Paper No. 138

Enhancing water availability to farmers for achieving higher cropping intensity—A new approach

By

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1. INTRODUCTION

1.1 With the development of Irrigation in Punjab it was felt that quantum of canal water being supplied for increasing intensity of irrigation and high delta crops is in-adequate. Also water-logging and salinity all over the canal command areas created another big problem in the irrigation system. In order to combat this twin menance and at the same time to increase quantity of water to the farmers, engineers and scientists in the country have been endeavouring to suggest various methods in this behalf.

1.2 The first solution of the problem advised by the foreign experts was sinking deep tubewells in water-logged areas under Scrap Projects. Ist Scarp Project was completed in 1962, followed by another 4 similar projects with the result that about 10,000 tubewells in public sector are functioning under these projects for reducing water-logging and salinity and giving additional water to farmers.

1.3 Alongwith Scarp tubewells, sinking of shallow tubewells was started by the farmers in private sector to augment their water requirements. The Punjab Government also encouraged this and subsidies were granted and by now over one lac of tubewells are operating in Punjab in private sector.

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1. Chief Engineer, Irrigation, Sargodha.
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1.4 There are 54000 water courses in the Province for irrigating 22 million acres of canal command areas. In early 1970 Punjab Government launched a programme of lining water courses with brick masonry under laid by polythene sheet. In view of very heavey financial outlay, the programme did not get impetus and gradually died out.

1.5 In 1973 a team of Agricultural experts came to Punjab from Colorado State University U.S.A. to advise on better water management. They conducted experiments at various places and advised that kacha water-courses should be improved and partial lining shoud be done. Under this advice a programme of improving and lining the water courses was launched in 1976-77. A Directorate of On-Farm Water Management was created and it launched pilot projects as enumerated below:—

1. O.F.W.M. US AID Assisted Programme.
2. W.M. Programme (World Bank Assisted).
3. Thal Water Management Programme (A.D.B. Assisted).
4. On-Farm Water Management Programme Bahawalpur and Rahim Yar Khan Project.
5. On-Farm Water Management 4th Drainage Project Faisalabad.

1.6 So far about 4000 water courses have been improved by fixing Nakkas, making culverts and with partial lining etc. in 16 districts of Punjab. About 15% water courses length (length of water courses taken as 3 miles) in sweet zone and 30% in saline zone is proposed to be lined by the On-Farm Water Management Organization.

1.7 In partial departure from the above planning of W.M.O. a new approach is presented through this paper with salient features as below :—

i. Lining of optimum length of water courses in saline zone to reduce water losses to about 1%.

ii. In the usable ground water zone, Kacha water courses be improved and thereafter maintained properly. No lining be done on such water courses.

iii. Shallow tubewells of average capacity 1.5 Cs. be installed along water courses in usable ground water zone to enhance the Farmer's canal water to achieve higher irrigation intensity and to fight the twin menace of water-logging and salinity; ENEMY No. 1 of Irrigated Agriculture of Pakistan.

2. WATER LOSSES FROM WATER COURSES

2.1 Water losses in main canal, branches, distys and water courses etc had attracted attention of irrigation engineers since the start of irrigation in Punjab. Till 1974 the consensus of various engineers was that the water losses in water courses ranged from 10-15%. Before quoting other authorities, special mention is made of an expert committee set up by the President of Pakistan in February, 1972 and this committee was composed of elite engineers of Pakistan mentioned below :—

i) Mr. A.R. Kazi,
Chief Engineering Adviser of Federal Government and Ex-Chief Engineer and Secretary Irrigation Department Sind.

ii) Mian Khalilur Rehman,
Commissioner for Indus Water (An eminent irrigation engineer).

iii) Mr. Shah Nawaz Khan,
General Manager Tarbela, (An eminent engineer of N.W.F.P.).

iv) Ch. Altaf Hussain,
Chief Engineer WAPDA (An eminent engineer from Punjab).

v) Sh: Abdur Rehman,
Director General WAPDA (An eminent engineer of Punjab Irrigation).

vi) Dr. Muhammad Afzal Kazi,
Dean Agriculture University, Faisalabad.

vii) Syed Muhammad Ayub,
Director, Irrigation Research Institute, Lahore. (An eminent Engineer of Punjab Irrigation).

viii) Malik Khuda Bakhsh Bucha,
Ex-Minister and an eminent Agriculturist of Punjab.

ix) Mr. N.A. Hassan,
An Agriculturist from Sind.

2.2 This committee of nine persons deliberated on the subject of losses in irrigation system and they concluded that "losses in the water courses were 15% of the discharge at head of the water course".

2.3 There could be no more authoritative version on the subject than the one delivered by this committee consisting of top experts in the field of irrigation and agriculture.

2.4 However, a few more authorities on the subject are narrated hereunder:—

i) Foreign consultants while preparing water development projects in Pakistan from 1960 onwards checked water course losses as under :—

Harza	= 10%
T&K	= 10%
Hunting	= 10%
World Bank Mission	= 10%

ii) A consortium of consultants, FIZAC have recently published a report on development of irrigation in Punjab in which they have stated as under:—

"Para 2.20 Vol: I Page - 8

The losses in water courses are estimated at 15%.

iii) Mr. P.J. Drurry of Sir Macdonald and partners, London (P.E.C. 1969) stated as below :—

> "Water course losses are determined by various investigators. A water course with a discharge of 2.5 Cs. surface width of 3 ft., the average depth of water 0.75 ft. and average length of 2 mile, gives an average total loss of 9.6% of the discharge at the head of water course, the range being 4 to 16%".

iv) Mr. Khungar one of the most brilliant irrigation Engineer of pre-independence days, analysed 8 years data from 1935-36 to 1942-43 on actual flow based on discharge measurements and worked out following water course losses :—

Canal System	Losses
L.C.C.	6.5%
LCS	6.0%
L.J.C.	6.5%
U.J.C.	7.3%

v) T&K in their Scarp Project No. 5 of August 1966 (Appendix G - 2) stated as under :—

> "Seepage from water course and field losses are 10% of the delivery at heat of water course. The estimated seepage rate is 6.2 Cs. per million Sq. ft. of wetted perimeter".

vi) Dr. Nazir Ahmed of Punjab Irrigation Research was required by the Minister Irrigation West Pakistan to prepare a study of losses through water courses and he gave the following figures :—

Water courses in clay loamy area	= 3 - 5%
Silty loam area	= 4 - 7%

Sandy soil = 10 - 15%

vii) IACA (Irrigation and Agriculture Consultants Association) conducted a vast study of water resources development in Pakistan and they concluded in respect of water course losses as under :—

Punjab = 7% of head of canal diversion.
Sind = 7.5% of head of canal diversion.

viii) Hunting Technical Services, while preparing LIP gave water course losses as 7.5% of head of canal diversion in Sind.

ix) Irrigation Research Institute have been studying the subject of conveyance losses and they gave out 11% to 22%.

x) In 1963 E.P. Palton et. al of WASID conducted experiments on conveyance losses and they worked out as under :—

$S = 0.06 \quad Q^{.68}$ for Thal Doab.
$S = .03 \quad Q^{.71}$ for Rechna Chaj Doab.

These relations give the loss for a 2 Cs. water course at 5% per mile and value of K (Seepage Factor) as 4.75.

Note (1) Montague formula in vogue in Irrigation Department gives exactly the same results with its relation $S = 0.67\ Q^{9/16}$.

Note (2) A water course of 2 Cs. capacity in sandy Thal has 0.1 Cs. per mile loss as per WASID. for comparison, loss by Clyma comes to 1.25 Cs. per mile i.e. 1250% more than WASID (Water logging Seminar 1976 page 199).

2.5 American Advisers

2.5.1 In 1973 a team of following advisers from Colorado State University (CSU) came to Pakistan and they conducted experiments on water losses in canal water courses and fields at Lar (Multan), Shadab (near Lahore), Mona Reclamation Station (near Sargodha) and other places :—

1. Dr. W.D. Kemper (Party Chief)
2. Dr. Wayne Clyma.
3. Dr. G.L. Corey.
4. Dr. A.C. Early.
5. Dr. M. Lowder Milk.
6. Dr. D.J. deMooy.
7. Tom Trout.
8. Dr. N. Dimmik etc.

2.5.2 Dr. Clyma et. al prepared a report in September, 74 (Field Report No. 2) and stated as below :—

i) Water course losses are with an average of 40% 30 - 50%
ii) Field losses are 22 - 30%.
iii) Seepage factor (K) is from 1 - 100.

This report is frequently referred to by the present On-Farm Water Management Organization. For example in their publication named "Directory of Water Courses Improved under USAID Pilot Project 1976-77 to 1980-81", it is stated that water course losses average over 40% (Clyma and Corey 1974) which is 4 times higher than what was previously estimated (Harza 1963). In a table of "Comparative water course efficiency in Indus Basin Project", this very report of Dr. Clyma of September, 1974 is mentioned alongwith other references.

This clearly shows that Water Management Organization of Punjab puts in great reliance on the investigations conducted by Dr. Clyma and others.

2.5.3 Dr. Clyma and others issued Field Report No. 3 in June 1975 on the subject of water management in Pakistan in continuation of their previous report of September, 74. This 60 pages document referred to the entire research work done in the field of water management in Pakistan and thus it can be taken as an authentic version of Dr. Clyma's work on the subject. Inter-alia this report states as under :

i) There are 78000 water courses in Pakistan with an average length of 20 miles each, out of it 1.5 miles is Sarkari Water Course and the balance 18.5 are zamindar ditches in an average chak of 400 acre and head discharge of 1.15 Cs.

ii) On a normal canal water course of 1.15 discharge loss will average to 25% of head moga discharge as under :—

Seepage loss	=	10%
Spillage loss	=	15%
Total	=	25%

iii) One water course carrying tubewell plus canal water, the losses have been repeatedly measured and an average to 40% as under :—

Seepage loss	=	15%
Spillage loss	=	25%
Total	=	40%

2.5.4 Comments on para 2.5.3 are as under :—

a) Seepage is taken as infiltration from channel X-section into soil and spill-

age is a preventable loss through over-topping, breach at nukkas and weak points etc. etc.

b) Seepage takes place from wetted perimeter and that is why seepage factor is made a function of million sq. ft. of wetted perimeter (PW). Presuming that the water course is old with voids in the bank soil filled with fine silt, it is reasonably clean, straight and section of required size, then the seepage rate is 6 to 8 Cs. per Msft. of pw.

c) From 1975 onwards, pressure on land has tremendously increased in Punjab due to variety of reasons. Zamindars are extremely keen to reduce operational (spillage, or breach or overflow) losses and they have enhanced maintenance efforts. Even in the chilly dark December nights, the Zamindar is always vigilant moving along his water couse to see that no breach or overflow occurs. It is, therefore, absolutely out of proportion to presume spillage/operational losses of the order of 25% as apparently adopted by Dr. Clyma and also by O.F.W.M. Spillage loss has been grossly over estimated by foreign advisers.

d) Seepage losses reported by Dr. Clyma in the above paragraph are correct and are the same as taken by Harza, T&K World Bank Mission and others. Punjab Irrigation engineers have always agreed with this seepage loss and have taken spillage loss as preventable one. It is noticed with great concern that On-Farm Water Management Organization has not referred to this report of 1975 any where in their printed documents.

2.6 In 1976 International Conference on Water-logging and salinity was held at Lahore in which CSU experts (Kemper, Clyma etc.) presented a paper on improvement of water courses to reduce water logging. In this paper certain statements worthy of critical notice were made as given below :–

i) 50% water course losses occur at or near nukkas.

ii) A 2 Cs. water course loses 26% water (.52 Cs) in 4000 ft. length. (This gives value of K = 32 and per mile loss at 34%).

iii) A 2 Cs. water course carrying canal plus tubewell water loses 52% water (1.04 Cs) in 4000 ft. length of water course (value of K = 64 and per mile loss works out 60 to 69%). It has been stated that if tubewell water is added to canal water then the water course will be deteriorated thereby doubling the loss.

iv) In a clean water course with nukkas carefully closed losses range from 1 - 5% per 1000 feet length.

v) At Mona losses got reduced from 15% per 1000 ft. length to 5% by cleaning water course.

vi) On a water course of 2.8 Cs. head discharge and 2500 ft. length, the loss was 60% as measured by Kemper.

vii) On the same water course 40% losses were observed in steady state conditions.

2.6.1 Comments on above

i) It appears that CSU team came in Pakistan in 1973 and raised the issue of extremely high water course losses. The statements made before the conference are complete departure of what Clyma et.al stated in Field Report No. 3 of June 1975 mentioned above.

ii) The statement that 50% losses occured near Nakkas is very hard to believe as Punjab cultivators are very efficient in closing and opening Nakkas with discharge 1-3 cs. However discharges beyond that are definitely beyond kassi work.

iii) It is stated that a 2 Cs. canal water flowing in a water course gives 34% loss per mile and the same quantum of discharge (canal plus tubewell) gives 69% loss per mile. It is not understood how losses become double if tubewell water is mixed with canal water when all other parameters i.e. quantity, X-section, length etc. remain the same. This is an incorrect and a fantastic conclusion drawn by the

CSU experts.

iv) It is stated at page 199 of this paper that in 2500 ft. length the discharge gets reduced from 2.8 Cs. to 1.12 Cs. This gives the rate of loss as under :—

Per canal mile loss	=	3.36 Cs.
Seepage factor K	=	132

This also shows that 2.8 Cs. discharge will be completely lost in 4200 ft. length. No person having little knowledge of water conveyance in earthen channels shall believe such a statement.

v) Professor Dr. M.K. Lowdermilk of C.S.U. surpassed others when in Dec. 1978 he stated :—

86 MAF is diverted into canals.

22 MAF is lost in canals (26% of head discharge of canals).

35 MAF is lost in watercourse (55% of delivery at head of water course).

29 MAF reaches Nakkas

He further stated that water course loss is more than 3 Tarbelas.

2.7 Dr. Amir Muhammad, a famous Agriculture Scientist and adviser to CMLA on Agriculture affairs, stated in 1978 as under :—

"The loss in water course ranges around 15% of the canal withdrawals".

Now assuming discharge at head of canal	=	100
Loss in canals	=	25
Balance	=	75 at head of water course.
Losses in water course	=	15

Balance	=	60 at Nakkas

Thus water course loss percent with,

i)	Canal head	=	15%
ii)	Water course head	=	20% which is much lower compared to CSU Experts.

2.7.1 Observations report by C.S.U. team in Mona Reclamation Project. 5 (Corey et.al (P - 45).

Date	=	15.11.75
Initial discharge	=	4.48 Cs.
Losses	=	3.58
Length	=	10340
K.	=	50
Losses	=	80%

The above data is obviously erratic and unreliable. On the same outlet, losses are shown 11% for the main water course.

2.8 It can, therefore, be concluded that it is not safe to go only by the advice of Foreign experts which militates against the age old findings of eminent scientists and engineers of this country.

2.9 A more realistic approach to the problem of saving water course losses would be :—

a) Motivating the cultivators to improve their water courses by straightening them, keeping them clean, compacting the banks with proper section and free board and installing pacca nakkas so that spillage and other preventable losses do not occur.

b) Lining of water courses should be restricted to saline areas alone where seepage water is completely lost for re-use and becomes a cause for water logging and salinity.

c) In useable Zone, instead of lining the water courses, the best course would be to encourage the farmers to instal more and more private tubewells along the water courses. Liberal loans on tubewell installations will enhance water availability for the farmer to his optimal requirements, resulting in increased intensity of irrigation.

2.10 **Field studies in Sargodha Zone:** Observations of losses on the water course in loamy clay soil having average maintenance has been carried out on outlet R.D. 502/L Magwana Disty: of LJC. Results obtained are as under :—

Date of observation	Q_o	Q_1	Length of water course	% loss	% loss / 1000'	Value of K (losses per million sq.ft. of wetted perimeter).
10.9.84	1.81	1.76	900	2.7	3.08	12.6
11.9.84	1.86	1.76	2600	5.4	2.1	8.8
12.9.84	1.86	1.71	3800	8.1	2.1	8.7
13.9.84	1.76	1.61	4900	8.5	1.7	6.6
14.9.84	1.86	1.71	7100	8.1	1.5	4.5
15.9.84	1.81	1.71	8200	8.1	1.0	3.9
16.9.84	1.81	1.57	10000	13.3	1.3	5.1
		Average		7.7	1.8	8.8

* From R.D. 9000 to 10000, there is a village abadi and water course is in bad condition.

2.10.1 Observations have been conducted with tin flume and have progressed daily as the 'wari' proceeded and observations being made at the middle of the turn. There are five pacca Nakkas and the remaining 8 nakkas are still kacha. Two nakkas are un-authorised. Section of the water course near kacha nakkas and at other places was wide and had more than the required wetted perimeter. SSWL in the area is 12' below N.S.L. Average wetted perimeter observed @ 250' interval comes to 4.66. Slope as observed actually in reach 2500 ft. was of the order of 0.23 per 1000'.

2.10.2 Perusal of the results show that on the average loss per million sq.ft. of wetted perimeter is 8.8 Cs. percentage loss in the middle reach at RD 3800 which is a weighted average length, is 8.1% against over all average of 7.7%. Average loss per 1000 ft. comes to 1.8.

2.10.3 Observations have been done by Muhammad Akram SEN. These were checked by Executive Engineer, Sargodha and Executive Engineer, Kirana on 13.9.84 and 14.9.84. Further observations of losses on this water course will continue after minor improvement of the water course section.

3. LINING OF WATER COURSES

3.1 In order to reduce seepage losses, brick lining of 54,000 water courses of the Punjab canals was taken up in 1976-77 under IDA, IFAD and ADB aids etc. About 15% water course length (total length assumed 3 miles) in fresh ground water (FGW) area and 30% in saline zone is being taken up by the On-Farm Water Management Organization (O.F.W.M.O.).

Progress so far achieved is as under : —

Year	Lined length
1976 - 77	9

1977 - 78	229
1978 - 79	656
1979 - 80	1961
1980 - 81	2930
1981 - 82	295
1982 - 83	495
1983 - 84	764
	7339 K.M. = 4477 Miles

3.2 Lining cost per miles is Rs. 2.25 Lac and cost per acre comes to Rs. 450/- and with labour etc. Rs. 620/-. Cost of length actually lined is shared between cultivators and Government in the ratio of 1:5. Recovery from cultivators shall be made in 5 years in 10 instalments as arrears of land revenue.

3.2.1 Cost per water-course for 100% length of lining, if done, shall be Rs. 7.5 lac and cost per acre for lining shall be Rs. 1733/-. Besides this, the farmers will spend Rs. 50,000/- on earth work and Rs. 1,17,000/- in the form of labour to bring the (total cost to Rs. 9.17 lac) per water course and the total expenditure per acre work out to Rs. 1833/-.

3.3 Monitoring of lining work done

3.3.1 The work is so far being monitored by the executing agency i.e. OFWMO and their results are published in great details.

3.3.2 It is estimated by the W.M.O. that with partial lining conveyance efficiency in water courses increased from existing 60% (average) to 85% i.e. losses decreased from 40% to 15%, increasing cropping intensity from 126% to 144% and increase of crop yield by 14.5%. Monitoring report of 1083 water-courses has been published by O.F.W.M.O. covering work done from 1977 to 1981 in Punjab. It

contains some startling data observations as under :—

i) Kacha water-courses have been improved in prism and banks, pacca nakkas and culverts have been provided but no lining of water-course has been done on 80 water-courses but the delivery efficiency has increased from 54% to 85%. Examples are :—

Sr. No.	Length improved (Meters)		Percentage pacca	Delivery Efficiency %	
	Kacha	Pacca		Before	After
124	6520	—	—	54	85
125	6300	—	—	54	85
129	11200	—	—	54	85
134	17576	—	—	55	80
135	8250	—	—	54	85
362	4850	—	—	33	85

This shows that improvement of a kacha water course with nakkas etc. is enough to give desired results without spending lacs of rupees of lining.

ii. In certain cases very small lengths have been lined but results are the same i.e. increase of conveyance efficiency from avérage 55% to 85%. A few examples are mentioned below :—

Sr. No.	Length improved		Percentage Pacca	Delivery Efficiency %	
	Kacha	Pacca		Before	After
19	3306	44	1.32	50	85
114-A	4000	5	0.13	45	85
155	4538	44	0.96	60	85

218	6019	7	0.12	62	85
162	8406	15	0.18	57	80

Scores of such observations as above, are recorded in the inventory. This shows that hardly any lining is required to improve delivery efficiency to a level of 85%.

iii. In certain other cases the percentage lining is very high compared to average of 15% but end result is increased efficiency to same 80 to 85%. A few examples are quoted below : —

Sr. No.	Length improved Meters		Percentage Pacca	Delivery Efficiency %	
	Kacha	Pacca		Before	After
573	2770	755	22	55	80
705	1757	648	27	57	80
745	3996	1075	21	56	80
795	2910	3171	52	48	80
814	4632	6940	60	74	85

3.4 Large number of such data observations are contained in the inventory which shows that increase in conveyance efficiency does not correspond to length of lining. It is not understood how such observations can be explained. In fact this inventory shows that increase of delivery efficiency lies much in the hand of the data observers. This rather proves that improvement of earthen water course with nakkas is enough to give the desired results.

3.5 Problems associated with lining

i. It is proposed to recover 42% amount spent by the Government on the material required for lining work from concerned cultivators in five years with 2

years grace period. Approximate recoverable amount per outlet is Rs. 45,000/- for a partially (30%) lined water course. This recovery may become problematic because Zamindars of head reach branches who do not get direct benefit of lining may not agree to share the cost. Proposed 100% recovery may become a cause of grouse for the head irrigators.

ii. By lining a water-course, we are rendering the system absolutely rigid. In new canal projects like Thal and Taunsa and old projects like L.J.C. & L.C.C. location of a large number of outlets are changed/adjusted on the demand of the share-holders. Also discharge of outlets is increased or decreased due to transfer of areas from one water-course to another. Changes in Chakbandis occur continuously due to factors beyond the control of the Government or cultivators. Once water courses are lined, then all these changes will become impossible, thereby creating great difficulties for certain share-holders.

iii. Similarly followings can be other causes of adjustment in size of water course :—

a. Change in Intensity of Irrigation on certain channels or inclusion into CCA of new areas lying within the chak boundary (About 1.0 million acres in Punjab) when some water becomes available on apportionment of Indus waters.

b. Addition of water on account of increased pumpage from private tubewell installation which is a continuous process.

iv. **Rate of losses from pacca sections of a water course.**

A quotation from Dr. Kemper Publication 68 is as under :—

At the lower end of branch 'P', there is a Section which has rectangular X-section and has 9" thick walls in brick masonry partly plastered and partly unplastered. The rate of loss from these sections was measured as 0.8 Cs per 1000,

showing thereby that a good plaster job on masonry wall should alsways be a part of pacca water course construction". 6 (Kemper et.al publication 68. (page 8 - 9).

Note: This quotation clearly shows that the real efficiency of lining is in plaster, which is deteriorated or cracked, becomes ineffective and the loss would become very high.

3.6 Financial inadequacies in project estimates

3.6.1 It is planned (paper of August 1984 submitted to Experts Committee) by On Farm Water Management Organisation that they will brick line 50,000 water courses all over Punjab taking 4500 ft. length (30% of the total) of each Water Course because it is presumed that this is the average length of main water course. The cost of the lining per water course from 1984 to 2004 ranges from Rs. 2.25 lac to 2.85 lac. In this way it has been estimated that all the 50,000 water courses shall be lined at a cost of 13.56 Billion Rupees.

3.6.2 This estimation is very rough and suffers from very serious defects as given here under : —

i. It has been presumed that in the next 20 years the increase of rates of labour and material etc. will be 1.33% per year, which is highly in-correct.

ii. Escalation of rates and interest charge have not been considered in the estimation. The correct rate of escalation enforced by Planning Commission is 8 to 6% as given in column 2 of table - 1. The compound interest rate is similarly fixed at 13%. In all Projects these provisions are essential and on the basis of this, total outlay after 20 years comes to Rs. 36.80 Billion which is 171% more than the figures contained in the paper (13.56 Billions). The calculations are contained in tables I & II.

3.6.3 Calculations show that the amount of Rs. 13.56 Billion will be spent up

by thirteenth year i.e. 1996-97 and by that year only 25500 water courses will be lined instead of 50,000. This clearly shows that the financial presentation is incorrect.

3.6.4 It has been calculated that for lining of 44826 water courses in usable zone, the total project cost will be Rs. 31.06 Billion and per acre cost Rs. 1538. For installation of 44826 No. of private tubewells along water courses in usable zone (explained in chapter 5) this cost will reduce to Rs. 3.8 Billion only and per acre cost will be Rs. 188. This comparison shows that sinking of private tubewells along water courses is far more beneficial than lining of water courses and it suits much to the economy of this developing country.

3.7 It is evident from inventory (1977-81 W.M.O.) of lining work done that water courses are not being lined on an average of 15% and 30% for sweet and saline water zones respectively as envisaged in the Water Management Project. Actual lengths lined is tabulated belwo : –

% of length lined	No. of such water courses	% of total water courses
0 - 5	204	19
5 - 10	564	52
10 - 15	242	22
15 - 20	61	6
20 - 30	9	0.80
More than 30	2	0.20

This will show that very small lengths are being lined.

TABLE - 1

CALCULATIONS FOR ESCALATION CHARGES

(LINING OF WATER-COURSE)

(Cost figures in Rs. Millions)

Year	Escalation Rate	Accumulated rate of escalation	Basic Cost	Escalation Charges	Total cost including escalation
1.	—	—	225	—	225.00
2.	8	8	230	18.40	248.40
3.	8	16.64	235	39.10	274.10
4.	8	25.97	240	62.32	302.32
5.	8	36.03	245	88.27	333.27
6.	7	45.82	500	229.10	729.10
7.	6	54.57	625	341.06	966.06
8.	6	63.84	750	478.80	1028.80
9.	6	73.67	800	589.36	1389.36
10.	6	84.09	810	681.13	1491.13
11.	6	95.13	820	780.06	1600.06
12.	6	106.83	825	881.34	1706.34
13.	6	119.24	830	989.69	1819.69
14.	6	132.39	840	1112.08	1952.08
15.	6	146.33	850	1243.80	2093.81
16.	6	161.11	860	1385.55	2445.55
17.	6	176.77	950	1676.46	2626.46
18.	6	193.37	950	1837.01	2787.01
19.	6	210.97	975	2056.95	3031.95
20.	6	229.62	1000	2296.20	3296.20

TABLE - II

CALCULATIONS OF INTEREST CHARGES @ 13%
(LINING OF WATER COURSES)

(Cost figures in Rs. Millions)

Year	Anticipated Expenditure	Principal	Interest @ 13%	Total	No. of water course	Cost/ water course
1	2	3	4	5	6	7
1.	225.00	112.50	14.62	236.92	1000	0.236
2.	248.40	236.92	46.94	295.34	1000	0.295
		124.20				
		361.12				
3.	274.10	295.34	56.21	330.31	1000	0.330
		137.05				
		432.39				
4.	302.32	330.31	62.59	364.32	1000	0.364
		151.16				
		481.47				
5.	333.27	364.32	69.02	402.29	1000	0.402
		166.63				
		530.95				
6.	729.10	402.29	99.68	828.78	1500	0.552
		364.55				
		766.84				
7.	966.06	828.78	170.53	1136.57	2500	0.454
		483.03				
		1311.81				

Year	Anticipated Expenditure	Principal	Interest @ 13%	Total	No. of Water Course.	Cost/ Water Course
1	2	3	4	5	6	7
8.	1228.80	1136.59 614.40 1750.99	227.62	1456.42	3000	0.485
9.	1389.36	1456.42 694.63 2151.05	279.63	1668.97	3000	0.556
10.	1491.13	1668.99 745.57 2414.56	313.89	1805.02	3000	0.601
11.	1600.06	1805.02 800.03 2605.05	338.65	1938.71	3000	0.645
12.	1706.34	1938.71 853.17 2791.88	362.91	2069.25	3000	0.689
13.	1819.69	2069.25 959.84 3029.09	393.78	2213.47	3000	0.737
14.	1952.08	2213.47 976.04 3189.51	414.63	2366.71	3000	0.789
15.	2093.81	2366.71 1046.90 3413.61	443.76	2537.57	3000	0.845

Year	Anticipated Expenditure	Principal	Interest @ 13%	Total	No. of Water Course.	Cost/ Water Course
1	2	3	4	5	6	7
16.	2445.55	2537.57	488.83	2934.38	3000	0.978
		1222.78				
		3760.25				
17.	2626.46	2934.38	552.18	3178.64	3500	0.908
		1313.23				
		4247.61				
18.	2787.08	3178.64	594.37	3381.38	3500	0.966
		1393.50				
		4572.14				
19.	3031.95	3381.38	636.65	3668.60	3500	1.048
		1515.97				
		4897.35				
20.	3296.20	3368.60	691.18	3987.37	3500	1.139
		1648.10				
		5316.70				

Rs.	36801	Million
Say Rs.	36.80	Billion

TABLE - III

CALCULATIONS FOR ESCALATION CHARGES
(PRIVATE T/WELLS)

(Cost figures in Rs. Million)

Year	Escalation rate	Accumulated rate of escalation	No. of T/Wells	Basic cost	Escalation charges	Total cost including escalation
1.	–	–	4400	220	–	220.00
2.	8	8	4400	220	17.60	237.60
3.	8	16.64	4400	220	36.60	256.60
4.	8	25.97	4400	220	57.13	277.13
5.	8	36.03	4400	220	79.26	299.26
6.	7	45.82	4400	220	100.80	320.80
7.	6	54.57	4400	220	120.05	340.05
8.	6	63.84	4400	220	140.44	360.44
9.	6	73.67	4800	240	176.80	416.80
10.	6	84.09	4826	241	202.65	443.65
		Total :–	44826	2241	931.33	3172.33

TABLE - IV

CALCULATIONS OF INTEREST CHARGES @ 13%
(PRIVATE TUBEWELLS)

(Cost figures in Rs. Million)

Year	Anticipated expenditure	Principal	Interest @ of 13%	Total	No. of T/Wells	Cost of one Tubewell
1.	220.00	110.00	14.30	234.30	4400	0.053
2.	237.60	234.30	45.90	283.50	4400	0.064
		118.80				
		353.10				
3.	256.60	283.50	53.53	310.13	4400	0.070
		128.30				
		411.80				
4.	277.13	310.13	58.33	335.93	4400	0.076
		138.57				
		448.70				
5.	299.26	335.93	63.12	362.38	4400	0.082
		149.63				
		485.56				
6.	320.80	362.38	67.96	388.76	4400	0.088
		160.40				
		522.78				
7.	340.05	388.76	72.64	412.69	4400	0.094
		170.02				
		558.78				

Year	Anticipated expenditure	Principal	Interest @ of 13%	Total	No. of T/Wells	Cost of one Tubewell
8.	;360.44;	412.69	77.07	437.52	4400	0.099
		180.22				
		592.91				
9.	416.80	437.52	83.97	500.77	4800	0.104
		208.40				
		645.92				
10.	443.65	500.77	94.07	537.72	4826	0.111
		221.83				
		723.60				
				3803.60	44826	

Say Rs. 3.8 Billion

4. MINIMIZATION OF LOSSES BY IMPROVEMENT OF KACHA WATER COURSES

4.1 Following defects are usually noticed on ill-maintained water courses causing losses :—

A) **Preventable losses** are those caused by:—

i. Inadequate water conveying sections resulting in overflow and breaches.

ii. Clogging by weeds and wild growth in and on the banks which impedes theflow of water and excessive evapotranspiration losses.

iii. Rodent holes which cause excessive leakage.

iv. Leaking Nakkas, weak sites in banks and pits on the junction points.

v. Excessive channel storage due to uneven bed of the water course.

vi. Loose soil composing the banks of water course.

vii. Inadequate free board and H.G. cover resulting in over flows and breaches.

viii. Ponds created by animals.

B) **Unavoidable losses**

i. Seepage losses.

ii. Evaporation losses.

Preventable losses enumerated above can be avoided by proper and frequent maintenance of the kacha water course including the following :—

i. Desilting the water course to provide an adequate water carrying

section.

ii. Straightening the water course as far as possible and cleaning its banks of all vegetative growth specially on the inside of the banks.

iii. Compacting the banks soil specially in sandy and other loose soil fills.

iv. Providing 9" to 12" free board over the highest watermarks and 3' bank width at top.

v. Providing a regular/uniform width to the section by widening the narrow and tightening the wider portions of the water course.

vi. Providing pacca Nakkas at all sanctioned junction points.

vii. Providing pacca culverts where-ever necessary.

viii. Proper maintenance of the water course with the maximum interval of 4 weeks and it should include setting right of all the above mentioned defects causing preventable losses.

4.2 Prevention of unavoidable losses

The quantium of these losses as stated earlier is between 10% to 15%. In usable ground water areas, these losses can be tolerated and retrieved by pumpage from ground water reservoir. However in saline water logged area minimisation of these losses will be necessary and complete lining of water courses may have to be resorted to so as to save every drop of canal water.

4.3 Several research workers, scientists, and agriculture experts have conducted experiments and proved that if earthen water courses are properly maintained, then losses can be minimised considerably at very low cost and labour intensive techniques requiring no appreciable financial outlay for materials etc. A few such reports are quoted below :—

i) In 4000 ft. long water course before cleaning and maintenance losses were

15% per 1000 ft. but after cleaning these got reduced to 5%. If the water courses are kept clean and maintained properly at 4 weeks interval then conveyance losses average to about 10 to 17%. 2 (Clyma et.al 1976 page II)

ii) Cleaning and maintenance at 4 week intervals should allow improvement of the water-course so that the rate of water loss is even less than that following a semiannual cleaning. Consequently, the top line of Figure 5 (attached) was drawn indicating a potential transmission efficiency ranging from 83 to 90% for a water course which is properly cleaned and maintained every four weeks.

iii) Construction of pucca nakkas and improving water course channels appears to be one of the best investment in Pakistan. 2 (Clyma et.al 1976 page 19).

iv) The benefits of pucca lining and improvement, are reduction of water losses and maintenance cost and increased control of water. Clyma et.al concluded that in view of high cost of pucca lining, same benefits can be achieved from pucca nakkas and earthen improvement. However in saline ground water areas, where other sources of water are not available and high value crops can be grown, then the benefit can be sufficiently high to justify the cost of lining of the main channel (portion of the water course). It is probable that within the next 50 years as crop yield increases the water courses in Pakistan will be pucca lined. Earthen improvement with pucca nakkas are economical interim measures which if properly maintained can help the farmers to develop the capital for many improvements including pucca lined water courses.[2] (Clyma et.al 1976 page 21-22).

v) On a well maintained earthen water course in Mona Project losses were found as under :–[3] (Kemper et.al July 1977 page 10).

1. Cs. Water course = 8%
2. Cs. Water course = 7%

vi) Several techniques for reducing the conveyance losses have been develop-

ed and tested at Mona. These include partial lining and earthen reconstruction of water courses. The use of lining has been discouraged because of its high cost earthen reconstruction has proved successful both because of its loss reducing capacity and because of farmer participation and low cost. Also lining requires engineering assistance which is not available; a much cheaper and simple alternate for reduction of conveyance losses is cleaning and maintenance of water courses. The average loss rate reduction to about 30% in an improved water-course identifies high potential in timely and proper water course cleaning and maintaining. Farmers may be advised for reduction of conveyance losses without waiting for engineering and financial assistance from the Government.[8] (Bowers June 1977 Foreword page i)

vii) Losses from spillage and leakage can be fully checked and seepage losses substantially reduced by earthen rehabilitation of water courses.[8] (Bowers June 1977 page 2).

viii) S.A. Bowers states on the subject as under :—

In Scarp areas where tubewells water is mixed with canal supplies, condition have further deteriorated. Water course remodelling for conveying the enhanced flow of almost 100% was seldom considered. The net result of this mis-management is apparent from excessive losses including seepage, leakage, spillage, over topping and storage etc. Leakage and spillage increases by development of pond like condition at nakkas. The result of such poor maintenance is 40% losses.[8] (Bowers June 1979 page 1).

Comments by Authors on (viii) Above

A very serious ommission was committed while planning Scarp Projects. The existing water courses in these areas were having an average capacity of 1.5 to 2 Cs. and water carrying section was kept accordingly. With commissioning of Scarp Tubewells, the discharge in water course was suddenly raised to 2 to 3 times the

original discharge. Remodelling of these old small water courses was not included in the SCARP estimates and the job was left to shareholders. With heavy increased discharge, spillage, breaches and all such losses occured, on Scarp water courses. The fault for such losses did not lie with the share-holders but with the planners of the Scarps. It was highly in-advisable to put 2 to 3 time more discharge without improving water courses. 100 years experience of Irrigation Department is that an optimum capacity of a water course should be 3 Cs. because this is the maximum discharge which the zamindars can possibly handle manually. But in Scarp, the discharges were raised to 5 to 6 Cs. Even now it is high time to design these water courses and adjust the sections accordingly.

ix) Average conveyance losses in an unimproved water courses but clean were 5.1% per 1000 ft. and on earthen improved water course, the losses were 2.3% per 1000'. This indicates that earthen improvement is more effective in reducing losses as compared with simple cleaning and maintenance.[8] (Bowers June 1979 Page 9).

x) It is determined that if conveyance losses can be reduced to normal wetted perimeter infiltration plus water surface evaporation plus infiltration into dry banks etc., the conveyance losses could be reduced to about 15% of the inflow. In fact steady state seepage should be reduceable to less than field in-take as a result of silt deposit on the water courses bed. This would not involve any physical re-order of the course system or expensive channel lining. Only earthen design improvement can bring the system upto its potential. Losses could then be further reduced without lining by realigning the field and water course lay-out. The average length of former branch should be reduced from 1000' to 500' thereby reducing channel wetted and potential steady state infiltration by about 10% and transient losses by 50% and 90% making water course conveyance efficiency.[9] (Trout 1979 page 78 - 79).

xi) If losses could be reduced to normal channel wetted perimeter infiltration rates, conveyance losses could be reduced to about 15%.[9] (Trout 1979 page 81-82).

xii) Results showed that amongst the alternates studied the optimal water

course improvement method consisted of earthen improvement of ten reaches with no treatment of other reaches. Partial lining was not profitable when lining cost Rs. 50/- per foot. Optimal water course improvement includes about 70% earthen improvement with no lining. It appears that with existing cost of lining, the Government Programme which emphasizes earthen improvement are correct.[11] (Bark at Ali Mona Oct. 83 Pages 84 & 86).

xiii) Improvements on other earthen water courses indicate an average savings of 50% of water losses, if essential investment in cleaning and maintenance of the improved water courses is continued. However under present economic condition in Pakistan, the decision to concentrate on earthen improvements and pacca nakkas and encouraging farmers to maintain and clean the improved water courses appeared to be near the maximum improvement that should be recommended.[7] (Kemper et.al April 1979 page 483).

xiv) Observations show that simple cleaning and maintenance actually bring the greatest return per unit investment which is mainly of local labour. It appears thatthe most affordable and profitable investment in water course improvement for the Pakistani farmer is to properly clean and maintain water course. This pays a rich devidend to the farmers.

These factors indicate a potential high pay-off for a programme which would inform the farmers of their existing losses, show them benefits of cleaning and maintenance in terms of increased water and to help them to organize proper maintenance.

Improvement of Sarkari Khal will not solve the delivery system loss unless farmers also enlarge, clean and maintain their own field channels.[7] (Kemper et.al April 1979 Page 488).

xv) It is interesting to point out that the portion going to be normal wetter

perimeter infiltration i.e. 9% represents what may be the minimum achieveable losses without channel lining. The excessive bank and bed seepage is a result of porous banks, high effective wetted perimeter resulting from rodent holes.[4] (Trout et.al July 1977 Page 31).

xvi) Losses could be reduced through wetted perimeter at the normal soil ,ntake rate, a conveyance efficiency of 90% can be achieved.[4] (Trout et.al July 1977 Page 33)

xvii) Water-course improvement porgramme should be such that it involves a minimal out-put of capital by the Government. This may include constructing, compacting earthen buffalo baths rather than masonry ones and utilization services of field assistance of Agriculture extension to do the engineering under directions of a trained agriculture engineer. A capital input of Rs. 15/- per acre plus provision of extension services is sufficient to motivate the farmers in this programme.[5] (Water Course Improvement in Mona Page 90).

xviii) The experiment that 4.6 Cs. branch water course showed as under :—

Length	=	4000 ft
Losses	=	0.4 Cs.
% age losses	=	9%

This indicates that average losses in a large earthen water course can be as low as 9%.[6] (Kemper 1978 Page 10).

5. PRIVATE TUBEWELLS

5.1 Private tubewells merit special mention in context of Water Resources Development (W.R.D.) in the Punjab in canal command areas, for 1.19 lac tubewells of average capacity 1.15 Cs. are pumping 20.43 M.A.F. at 20% utilization factor. Annual average pumpage per tubewell comes to 170 A.F. or 23 Cs. These are mostly installed in F.G.W. Zones. Without sufficient recharge from canals and water courses, these tubewells cannot run economically.

5.2 Watercourse lining in various water quality Zones.

The irrigation system of the Punjab Province consists of 24 canal commands with total G.A./C.C.A. of 24.32/20.27 million acres. Field investigations have revealed that ground water quality of various commands is as under :—

Saline Zone	=	4.129 Million acres.
Usable Zone	=	20.19 " "
F.G.W. Zone. (other than Scarp)	=	9.476 " "

Usable zone has salinity upto 3000 PPM. Fresh ground water has salinity upto 1500 PPM. Saline water has salinity more than 3000 PPM. Mixing zone has salinity from 1500 to 3000 PPM.

5.3 To irrigate 24.32 million acres G.C.A. 54000 outlets are provided on Punjab canals with an average of 450 acres per outlet. These outlets are distributed in various water quality zones as under :—

1)	Water course in saline area	=	9174
2)	Water courses in usable zones	=	44826
	Total	=	54000

5.4 It is estimated by W.M.O. that total cost of lining per mile is Rs. 2.50 lac. Average length of water course is assumed 3 miles.

Cost and length of lining for various percentages is given below : —

Percentage lined	Length	Cost in Million Rs.
100	3 miles	0.76
85	13464 ft	0.646
50	7920 ft	0.38
30	4752 ft	0.228
15	2376 ft	0.114

5.5 Suggestions

i) Water loss through water courses in saline areas cannot be recovered by pumping. Thus lining of water courses in such areas upto such optimal length that conveyance efficiency increases to 99% will be extremely paying investment and requires to be placed at top priority.

ii) In fresh ground water areas already zamindars have installed over one lac tubewells for supplementing canal water. In such areas private sector enterprise of exploiting ground water is the halmark of the present benevolent Government. The rate of numerical increase of private tubewells is extremely rapid and requires to be given further impetus by the Government in providing electricity, soft loans etc. It is proposed that instead of lining a water course in sweet zone, it would be more beneficial and economical to install a private tubewell. The average cost of a tube-well (AV 1.5 Cs) will be Rs. 0.60 lac as against lining cost of Rs. 2.28 lac on a water course with 30% lining. The huge savings can be utilized elsewhere. Thus by spending a fraction of this large amount involved on lining, the discharge of water course can be increased thereby increasing the intensity of irrigation to desired level.

iii) It is proposed that instead of lining water courses in fresh usable water area, it will be more beneficial and cheaper if tubewells are installed on all the 44826 water courses.

Average cost of one tubewell material only (0.60 – .10) = .50 lac Rs.

Cost of 44826 tubewells = 2241 Million

As against this outlay the cost of lining 44826 water courses for 30% length only comes to Rs. 10220 million. These are initial costs without escalation and interest charges over period of execution of project. This lining of water courses will give a water saving of 10085 Cs. as given below :–

$$44826 \times \frac{15}{100} \times 1.5 = 10085 \text{ Cs.}$$

Additional water given by 44826 tubewells of 1.5 Cs. capacity at 35% operational factor comes to 23534 Cs. discharge i.e. 3.67 times more than saving by lining.

The above data is tabulated below :–

Item	Cost in Million	Cost per acre	Water saved Cs.	Additional water per 1000 acre
Lining water courses.	10220	506	10085	0.50
T/Wells 1.5 Cs. capacity	2241	111	23534	1.16

5.6 Existing private tubewells pumping about 20 MAF, with the coming in of proposed tubewell, the overall pumpage will increase to about 36 MAF (20 + 16)

which is in excess of the existing re-charge. The over-draft will lower water table and will prove an extremely good anti-water-logging measure. However, the matter of re-charge and pumpage requires detailed investigations, specially with coming in of more water from Tarbela and proposed Kalabagh Dam.

5.7 In Scarp Vi a very wise course of action has been adopted by extending electric lines upto the threshold of the farmers so that they may instal electric tubewells in the private sector. This has been done for the first time on the suggestion of Engineers of Punjab Irrigation (Raja Sa'adat Mand Khan and others) and this approach is going to pay very rich dividends as compared with installation of tube-wells in the public sector.

5.8 The additional water shall enhance intensity of irrigation to 200% with more crop yield which can not be attained with the present canal water resources. In fact the benefits of the proposal are so obvious and high that these can stand any economic analysis and scrutiny.

5.9 Increase of intensity of irrigation

It is estimated that for an existing intensity of irrigation of 120% suppose water supplied by the canal system is one M.A.F., then for higher intensities the requirement is as under :—

Intensity %	Water requirement M.A.F.
120	1.0
150	1.25
200	1.64

Now if 1.5 Cs. tubewell is provided on a water-course of 1.5 Cs. discharge then the water course will get an average 77% more water and this will give intensity of 214% say 200% against the existing of 120%.

W.M.O. is to spend 13 billion rupees on partial lining of 50,000 water courses which gives an average cost of 2.28 lac per water course. If this heavy amount is spent on :—

(a) Lining of 9174 water courses of saline zone for 50% length at a cost of Rs. 3486 million.

(b) Providing 44826 tubewells on each water course at a cost of Rs. 2241 million.

The total cost of above proposal comes to Rs. 5.73 billion against Rs. 13.56 billion to be spent by W.M.O.

There can be no better spending of Government money than proposed above.

5.10 Private tubewells as an Anti-Water-Logging measure

It has been estimated by FIZAC consultants that total recharge from water course and fields in all the Punjab canal commands comes to 10 MAF (Annex - 4 Table 1). It is estimated that out of this 70% is recharge from water course and 30% from fields which gives water course recharge of 7 MAF. As against this we would be pumping 16 MAF annually ($23534 \times 2 \times 340 \times 10^{-6} = 16$). Thus annually we will be over drawing 9 MAF from G.W. Reservoir which is a big anti-water-logging and ultimately anti-salinity control measure. In usable area the salinity ranges from 1500 to 3000 as per limits fixed by WAPDA. At places where salinity is say more than 2000 PPM, use of Gypsum can be resorted to in public as well as private sector to reduce the salinity of water to reasonable extent. Recently a study of utilization of Gypsum for agriculture and other sectors has been got conducted by Federal Government in which it has been estimated that with the addition of gypsum @ 0.1 Ton per acre-foot of water (Page 2.17 of Feasibility Study-Utilization of Gypsum in Pakistan), the salinity of water is reduced. So the use of Gypsum as recommended has an important impact on increasing intensity of irrigation by using

managable quality water. Subsidy on Gypsum has already been approved by the Federal Government which will have a great impact on agricultural production.

It is estimated that 50% pumping (8.0 MAF) will need Gypsum treatment because of proposed shallow tubewells (useable water quality Zone estimated for 350 ft. by FIZAC). Total quantity of Gypsum needed is $8.0 \times 10^6 \times 0.1 = 8,00,000$ tons. For each tubewell it comes to 38 tons per year. Assuming cost including carriage etc. 130/- per ton, the cost per tubewell comes to Rs. 5000 per year. The cost per acre comes to Rs. 11/- which is a very meagre cost as compared with likely benefits of greater intensity and yield.

6. CONCLUSIONS AND RECOMMENDATIONS

1 The assumption of water course losses upto 40% and above is not on correct basis. The correct figure varies between 10% to 15% as has been established by various authorities.

2 Proper improvement of kacha watercourses (Fixing pucca nakkas, straightening, cleaning and compactionof bank etc. of properly designed water course) and subsequent maintenance at short intervals is extremely beneficial to Farmers and maximum stress requires to be laid on this.

3 Partial lining of the head reach in usable ground water zone does not reduce losses commensurate with the costs involved and can be dispensed with till financial position of Farmers becomes very sound. Infact when Farmers become financially well off, they will themselves line their water-courses instead of seeking assistance from the Government.

4 As water losses in saline areas are irretrievable, lining of optimal length of water courses is very essential to save every drop of canal water.

5 In usable ground water zone, tubewells in private sector may be encourag-

ed through liberal loans so that sufficient additional water becomes available, thereby achieving crop intensity of 200% and at the same time increasing the crop yields and reducing water-logging and salinity. Private Tubewells shall be shallow constructed with indigneous materials.

6 Use of canal water courses for conveying tubewell water may be freely allowed, so as to encourage development of tubewells in the private sector. This is possible only if kacha water-courses are improved and not made rigid by lining.

7 Use of Gypsum for improving soils and quality of water may be encouraged by subsidising its cost liberally. As has been announced by the Federal Government recently, this is a positive step towards increasing agricultural production.

8 Project estimates for lining of water-courses should be prepared by the concerned agencies as per criteria fixed by the Planning Commission i.e. addition of escalation and compound interest charges etc so as to obtain correct cost benefit ratio and I.R.R. to give a correct picture to the Government.

9 Monitoring of work done by Water Management Organization may be entrusted to a separate agency so that correct assessment of the impact of the achievements is brought before the Government.

10 A standard of proper maintenance of water-channel may be fixed and this may be made a pre-requisite for loans for a private tubewell. Improper maintenance may be strictly penalized so that proper and adequate maintenance of water courses becomes a continuous operation and a regular feature on farm activities. Provisions of canal Act may be enforced properly, under which in case of default the water course maintenance can be done by the Government at the cost of irrigators, recoverable as arrears of Land Revenue.

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