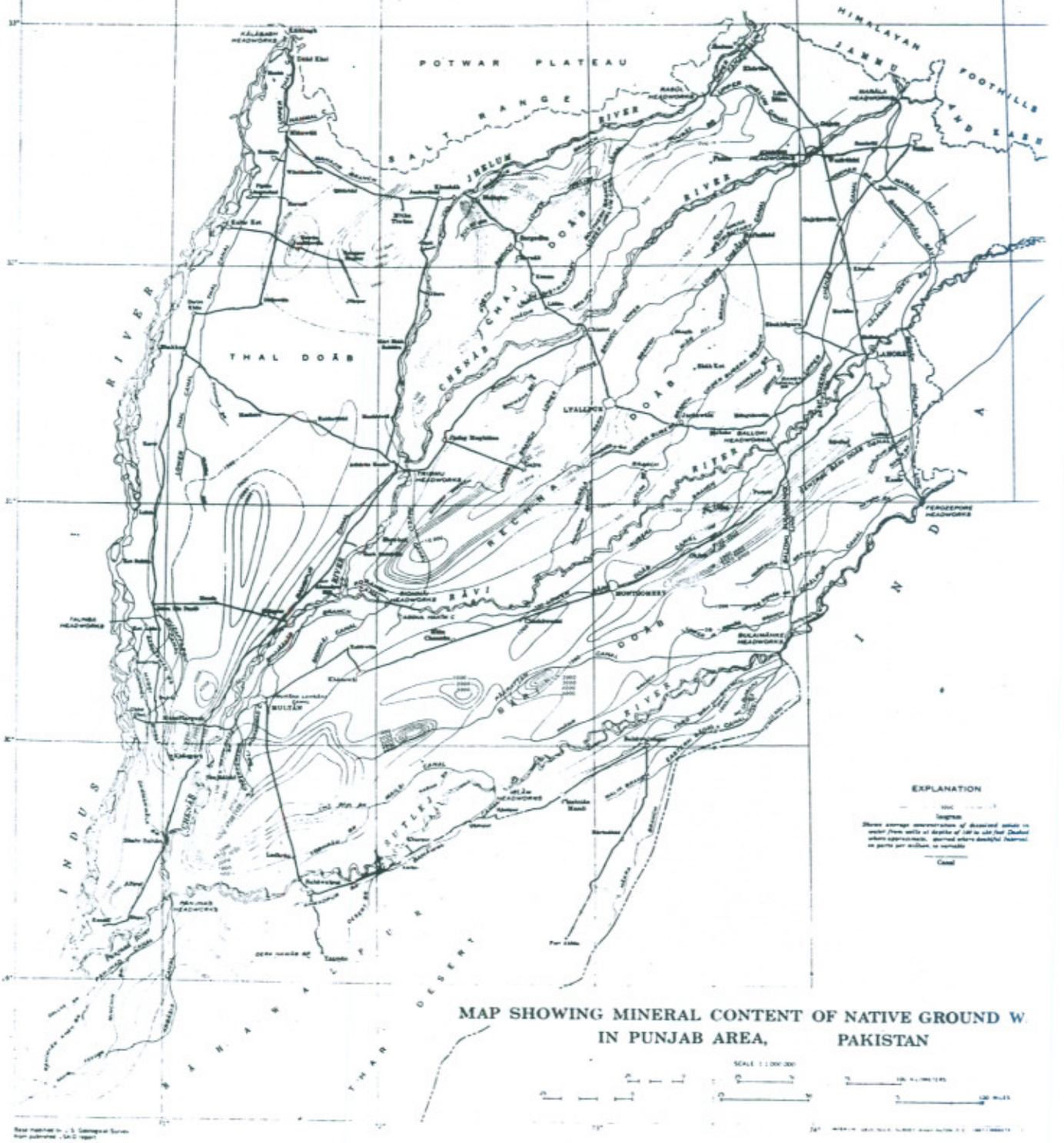
SCALE 1:1 000 000

COURTESY
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY
UNDER THE AUSPICES OF THE
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

WATER-SUPPLY PAPE
PLATE-III

PAPER



MAP SHOWING MINERAL CONTENT OF NATIVE GROUND W
IN PUNJAB AREA, PAKISTAN