Waterlogging and Salinity in the Indus Plain: Rejoinder

by

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Most of the points raised by the Panel members, Drs. Roger Revelle, Harold Thomas and Robert Dorfman, have been answered in the comment by Dr. Frank M. Eaton. Dr. Nazir Ahmad has further elaborated some of the issues involved. The author will confine his remarks to two basic issues, namely, pumping of water for irrigation purposes in the non-saline high quality groundwater areas in the Northern Zone of the Indus Plain and provision of horizontal sub-surface drainage facilities in areas where the groundwaters are saline and unfit for irrigation use.

The author is happy to note that the Panel members acknowledge the significant contribution made by private tubewells to the productivity of agriculture in West Pakistan. The author agrees with the Panel members that private tubewells will be developed mainly in areas that have adequate supplies of high quality groundwater and not in areas where the groundwater is too saline to be applied to land without dilution with canal water.

Ina previous article, the author proposed that horizontal sub-surface drainage facilities should be provided in the saline groundwater areas [5, pp. 387-395]. The Panel members do not agree with this and propose instead deep tubewells for irrigation as well as for drainage purposes. They suggest that with the use of deep tubewells and canal water the salt be flushed out of the root zone and washed downward with recycled pumped water to be stored underground.

The Panel members consider that drainage structures are expensive, and argue that provision of drainage facilities should be postponed as long as possible (p. 350). The author considers that this is a dangerous recommendation. As pointed out by Dr. Eaton (p. 382), the areas of bad waters will progressively expand during the next 10 to 50 years until all waters are salinized. With increasing salinity of groundwaters, agricultural production will progressively decline unless large scale drainage channels are constructed to remove part of the pumped waters out of the area.

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Dr. Eaton has raised two important questions on this issue (p. 383). He asks *i*) who will pay for pumping the bad waters and *ii*) how will these be disposed of?

As stated by Dr. Eaton, neither the government nor the farmers will be abl to pay for the drainage structures when all the groundwaters have been salin ized; certainly, they are better able to do so now when only part of the grounc waters are salinized.

It would be in the interest of Pakistan to install tubewells in the non-salin best quality groundwater areas only. These areas lie in the upper reaches of the Rechna, Chaj and Bari Doabs and along both sides of the rivers in the Punjab and Bahawalpur. Farmers are already installing tubewells in these areas. To keep the groundwater of these areas in good condition, Dr. Nazir Ahmad has suggested that the canal water supply to these areas should be increased during the summer season when there is excess water in the rivers. This would increase the infiltration of fresh water to the groundwater and in this way these areas could be kept fit for pumping for an almost indefinite period.

According to Harza Engineering Company International, the present river diversions into the West Pakistan canals are about 83 MAF per year, 48 MAF in the Northern Zone and 35 MAF in the Southern Zone [9, p. 39]. About 20 MAF of water is lost through seepage and evaporation in the rivers and about 61 MAF goes to the sea mainly during the summer season [9, p. 39]. It should be possible to divert some 10 MAF additional water to the non-saline groundwater areas out of the 61 MAF now going to the sea.

If the capacity of canals is increased and additional water is diverted onto these areas during the *kharif* season, the *rabi* water supply can be withdrawn from these areas. The farmers can install tubewells and meet the full need of the *rabi* crops by pumping groundwater. The *rabi* water removed from these areas can be diverted to saline groundwater areas in the lower reaches of the doabs where tubewells cannot be installed on account of high salinity.

In order to encourage the farmers to install tubewells in the non-saline groundwater areas, electricity should be provided to the whole of this area, and credit should be extended to the farmers for the purchase of tubewell materials.

In the remaining areas of the Punjab and Bahawalpur where groundwater are relatively more saline, drainage facilities must be provided to remove th salt from the area. However, a basic problem of these areas is the deficiency of irrigation water. The capacity of the canals will have to be increased and addi tional river water will have to be diverted on to these lands to meet the consumptive use requirements of crops and to leach down the salts. At the same time drainage channels will have to be constructed. As pointed out by Dr. Eaton, the drainage facilities must be provided before, rather than after, the agriculture is impoverished.

Saline Groundwater Areas

The most damaging recommendation in the *Revelle Report* was the proposal to pump water in the saline groundwater areas (having an average salinity of 6000 ppm), to mix it with canal water and to use the mixed water with an average salinity of 2000 ppm for irrigation purposes [18, p. 281]. The Panel members now consider (p. 344) that at least in half of the saline area the groundwater has a salinity of less than 5000 ppm, and this can be used for irrigation if it is sufficiently diluted with canal water. For justifying the use of this saline groundwater, the Panel members have developed a set of equations which are given on pages 348-350 of their paper.

Taking two examples, one with irrigation by canal water and the other with irrigation by mixed canal and tubewell water, the Panel members have shown (p. 350) that the salinity of the mixed water can be 0.188/0.0192 = 9.8 times larger than that of the canal water. Thus if the surface water has a salinity of 200 ppm, the concentration of the mixed water can be 2000 ppm, corresponding to a groundwater with a salinity of 3800 ppm, mixed with an equal quantity of canal water.

It appears that the Panel members obtained their result by making two incorrect assumptions: 1) The depth of irrigation water was taken as .65 feet (or 7.8 inches) and the interval of canal irrigation was taken as 4 weeks; 2) with 25 per cent increase in water supply with the installation of tubewells, the interval of irrigation of mixed water was reduced from 4 weeks to 1.5 weeks. The actual depth of irrigation in West Pakistan is 3 to 4 inches which is about one half of that assumed by the Panel members. The water is generally applied after 2 weeks. When irrigation supply is increased by 25 per cent, the interval of irrigation can be reduced from 2 weeks to 1.5 weeks, but not from 4 weeks to 1.5 weeks. If the example on page 349 is recalculated by taking depth of irrigation as 0.325 feet and interval of irrigation as 2 weeks, the salinity concentration of the mixed water would be 0.188/0.048 or 3.9 times that of canal water. If the salinity of canal water is 200 ppm, the salinity of mixed water can be 780 ppm, corresponding to a groundwater salinity of 1360 ppm when mixed with an equal quantity of canal water.

To use mixed canal and tubewell water having a salinity of 780 ppm for crops of medium salt tolerance, about 18 per cent additional water will have to be provided for leaching purposes [18, p. 117]. This would mean that 30 per cent of the tubewell water will have to be pumped for leaching purposes only[1]. If on the other hand saline water containing as much as 3800 ppm is pumped and mixed with an equal quantity of canal water and mixed water having a salinity of 2000 ppm is used for irrigation as suggested by the Panel members, nearly 67 per cent of the mixed water would be required for leaching purposes with crops of medium salt tolerance [18, p. 117]. This means that about 80 per cent of the pumped water will have to be used for leaching purposes only[2]. In the case of crops of high salt tolerance such as cotton and barley, the leaching requirement will be about 25 per cent of the mixed water or about 40 per cent of the pumped water. Even with the provision of drainage and removal of 40 to 80 per cent of the pumped water as drainage water, there would be deterioration of land due to sodium damage and large quantities of gypsum will have to be provided to keep the soils in good condition.

Dr. Eaton has developed a method for estimating the amount of gypsum and the additional amount of water which should be applied to the land to prevent high alkalinity, serious soil impermeability and deficiencies of calcium and magnesium required for normal plant growth (*see*, pp. 387-391).

For saline groundwaters of the Northern Zone of the Indus Plain the author has calculated, from water analyses of Water and Soils Investigation Division of West Pakistan WAPDA [7; 15], the gypsum and leaching requirements for all groundwaters having a salinity between 3000 and 3900 ppm in the Chaj and Rechna Doabs according to Dr. Eaton's method. Calculations have been made for the undiluted groundwaters as well as for the groundwaters when mixed with an equal quantity of canal water. The results are summarized in Table I. For all groundwaters having an average salinity of 3500 to 3600 ppm, when mixed with an equal quantity of canal water the gypsum requirements (for the mixed waters having a salinity of 1800 to 1900 ppm) average about 3000 pounds per acre foot of mixed water in the Chaj Doab and about 2000 pounds per acre foot of mixed water in the Rechna Doab. The leaching requirement for crops of medium salt tolerance average about 75 per cent in the two doabs. This means that about 85 per cent of the pumped water will have to be used for leaching purposes only.

[1] Suppose 100 parts of canal water are used to mature one acre of crop. If 100 parts of tubewell water are mixed with the same, the total quantity becomes 200 but 36 parts of additional water is required for leaching purposes to mature 2 acres of crops. Thus canal water is increased to 118 parts and tubewell water to 118 parts. The 118 parts of canal water when used alone can mature 1.18 acres of crops. Therefore 118 parts of tubewell water mature 0.82 acres of crop and are thus equal to 82 parts of canal water. The remaining 36 parts of tubewell water or 30 per cent is used for leaching purposes.

[2] Calculated as explained in footnote 1 above.

TABLE I

GYPSUM AND LEACHING REQUIREMENTS OF GROUNDWATERS OF THE CHAJ AND RECHNA DOABS, UNDILUTED AND MIXED WITH CANAL WATER FOR CROPS OF MEDIUM SALT TOLERANCE

Doab	Well number[a]	Salinity of water ground	Undiluted groundwater		Groundwater mixed with canal water[b] in equal proportion	
			Gypsum requirements per acre foot of water	Leaching requirements	Gypsum requirements per acre foot of water	Leaching requirements
(1)	(2)	(3)	(4)	(5)	(6)	(7)
		(ppm)	*(pounds)*	*(per cent)*	*(pounds)*	*(per cent)*
Chaj						
	C.26	3,000	4,951	343	2,370	67
	C.39	3,530	10,144	410	4,975	70
	C.42	3,500	3,398	838	1,596	84
	C.43	3,580	4,797	384	2,291	68
	C.50	3,580	5,316	—	2,551	127
	C.62	3,790	8,702	458	4,280	73
	C.63	3,790	5,373	479	2,581	73
	C.64	3,910	6,512	2,717	3,617	107
	CTLD.14	3,690	4,848	493	2,434	75
	CTLZ.38	3,030	5,162	447	2,476	73
	CTLZ.48	3,000	8,955	182	4,373	50
	CTLZ.50	3,700	10,245	282	5,015	63
	CTLZ.53	3,650	4,708	—	2,246	121
	CTLZ.55	3,000	4,572	305	2,179	63
	CTW.31	3,400	7,888	291	3,838	62
	Average	3,477			3,070	77
Rechna	RTLF.17	3,780	3,496	2,226	1,645	95
	RTLG.15	3,450	4,844	419	2,312	70
	RTLZ.28	3,260	7,495	167	3,648	48
	RTLZ.30	3,630	3,393	328	1,589	65
	RTLZ.31	3,800	4,530	459	2,167	72
	RTLZ.32	3,680	3,868	1,074	1,828	88
	RTLZ.33	3,370	nil	321	nil	64
	RTLZ.47	3,560	nil	199	nil	52
	RTW.28	3,910	1,884	1,132	835	82
	RTW.54	3,970	3,945	4,445	1,748	101
	RTW.53	3,940	669	321	229	64
	R.11	3,990	6,575	700	3,189	81
	R.14	3,750	6,573	259	3,178	59
	R.15	3,600	5,304	550	2,548	76
	RCC.30	3,580	9,287	347	4,535	66
	Average	3,685			1,963	72

Notes: *a*) Well numbers as given by the Water and Soils Investigation Division of WAPDA in their publications [7; 15].
b) Assuming Jhelum and Chenab river water at Trimmu containing 208 ppm [16, p. B-6]

Sources: Columns (2) and (3): Chaj Doab [7, Tables 2 and 3]
Rechna Doab [15, Tables 2 & 3].
Columns (4) to (7): Calculated according to Dr. Eaton's method (*see*, Table I on pp. 388-389).

For consumptive use requirement of 4.0 acre feet per acre, the leaching requirement will be about 3.0 acre feet per acre and the total water requirements would be about 7.0 acre feet per acre. The gypsum requirements for these waters would be about 10 tons per acre per year in the Chaj Doab and about 6 tons per acre per year in the Rechna Doab. The cost of gypsum is estimated as 70 rupees per ton delivered in the West Pakistan villages. For use of the saline groundwaters, even when mixed with canal water, about 400 to 700 rupees per acre would have to be spent on gypsum every year. It is clear that on account of extremely high gypsum requirements these waters cannot be used for irrigation even when about 85 per cent of the pumped water has to be used for leaching purposes and only about 15 per cent contributes to the consumptive use requirements of crops.

It may be stated that above calculations are based on the experimental work carried out in the south-western United States and in some other countries. When similar experimental work is carried out in the Chaj and Rechna Doabs, the actual gypsum requirements may be found to be somewhat different. However they are not likely to be so different as to make the use of soduim-rich saline waters having more than 3000 ppm as economic.

As previously suggested by the author [5], but most forcefully put by Dr. Eaton, provision of horizontal sub-surface drainage is the only solution for the saline groundwater areas of West Pakistan. A basic requirement for the use of horizontal sub-surface drainage is the provision of additional river water to these areas. A programme for increasing the capacity of canals to divert additional river water and installation of horizontal drainage should therefore be initiated immediately for these areas.

The canal water supply is not likely to be adequate for all the culturable canal commanded areas. It is, therefore, essential that canal water should be used on the best agricultural areas already under irrigation. Out of the total canal commanded area of about 32.8 million acres, there are some 1.5 million acres of highly saline uncultivated or abandoned lands in the Punjab and Bahawalpur and about 1.4 million acres in Sind [17, pp. 18 and 23]. The West Pakistan WAPDA and Irrigation Department are engaged in the reclamation of these soils. As will be clear from Table VI (page 369) in the report by Panel members, installation of tubewells in the highly saline soils would cause the good groundwaters to deteriorate 35 years earlier than installation of tubewells in non-saline soils. It is therefore essential that no tubewells should be installed in the highly saline soils even when these lie in good groundwater areas. Tubewells installed in the non-saline soils would draw down the watertable under the saline soils also and the groundwater would thus be used on good soils. Similarly no canal water should be used for the reclamation of these areas or for the development of any other uncultivated lands. All canal waters as well as all tubewell waters from the high quality groundwater areas should be used only on the best agricultural lands already under cultivation.

Horizontal versus Vertical Drainage

The Panel members have enumerated 5 disadvantages of the horizontal drainage system on pages 354 to 356 of their paper and have concluded that horizontal drainage does not "warrant much attention...in the primary scheme of water resources development in the Indus Plain".

The first objection of the Panel members to horizontal drainage is that salt removed in the drainage depends largely upon the salinity of the upper layers of groundwater. The author considers this to be the principal advantage rather than the disadvantage of the horizontal drainage system. It is easier to dispose of salt removed from 7 to 10 feet of the soil profile and the upper groundwater than it is to dispose of the salt removed from 250 feet of the soil profile. In this connection Mr. Arthur Pillsbury, Professor of Irrigation and Engineering, University of California at Los Angeles, and Consultant to the Land and Water Development Division of FAO, has stated that "the zone of concentration of ground water is the root zone, and that the most efficient point to separate degraded waters, before they become diluted is immediately below the root zone" [14, p. 8]. Professor Pillsbury considers that this separation can be done efficiently *only with horizontal sub-surface drainage facilities* [14, p. 8] and that pumping of groundwater is *completely inefficient for drainage alone* [14, p. 6]. According to Professor Pillsbury many vertical drainage schemes were started in the south-western part of the United States beginning in the early 1920's but at present there is *not a single "drainage" well* operating where the water is not used to help irrigate the overlying land or is used to satisfy downstream water rights. Professor Pillsbury further states that where saline waters are being pumped an *extreme corrosion and incurstation* (all italics ours) problem with the well and pump appear to be inevitable [14, p. 6].

Another point raised by the Panel members is that vertical drainage results in a "smaller investment in conveyance channels and better salinity control because salt can be returned to the rivers during periods of high run off or routed to salt lagoons at times when irrigation requirement is small."

As the idea of drainage tubewells pumping into rivers during "periods of high run off" has been recommended by the Panel members as well as by Tipton and Kalmbach, Inc. Consultants to WAPDA, it is necessary to examine it in detail. By 1970, the entire flow of the Sutlej, Beas and Ravi Rivers (designated as the Eastern Rivers in the Indus Water Treaty) will be diverted by India and there will be no period of high run off in these rivers. No saline tubewell waters can, therefore, be returned into the Sutlej and Ravi Rivers.

The same would be the condition of Chenab and Jhelum Rivers after a few years. According to Mr. S. S. Kirmani, Chief Engineer, Indus Basin Projects, West Pakistan WAPDA, "After the completion of the Indus Project, most of the flows of the Jhelum and Chenab Rivers will be fully used in the existing irrigation system and for the replacement of the irrigation uses on the Eastern Rivers" [11, p. 247]. The Chenab and Jhelum Rivers will have a surplus of only 2 to 3 MAF which will consist of erratic and infrequent flood peaks of only a few days duration.

No drainage tubewell waters from any part of the Punjab can therefore be returned to any river during the "period of high run off" because there will be no period of high run off after 1975. If canal capacity is increased and more river water is diverted on to lands as suggested earlier in this paper, there may not be any period of high run off after 1970.

The Indus is the only river in which some 35 MAF will continue to flow to the sea during the period of high run off but topography does not permit drains in any area in the Punjab part of the Indus Plain to outfall to the Indus River. Drainage waters from the lower part of the Bahawalpur and Sind could be returned to the Indus during the period of high run off, but that would damage the agriculture in Lower Sind, slowly but certainly. As pointed out by Dr. Eaton (p. 382), the longevity of agriculture which supports many millions of people should be viewed in terms of centuries rather than on the basis of an expedient which may suffice for only a limited number of years. Alexander Karpov has pointed out there are millions of acres in North Africa and Western Asia where great cultures once flourished. At present nothing is left but sand dunes, salt marshes and eroded landscapes [10, p. 227]. The proposals of Panel members and of Tipton and Kalmbach would similarly convert the Indus Valley agricultural areas into barren salty lands.

The Panel members have also proposed disposal of saline pumped waters into desert lagoons. This is possible for Bahawalpur and parts of Sind, but unfortunately there are no desert lagoons in the Rechna and Chaj Doabs where large quantities of pumped waters from the highly saline groundwater areas of these doabs could be disposed off. The conclusion is therefore inescapable that there is no place for disposal of pumped water from the highly saline groundwater areas in the Punjab. These must remain where they are. Salt from the upper 7 to 10 feet of the soil profile only should be removed by horizontal drainage. This would be small and can be disposed of in on-farm evaporation flats as suggested Dr. Eaton (pp. 384-385) or in larger evaporation flats at the lower end of each doab as previously suggested by the author [5, pp. 394-95].

The Revelle Report also recommended "the use of salt tolerant crops" in areas where saline groundwaters are to be used [18, p. 99]. Tipton and Kalmbach are again proposing "basic changes in the agriculture" of West Pakistan and the introduction of "new crops" in saline groundwater areas. The author would like to point out that introduction of "new crops" does not lessen the soil salinity brought on the land by the saline waters. The people of the Tigris-Euphrates Valley tried this method to stave off the effect of salt; they replaced wheat with barley, which is more salt tolerant. That helped temporarily, but the salt content continued to increase and the civilization declined and passed away [10, p. 241]. The same thing would happen to West Pakistan if it tried to introduce new salt tolerant crops proposed by the Panel members and by Tipton and Kalmbach, instead of solving the basic problem of the removal of salt from the irrigated areas by the provision of horizontal sub-surface drainage facilities.

The second objection of the Panel members regarding flat topography and cost of horizontal drains has been discussed at length by the author in a previous issue of this *Review* [5, pp. 388-394]. Calculations made by Dr. Mushtaq Ahmad, Director, irrigation Research Institute, Lahore, indicate that the natural slope of the country is more than adequate for the slopes required for seepage drains in West Pakistan [13, pp. 10-56].

The third objection of the Panel members is that open drain systems occupy a significant portion of land area inbetween the cultivated fields and hence cause the farming operation to be spread out on more land. This objection is not valid for West Pakistan, where the canals have already been laid out. Actually, in a considerable part of the Punjab, shallow main drains have already been constructed. Mr. C. R. Maierhofer, Chief, Division of Drainage and Groundwater Engineering of the United States Bureau of Reclamation, considers that deep drains should be constructed where these shallow drains are located [12, p. 14].

The fourth objection of the Panel members that deep main drains and open field drains are difficult to maintain is somewhat more telling. For this reason, field drains are generally covered. The cost of maintenance of tile drains is very low [12, p. 16]. The large collector drains and main drains are generally open. They have to be maintained in efficient condition just as canals are maintained in efficient condition. The removal of weeds and debris and repair of side slopes is far more economical than the operation, maintenance, and frequent replacement of corroded and incrusted tubewells in saline groundwater areas in any country of the world, but more so in a country like Pakistan where labour is underemployed and unemployed.

The fifth objection of the Panel members regarding the public health hazard of stagnant water and swampy reaches of open drains would be valid only if the drains were not properly maintained. There is no point in constructing the drains if these are not to be properly maintained. When properly maintained there is no public health hazard.

Role of Public and Private Tubewells

The Panel members consider that government tubewells are better than private tubewells for the following reasons:

1) Government tubewells are somewhat more economical than private tubewells (pp. 339-340 and Table IV).

2) Government tubewells can be more easily integrated with canal operations than private tubewells (pp. 340-341).

3) Government tubewells can be used for reclamation of saline soils and the underground reservoir can be used for storage of salt flushed out of root zone (pp. 342 and 350).

4) Government tubewells are better adapted for the exploitation of poor quality and sodium-rich groundwaters which can be used by mixing with canal water (p. 342).

5) Government tubewells are better adapted for control of lateral migration of salinity. (p. 342).

6) Government tubewells are better than private tubewells on account of their social effects (pp. 342-343).

The author considers that it is not necessary to have government tubewells for any of the above reasons:

1) In calculating the cost of pumping water from government and private tubewells, the Panel members have used full cost of the private tubewells but only part of the cost of government tubewells. The total cost of a private tubewell (of 1.25 cusec capacity) to the economy was estimated as 7,800 rupees by the author, whereas cost of the government tubewell (of 3.9 cusec capacity) to the economy was estimated as 79,700 rupees by WAPDA [4, p. 255]. In Table IV of their paper, the cost of project preparation, cost of equipment required for drilling government tubewells, cost of government staff, fee to be paid to the contractors engaged after international bidding, contingencies, and interest

during the period of construction all amounting to 27,800 rupees for each 3.9 cusec tubewell have been ignored by the Panel members. Furthermore, the life of government tubewell has been taken as double that of private tubewells for which there is no justification [4, pp. 238-39]. (*see also*, Table I on p. 372).

The author has included the full cost of government tubewells and recalculated cost of pumping water in Table IV of the report of the Panel members, assuming life of both tubewells to be 10 years. On this assumption the cost of pumping water from government tubewells comes out to be 44 per cent higher than private tubewells when the load factor is assumed as 25 per cent. However, government tubewells have been worked on a load factor of over 50 per cent. If this is adopted, the cost of pumping water from government tubewells is equal to that from private tubewells.

2) There is no reason why farmers will not integrate the working of private tubewells with the working of canals. Already the farmers of Gujranwala and Sialkot districts where canal water is supplied only during the *kharif* season are integrating the working of private tubewells with the canal water and have attained the highest intensity of cropping [6, p. 26]. It is simple: the moment, the canal is closed, the farmers switch on the tubewells. Dissemination of information about canal closures is good but is not absolutely necessary.

3) As already pointed out, all canal water and tubewell water should be used on the best agricultural lands already under cultivation and not on reclamation of highly saline soils. Such reclamation by government tubewells will only deteriorate the quality of groundwater by adding salts leached down from the soil profile.

4) As previously stated saline and sodium-rich groundwaters should not be pumped at all. They would increase water supply but would cause deterioration of soil and reduce the total agricultural production in the country.

5) The centrifugal pumps used by the farmers have a maximum draw down of about 20 to 25 feet. With private tubewells located in the upper reaches of the doabs and lowering the watertable to about 20 feet, and with drains lowering the watertable to about 7 to 10 feet in the saline areas, there is no danger of contamination of non-saline groundwaters with infiltration from saline groundwater areas. On the other hand, there would be some danger with government tubewells pumping water to 100 feet depth in non-saline areas and to 50 feet depth in the saline areas as proposed by the Panel members.

6) In all areas where an adequate number of tubewells has been installed, the price charged by tubewell owners varies from 2.5 to 3.5 rupees per hour

whereas the cost of operation of tubewells comes to about 1.2 to 2.6 rupees per hour [6, pp. 17-18]. With additional tubewells being installed every year, the price charged by owners is being reduced year by year. No government regulation on the price of tubewell water, as proposed by the Panel members, is necessary.

Some of the major points in favour of private tubewells are the following: *First*, the private tubewells mobilize domestic resources and thus increase the total size of the development programme to that extent. A greater increase in agricultural production in West Pakistan would result if the farmer's resources are used for installation of tubewells and government resources are used for increasing the fertilizer manufacturing capacity and for electric transmission and distribution facilities than if government resources are used for drilling of tubewells. *Secondly*, foreign exchange required for private tubewells is very small whereas the foreign exchange component of government tubewells approximates 58 per cent of the total cost.[3]. If an appropriate "shadow price", say 7 rupees to a dollar is used for foreign exchange, the cost of government tubewells increases by approximately 27 per cent. The cost of pumping water from government tubewells then becomes 67 per cent higher than those from private tubewells when the load factor is the same. When government tubewells work twice the number of hours compared to private tubewells, the cost of pumping water is 14 per cent higher in these when foreign exchange is appropriately valued. *Thirdly*, private tubewells contribute to the development of local industry such as diesel engines, electric motors, drilling rigs, and other manufacturing capacity. The government tubewells damage the established manufacturing industries by importing the same equipment, goods and services from abroad. *Finally*, the private tubewells not only mobilize domestic resources but also develop a strong class of highly energetic farmers who act as leaders in modernizing agriculture in the country. The government tubewells depend upon tied foreign loans obtained with high rates of interest, increase the foreign debt of the country and stifle the energetic class of farmers by destroying their previously installed tubewells and installing expensive government tubewells instead.

Concluding Remarks

The system of tubewell installation for irrigation *and drainage* purposes as recommended by the Revelle Panel and by Tipton and Kalmbach and that being followed by West Pakistan WAPDA is a temporary expedient and a self-destruc-

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[3] Total cost of tubewells (excluding electrification and drainage facilities) in SCARP 3 is estimated as 123.5 million rupees, out of which 71.8 million rupees (15.1 million dollars) are required in foreign exchange for equipment, goods and services that must be imported [16, p. 48].

tive system. The saline groundwaters being pumped or proposed to be pumped can neither be used in the same area nor can they be passed on to downstream users without acceptance of ultimate desolation. The salts must be removed from the irrigated areas by a permanent horizontal sub-surface drainage system and the saline waste disposed of in evaporation flats in the Upper Indus Plain and conveyed to the sea through special canals in the Lower Indus Plain.

A basic problem in the irrigated agriculture of West Pakistan is the deficiency of water supply to meet the consumptive use requirements of crops and to leach down the salts. This deficiency is being made good by the farmers in the non-saline groundwater areas with the installation of private tubewells. The government must increase the capacity of canals and divert additional river water on to the best agricultural lands in the saline groundwater areas and initiate a programme for the construction of subsurface drainage facilities.

Reclamation of saline soils even in high quality groundwater areas would cause the groundwater to become unfit for use due to leaching down of salts. No canal or tubewell water should therefore be used for such reclamation. Similarly no canal or tubewell water should be used for the development of marginal lands and all available water supplies should be used on the best agricultural lands already under cultivation.

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