CHAPTER - 4

ANALYTICAL STUDY OF THE LOSSES

4.1 INTORUDCTION

Daily discharge data (both morning & evening) has been collected from the field for Upper Ganga Canal right from head at various control points such as for river at Raiwala; Haridwar Dam; offtakes of Uttari Khand, Deoband Branch, releases into Mat Branch as well as supplies released into Hathras Branch. Studies have also been conducted on the disty. & minor system of Agra canal in Haryana & U.P. as the releases both from WJC & UGC system merge at Okhla into Agra canal and since water-use efficiency is being analysed for these two system separately, the resultant efficiency on waters amalgamated both from WJC & UGC into Agra canal offtakes offers an opportunity to analyze the results.

The Irrigation Department U.P. in its various divisions was not equipped with current meters & as such in head reaches the discharges were observed either by Irrigation Research Institute Roorkee or sometimes by investigation and planning divisions. One such site is at 21.39 Km of U.G.C.

River discharge through barrage is computed using formula for discharge through orifice & ready reckoner discharge tables prepared for different pond levels on u/s & d/s of barrage. The coefficient of discharge has been worked out by Irrigation Research Institute, Roorkee with the help of model studies & as such discharge being reported was ! 10%.

There is incidence of silt movement in canal and %age of normal flow is stated to go down to about 90% during monsoon when water has high silt content & bed gets silted up. After monsoons silt in bed is picked up &

washed down with silt free water and percentage to normal goes up almost to 105%.

Occasional observations are thus needed. Observation on canals, branches and distributaries are done with velocity rods & floats. Calibration of gauges on masonry walls or gauge wells is required to be rechecked & zero of gauge is to be co-related to GTS bench mark.

4.2 FIELD EFFICIENCY

Field irrigation requirement has been worked out on U.G.C. in UPCIP (U.P consolidation Irrigation Project) by assessing 35% losses. These losses include : -

a) Loss in lined watercourse from outlet head to 5-8 ha block
b) Loss in Kacha gul within 5-8 ha block
c) Water application losses

Study conducted already on U.P. channels, assessed losses in Kacha watercourses @ 4% per 100 metre length. Assuming gul length of 200 metre (average), the gul efficiency has been rated at 0.96 X 0.96 = 0.92 (92%).

It has been assumed in the project that lining of watercourses will reduce losses to 25%; would render watercourse efficiency to 90%; as such channel efficiency from outlet to field had been worked out 0.96 x 0.90 = 0.864.

An assumption of 0.80 as average attainable water application efficiency was made giving field efficiency below outlet as 0.864 X .80 = 69%.

Canal efficiency : - UP Consolidation Irrigation Project envisaged 30% losses in canals for the lined system.

With conveyance efficiency of Main canal 95%
Branch canal 90%
Distributary & minors 85%

Conveyance efficiency upto outlet head as 0.95 x 0.90 X 0.85
= 73 %

& overall efficiency thus = 0.73 x 0.69 = 50.4 % for lined system

4.3 SEEPAGE LOSS

The U.G.C. project assumed seepage loss on unlined system at 8 cusecs per million sq.ft of wetted perimeter (2.44 cumecs per million sq.m. of wetted perimeter). For lined canal this loss was taken as 25% of above. The evaporation loss was assessed & assumed as 2 to 5% of the seepage loss and thus ignored in computations. Seepage loss on the canal system of U.G.C. depends on

i) Permeability of the soil
ii) Spring level conditions
iii) Quantum & depth of flow in canal
iv) Velocity

Seepage loss per cumecs of water flow are much higher for smaller channels than bigger channels as wetted perimeter per cumecs discharge is much higher. Losses as worked out for 20 km length of channel at 2.44 cum / million sq.m of wetted perimeter for lined section are given below :

S.No.	Discharge at Head	Seepage loss % of Discharge at head	
	(Cumecs)	(Unlined)	(Lined)
1	225	1.02	0.22
2	60	1.21	0.44
3	10	5.56	1.18
4	0.6	24.30	5.08

For same channel - seepage loss per cumec more when running with less discharge or shallow depth.

As observed during various periods of rotational flow, the losses were more in the initial running period after closure.

UPCIP assumes a percolation rate of 1.0 to 5.0 mm / day for soils suitable for rice cultivation under puddled conditions, 5 to 7.5 mm for marginally suitable ones and more than 7.5 mm for soils unsuitable for rice cultivation.

4.4 LOSSES ASSUMED IN ROTATIONAL PROGRAMME & FIELD OBSERVATIONS OF LOSSES ON UGC SYSTEM

The procedure for distribution of water prescribed and followed on UGC in the foregoing pages envisages cropwise allocation on probable availability division-wise as their share. Typical assessment for Kharif & Rabi crop has been depicted at Annex 4.1. During Rabi period the main line losses @ 31.15 cumecs and supplies earmarked for Delhi Water Supply Undertaking are deducted at source from the shares of UGC available at Dhanauri. The conveyance losses in the branches and distributaries are however incorporated in the shares of each division.

Typical allotment of Muzafarnagar Division (A) @ 16% includes losses @ 9.91 cumecs. Meerut Division, includes losses @ 11.32 cumecs

Bulandshahar Division includes losses @ 3.39 cumecs. Main line losses taken as 31.15 cumecs even though actual supply had however been variable; and share of various divisions kept with losses assumed as above.

During the period when Lower Ganga Canal & Parallel Lower Ganga Canal (PLGC) supply have share on Ganga water; the U.G.C. share say for period of March ranges between 45 to 65% depending upon actual availability & when L.G.C. has no share; the U.G.C. share increases in the range of 85%. Agra canal share also increases due to more availability in the latter case & this canal too can have discharge upto 16% of total. The regulation instructions expect control points to be strictly maintained such as

X_{EN} Muzaffarnagar Division to maintain Belra a specified discharge for different weekly allocations

X_{EN} Meerut division to maintain Newari, similarly

X_{EN} Bulandshahar to maintain Walipure i.e. Boundaries to be maintained at the cost of channels.

SOME EARLIER STUDIES & OBSERVATIONS ON UGC (1901) SHOWING VARIABLE DUTY IN DIFFERENT TRACTS OF SAME U.G.C. SYSTEM

TRACT	DELTA (FT)	
	KHARIF	RABI
Northern Part of UGC	2.92	1.50
Anupshahr	2.41	2.50
Meerut	2.66	1.60
Bulandshahar	2.58	1.83
Aligarh	2.60	1.50

Some earlier studies & observations
Duty of Water in Kharif (1901) (a comparison)

Canal	Average utilisation in cusecs at the head of canal during season	B= Base i.e. No. of days canal was in flow	D=Duty of Discharge utilised	Delta (Feet) <=equival-ent aggregate depth of water on the fields on the basis of utilised discharge	V=Volume utilised per acre Irrigated (Cft.)
Upper Ganga Canal	5152	127	73	3.41	150,320
Lower Ganga Canal	3133	141	67	4.16	181830
Eastern Jamuna Canal	1310	169	120	2.75	121680
Western Jamuna Canal	4200	181	64	5.58	244350

Duty & Delta in Rabi Season (1901 - 02) (a comparison)
(Study carried out by RG Kennedy)

Canal	Average utilised discharge at head of canal during the season (Cusecs)	B=Base Number of days the canal in flow	D=Duty of the discharge utilised	<=Equival-ent aggregate depth of water on the field on the basis of utilised flow (Feet)	V=Volume utilised per acre irrigated (cft.)
Upper Ganga Canal	4290	182	159	2.25	98900
Lower Ganga Canal	2837	182	191	1.83	82330

Canal	Average utilised discharge at head of canal during the season (Cusecs)	B=Base Number of days the canal in flow	D=Duty of the discharge utilised	<=Equival-ent aggregate depth of water on the field on the basis of utilised flow (Feet)	V=Volume utilised per acre irrigated (cft.)
Agra Canal	1219	182	135	2.66	116480
Eastern Jamuna Canal	1252	170	190	1.75	74940
Western Jamuna Canal	2801	182	115	3.08	136740

DELTA STATEMENT OF VARIOUS CHANNELS
Jatwari Disty.
(Jewer System)
(Q=40 cs)

S.No.	Crop	Irrigation Achieved (Ha)	Water Delivered (Cusec Days)	Delta (ft.)
1	Kharif 1407	349	1880	4.30
2	Rabi 1407	661	2360	2.85
3	Kharif 1408	247	880	2.85
4	Rabi 1408	514	1400	2.17

Baldev Disty
(Lower Mat Branch System)

S.No	Crop	Irrigation Achieved (Ha)	Water Account (Cusec days)	Delta (ft)
1.	Kharif 1407	473	2624	4.43
2.	Rabi 1407	915	2271	1.98
3.	Kharif 1408	456	3851	6.76
4.	Rabi 1408	331	1339	3.23

Proposed discharge = 120 cs
Present discharge = 70 cs
Outlets = 55

Dagheta Disty
(Lower Mat Branch System)

S. No	Crop	Irrigation Achieved (Ha)	Water Account (Cusec Days)	Delta (Ft)	Remarks
1.	Kharif 1407	674	2897	3.43	Tail fed
2.	Rabi 1407	900	2685	2.38	Tail fed
3.	Kharif 1408	463	3856	6.66 *	No supply at Tail
4.	Rabi 1408	217	1376	5.07 #	No supply at Tail

*** Water reached upto 24.4 Km Length**
 # Water reached upto 10.00 Km Length

Chandpur Minor
(Jewer Disty System)

Designed Discharge = 4 cusecs (0.11 cumec)

Number of Outlets = 12

Crop season Rabi 2000 - 01

Irrigation Achieved = 191 ha

Water delivered = 216 cusec days (6.11 cumec days)

Delta = 0.905 feet (0.275 mt)

4.4.1 Losses on Main Canal (Head Reach)

In the distribution programme these losses have been assumed between 0.5 to 2.6%, the actual releases data collected from the field (Annexure 4.3,4.4,4.5 & 4.9) show variable figures & average loss in the head reach is 1.55 %. The first main distribution with branches & offtakes occures in Muzaffarnagar division & on the offtakes d/s Belra. Losses worked out

between Belra & Niwari on UGC for various months (discounting non-reconcilable periods) have been analysed below.

Average Upper Main Line loss on UGC = 1.55 %

Efficiency at Belra = 98.45 %

Month Year	Supplies at Belra (Cusec days)	Utilisation (Cusecs days)	Availability at Niwari (Cusec days)	%age loss
Dec 2001	143770	48365	87112	5.76
Dec 2000	180757	70500	99709	5.8
Feb 2001	121474	39421	72101	8.19
Oct 2001	51505	17165	31752	5.02
Sept 2000	173038	-	92652	Discounted (not reconcilable)
July 2002	165915	62900	98289	2.84
June 2000	171726	53005	103242	9
June 2001	227109	81804	128300	7.48
April 2000	184643	86843	82587	8.23
April 2001	156131	-	66339	Not reconciled (discounted)

Average Loss = 6.54 %

Main line lower of Upper Ganga Canal = 6.54 %

Efficiency at end of UGC upto Niwari = 0.9845 x 0.9346

= 0.9201

= 92 %

4.4.2 Losses between control points on mat branch

M-33 & UTILISED DOWNSTREAM

PERIOD	SUPPLIES RELEASED (Cusec Days)	SUPPLY UTLISED (Cusec Days)	% LOSS
April, 2000	11765	10585	10
May, 2000	24927	22526	9.6
June, 2000	27256	25356	6.97
July, 2000	27620	25356	6.97
Aug, 2000	32000	28890	9.7
Sept, 2000	32095	29995	6.78
Oct, 2000	11202	10803	3.56
Nov, 2000	18976	16976	10.5
Dec, 2000	19249	17549	8.83
Jan, 2001	23798	19356	18
Feb, 2001	21003	18193	13.37
March, 2001	14723	12323	16.3

Average loss (over 12 months) = 9.85 %

Losses between control points on Mat branch, selected at intermediate points as channel is long. Similarly losses between control points on other branch system / major distributary like Jewer disty. work out in the range of 10 to 12.5 %.

Average loss at end of branch & major disty system
= 1/4 [9.85+10.0+11.0+12.5] = 10.8 %

4.4.3 Losses on Mat Branch

Released at head & loss as per Recorded utilisation

Period	Supplier release at head (Cusec days)	Loss (Cusec days)	% age loss
4/2000	20231	4527	22
5/2000	37898	5705	15

Period	Supplier release at head (Cusec days)	Loss (Cusec days)	% age loss
6/2000	35242	6323	17.94
7/2000	49646	6234	12.55
8/2000	53715	4465	8.31
9/2000	50362	2807	5.57
10/2000	15048	-1707	Not reconcilable
11/2000	30876	3446	Not reconcilable
12/2000	32733	1394	4.25
1/2001	35487	2099	5.91
2/2001	31393	6128	19.5
3/2001	18454	2910	26.0

Losses (leaving aside abnormal) range between 8.31 % to 15 %
Losses during rainy season & winter months are less
Losses assumed & reckoned in distribution of share on Upper Main Branch = 8.5 %

Efficiency at end of major disty. & branch system

= 0.92 x 0.892 = 82%

Observation of releases & utilisation on some of the distributaries & minors on Jewer disty reach d/s Jatari and Kamari Disty, Baldev Disty, Hathni Disty, Zikarpur Disty, Mataur Disty. show a loss varying from 10.5 to 16 % the condition of some of the channels being very poor. Some outlets were overdrawing with cross bunds downstream of the outlets; velocity lower than designed, each channel being different in manner of maintained section; status of equity; incidence of unauthorised drawal or practices; type of outlets, their fixation; even withdrawal by open cuts on Jewer Disty .(Water account & irrigation pertaining to Jewer distrtibutary is given at Annex 4.2); it would be misleading to draw an average. Supplies

reaching channels of Mathura division was short of authorized share as per design & CCA. The officers of Mathura division wished that losses as per norms fixed showed also be added in the share of Mathura division which was stated to not being done.

Losses thus averaged upto tail of minor or outlet head of watercourse from a minor or a disty = 11 %

Efficiency at outlet head would thus work out to 0.82 x 0.89 = 72 %

(Where the system was lined upto disty and minor system)

The system of distributary & minor network of UGC especially on Agra canal & lower down on Mat tail reaches and Jewar system are unlined or not maintained in regime. Besides above features there has been vegetal growth and obstruction in bed. Losses on such like channels upto head of outlet work out to higher extreme side of variable losses i.e. 16%. Efficiency with such condition
0.82 x 0.84 = 68.88
Say 69%

LOSSES BASED ON CUSEC PER MILLION SQ. FT OR CUMECS / MILLION SQ. M OF WETTED PERIMETER

The existing section of the channels such as Mat Branch in middle & tail reaches; Jewer disty in the head, middle & tail reaches and their offtakes right upto tail end of system in Mathura division; the offtake system of Agra Canal fed by UGC primarily through Hindon as well as some of the offtakes of Harduaganj Disty; showed,

i) The existing section of channels is far from designed section both in bed width; full supply depth & slope

ii) The supply running in the tail end portion of channels in much less than full supply; velocity is lower & with pipe outlets not in ideal proposition for equity in distribution; occasional obstructions; bed bars, bunds specially on Jewer disty. in division & unauthorised drawal defeat the observation of discharges made without co-relation to withdrawal of individual outlets.

Supply at Tail

Upper Ganga Canal system which has comparatively better percentage availability than W.J.C. has however not been able to feed adequate or equitable supplies in the tail reaches. System wise drawal on Mat Branch & Jewer System & their offtaking channels show the supplies do not reach the tails on many channels. Even the rotational programme or programme of share distribution amongst various divisions show that supply tapers off to NIL far ahead and upstream of tail reach. This shows equitable distribution is not being ensured. The programme indicates that channels mentioned here under were not expected to be supplied water at tails.

Upper Mat Branch (Kharif) Roster Rabi 1409 Fasli.

Hahepa Minor
Hasauta Minor
Banchawali Minor
Bajanta Minor
Kishorepur Minor
Ranehra Minor
Inayatpur Minor
Uttrawli Minor
Salempur Minor
Tanaga Minor
Baroda Minor

These offtakes are not even at the tail end of parent channel.

Tails of following channels of Mathura district were not assured / expected to receive supply in tail reach.

Uttari Minor
Uttasni Minor
Madale Minor
Gaurolla Minor
Kolaua Minor
Tail reach of Jewer Disty.

Lower Mat Branch System Kharif 1408 Falsi (2000)
Following channels not assured of supply
Khanwali Minor
Kupa Minor
Nawipur Minor
Saimra Minor
Naraich Minor

Following channels likely to receive supply only upto certain lengths

Bankner Minor upto 4 Km
Parsauli Minor upto 1 Km
Jarura Minor upto 10 Km
Surir Minor upto 2 KM
Mursan Minor upto 12.2 KM
Haraute Minor upto 3 KM
Gauray Minor upto 7 KM
Sadalead Minor upto 30 KM
Aqira Khera upto 7 KM

Mahavau upto 11.2 KM
Kursanda Minor upto 10.4 KM
Jugsam upto 20.6 KM
Daghet Minor upto 16.2 KM
Khandauli Minor upto 10 KM
Baldeo Minor upto 16 KM
Awairni upto 9 KM*
Agai Minor upto 4 KM
Daulatpur upto 4 KM
Garhsauli upto 4 KM
* L-Section of Awairni Minor is enclosed at Dwg. 4.1.

Such stipulation or information about some channels which are not likely to be fed but entitle for supply do not come in schedule printed for Muzaffarnagar & Meerut circles. This shows the head reach channels of U.G.C. have preferential or over-riding preferences. Executive Engineer, Mathura division had during site visit informed that whereas "Losses" were incorporated while working out shares of other divisions; this was not done for Mathura division resulting in less supplies. As far as canal act is concerned, all areas included in CCA have to be ensured pro-rata available supplies & losses accounted for all channels in interest of equity.

With the existing section of Baldev disty, full supply depth & existing slope; in a wetted perimeter reach of 514800 sq. feet losses worked out as 3.9 cs after deducting drawal by outlets, actual loss per million sq. ft of wetted perimeter worked out to 7.57 cusecs or 0.214 cusecs per million sq.m of wetted perimeter.

Similarly losses based on wetted perimeter area of various channels such as Mat Branch lower reach; Jewer Disty (Dwg. 4.2 & Annex. 4.12) & Baldeo Disty (as described above) Kamary Disty; Awirni Mr;Chandpur Mr.

Mahavan Disty; Dagheta Disty; Jatari Disty; Hathni's Disty; all indicated that losses were more than those assumed as 8 cusecs / million sq. ft of wetted perimeter (approx. 7.5 cusecs as worked out based on share calculations on UGC barring winter & monsoon months). The loss between 7.6 to 9 cusecs on unlined channels & poor maintained channels.

Discharge observed on unlined watercourses, each on Baldev Disty (Mat Branch System); Jatari Mr. (Jewer System) & Hathni Disty and Palwal Disty of Agra Canal System served by UGC through Hindon & WJC flows revealed losses in the range of 11.5 to 16.2% and in the range 9.35 to 12.1 cusecs per million sq. ft of wetted perimeter. None of the water course had been lined and condition of the water courses ranged from satisfactory on Baldev disty to poor on Jatari nor and Hathni Disty. The condition of watercourses on Palwal Disty was comparatively better. The lining of water course was stated to have been done on some watercourses partly & as per experiments conducted on the area in contiguity; losses on lined watercourses were 9 to 11%, the length of these watercourses were however smaller than on WJC.

4.4.4 Field Application Losses

The length of laterals being small; type of soil; field preparation being different research cannot be replicated. It was also noticed that discharge in the outlet itself was variable even for the same week & it fluctuated even during 24 hrs. The time taken for filling up or watering field varied and some of the farmers were also doing supplimentary irrigation by wells. The overall scenario of crop efficiency thus depended on supply for irrigation for canal as well as from tubewells. No data of actual irrigation booked was supplied despite requests.

The variable delivery of water on the same water course over operation of weekly osrabandi is one aspect; the water allowances also differs over various offtakes substantially. Some of the examples are : -

S. No	Name of Channel	Discharge at head (cusecs)	CCA (ha)	Water allowance
1.	Jewer	5.2	336	6.19
2.	Talra	5.6	547	4.09
3.	Sunpera	7.00	200	14
4.	Hasrana	4.50	182	9.89
5.	Alipura	17.0	1380	4.92
6.	Bailane	5.0	342	5.84
7.	Gadhana	5.0	299	6.68
8.	Shairg	84.0	5274	6.37
9.	Kherli	5.0	106	18.8
10.	Chandpur	6.24	283	8.8
11.	Raunikha	40	3911	4.09
12.	Ravupra	26	2807	3.70
13.	Nand Kishre Pura	14.5	1449	4.01
14.	Amerpur Palaka	7	700	4.00
15.	Right Phalda	40	4495	3.56
16.	Karauli	28	3162	3.54
17.	Dayanatpur	12	1390	3.45
18.	Veerumpur	15	1415	4.23
19.	Ruehera	17	2000	3.40
20.	Kishorepur	8.5	64	3.9
21.	Varnota	103	8170	5.04
22.	Khawajupur	297	33462	3.66
23.	Chaureeli	9	620	5.80
24.	Shivarau	8	607	5.27
25.	Vaina	4	278	5.75
26.	Gopalgarh	2	167	4.79
27.	Sikarpur	17	1328	5.12

S. No	Name of Channel	Discharge at head (cusecs)	CCA (ha)	Water allowance
28.	Jaitari	5	344	5.81
29.	Karanpur	70	6930	4.10
30.	Gadak	70	4692	5.97

4.4.5 Losses in the Field

In addition to transit losses in the conveyance system & distribution network accompained with avoidable losses due to leakages and losses due to structural defects or inadequacies, studies conducted on overall evaluation reveals that losses below the outlet & on the field constitute a major component of loss of irrigation water.

Water is supplied to farmer based on water allowance sub-system wise on U.G.C. by allocation of size of pipe outlet & this differs as explained above. The farmer receives the supply as per osrabandi but the actual results he achieves in productivity per unit volume of water depends upon the versatility in application of water; the soil character of the fields; subsoil water table; levels & slope of field etc.

Recommendation for improving water use efficiency by minimising loss below the water course on field / farm itself.

Water Applied to The Plant Proper & its Consumptive Use

The Water Use Efficiency has been worked out on the conveyance and distribution system right upto delivery in the command Chak of the outlet under cultivation & application by different methods.

Net Water Use Efficiency is the efficiency after application of water in the root zone of crop & avoidable wastage by evaporation over crop canopy & in filtration below the root zone. These have to be assessed to work out actual gainfull utilisation of water released.

In-filtration & Redistribution

Infiltration of Irrigation in the soil profile is modelled by employing empirically and physically based concepts. In the empirical approach; the infiltration process is not given any time distribution and soil profile is treated as a tipping bucket. Each layer is assumed to fill to its field capacity wetness instantaneously and remaining water is cascaded to lower layers. Any water passing beyond the bottom layer is lost to deep drainage.

As with in-filtration, the movement of water in rootzone has been estimated in a simplified way by transferring water from one layer to another. Transpiration (T) is the most important component of water balance from standpoint of bio-mass production. The first step in simulating T is the estimation of evaporative demand E_o which is satisfied by interception and soil evaporation and transpiration. Estimation of E_o with Penman (48); Priestley & Tayler (72); and Monteiths (65) method makes use of daily meteorology variables and the diffusive resistance of canopy. Because of the assumptions & approximation, daily pan evaporative values have been used for computing E_o.

The Pan-evaporative value are available for WJC Command in Haryana & UGC in (UP). These; for various crops are depicted at Annexure 4.14.1

With these values taken in the command which are quite representative keeping in view agro-climatic; cropping pattern, irrigation scheduling

prevalence and growing stages of crop and with; delta available & annexed for both the system it has been possible to work out percentage gainful utilisation in the root zone: remaining having been considered to be lost in deep drainage by infiltration & avoidable extra evaporation.

Delta

The statistics of delta worked out on UGC as appended with the report shows its variation between 1.98 to 6.66 during Kharf and 2.17 to 5.07 for Rabi. This huge variation as found for data made available for channels on Mat branch lower reach; Jewer system etc. The ET_0 value for the zone are similar to WJC central command of the order of 1700 - 1900 mm for the year varying for crop season of Rabi & Kharif depending on type of crop. For sugarcane area it is around 600 & 1165 mm. Effective Moisture storage varies between 50 mm to 130 mm.

Since variation is enormous; Cropping pattern variable; soil evaporation variable; water actually utilised for maturity of crop is vastly variant. Rational data for Delta; ET_0 has been taken & average avoidable loss keeping in view of various crop values has been taken as 25% & overall water use efficiency works out to vary between 38% to 33%.

4.5 RECOMMENDATIONS FOR IMPROVING WATER USE EFFICIENCY BY MINIMISING LOSS BELOW THE WATERCOURSE ON FIELD ITSELF

Land Levelling

Proper grading of land to be irrigated is essential for efficient application of irrigation water ; disposal of excess rain water in humid & sub-humid areas conserving rain water in arid and semi-arid areas. Unevenness & undulating terrain & fields contribute to low efficiency. However, criteria &

extent of land levelling for water use efficiency is guided by soil profile, land slopes; source of irrigation water; method of irrigation, climatic condition & type of crop to be grown.

Studies conducted in Haryana Agriculture University in plots of 35 x 7.5 m size by establishing five different levelling indices i.e. 1.2, 2.0, 2.5, 3.0 3.7 and under each levelling index; two irrigation treatments i.e. applying only a fixed 6 cm depth & applying enough water to irrigate the plot adequately such as none of it was left unirrigated. Table 4.2,4.3 and 4.4 show results. The application and distribution efficiencies are much higher with 6 cm fixed depth of irrigation water applied than when plots are completely covered (Table 4.2) However, storage efficiency is lower in fixed depth treatment. In both the treatments however, three efficiencies decreased as the levelling index increased. The application & distribution efficiency in the best levelled treatment 1.2 cm were 15 to 20 and higher as compared to 3.7 cm levelling index.

Grain yield & water use efficiency versus levelling index

The three-year average data of Wheat and Bajra grain yield & water use efficiency showed that yields reduced considerably under both the irrigation treatments as the levelling index increased. However if irrigation water is not a constraint & farmer tends to overuse it (thus able to waste it); then by applying complete irrigation or excess water; loss of yield due to poor levelling can be minimized. The amount of total water used in Wheat crop showed that about 50 and more irrigation water had been applied in 3.7 cm levelling index under complete irrigation treatment as compared to only 30.6 cm in 1.2 cm levelling index and fixed 6 cm irrigation treatment (Table 4.3). It was observed that considering yield; cost of levelling, amount of irrigation water applied & water use efficiency,

the optimum value of levelling index should be 2.5 cm where irrigation water is limited.

TABLE - 4.2

Irrigation Application, Storage and Distribution Efficiency under different levelling Index

Levelling Index(cm)	Application Efficiencies (%)	Storage Efficiencies (%)	Distribution Efficiency (%)
6 cm depth Irrigation Treatment			
1.2*	78.5	62.0	93.3
2.0	73.0	71.2	90.7
2.5	69.8	65.9	86.2
3.0	67.0	64.4	82.5
3.7	65.7	62.8	72.3
Complete or adequate Irrigation Treatment			
2.0	67.6	68.0	88.7
2.5	63.6	67.5	80.6
3.0	60.0	68.1	77.3
3.7	52.6	72.2	67.9

* In 1.2 cm (levelling Index), the actual depth of Irrigation was 5.2 cm.

Wheat & Bajra grain yields (q/ha) and Water Use Efficiency (WUE) (Kg/ha-cm) in different levelling index under 6 cm and complete irrigation (3 years average)

TABLE - 4.3

Levelling Index	Yield & WUE in 6 cm & complete Irrigation							
	Wheat				Bajra			
	Yield		WUE		Yield		WUE	
	6 cm	Complete Irrigation	6 cm	Complete Irrigation	6 cm	Complete Irrigation	6 cm	Complete Irrigation
1.2	46.6	-	166	-	37.3	-	120	-
2.0	42.2	44.2	138	136	34.2	36.6	106	117

Levelling Index	Yield & WUE in 6 cm & complete Irrigation							
	Wheat				Bajra			
	Yield		WUE		Yield		WUE	
	6 cm	Complete Irrigation	6 cm	Complete Irrigation	6 cm	Complete Irrigation	6 cm	Complete Irrigation
2.5	39.3	41.9	128	120	32.9	34.1	99	99
3.0	36.5	40.2	116	108	31.4	29.6	92	82
3.7	34.9	37.3	110	92	27.9	29.7	84	83

TABLE - 4.4

Total Water Use (cm) in different levelling Indices under 6 cm & complete irrigation

Levelling Index	Water Use (CM)*	
	6 CM	Complete Irrigation
1.2	30.6	-
2.0	34.0	38.3
2.5	34.4	40.8
3.0	34.9	42.8
3.7	35.4	47.0

* Total water use is inclusive of irrigation water, rainfall & profile water

Field observations on selected chaks of Jatari Mr., Baldeo Disty & Hathin Disty reveal losses in the range of 15-20 %.

Study conducted also showed that on a freshly ploughed up field of size 30 M x 30 M half a cusec canal supply was released. The time taken to cover the field was observed. Discharge was then increased to double & it was noticed that 0.5 cusec of water requires 1.40 times the volume of

water to cover same areas as when as discharge of 1.0 cusec was released. This experiment was conducted on sandy-loam soil. Results vary on different types of soils.

4.6 RECOMMENDED METHODS FOR FIELD APPLICATION UNDER DIFFERENT CONDITIONS FOR OPTIMISING WATER USE EFFICIENCIES

Improper methods of water application does not result merely in water loss due to percolation beyond the reach of crop root zone but also a loss of nutrients due to leaching. This also results in non-uniform distribution & reduced crop yields. Efficient water application is one that enables uniform application of water according to the need of the crop with its minimum loss and at rate and frequency consistent with intake water retention characteristics of the soil. Important factors for choice of method are : -

i) Crop Species	Rooting depth; consumptive use and peak daily water use; critical stages for watering criteria
ii) Climate	Temperature; relative humidity wind velocity; rainfall
iii) Land topography	Depth of soil; land preparation cost
iv) Soil Characteristics	Water intake & retention properties
v) Irrigation Water Supply	Canal supply : - Adequacy of water, size of stream, Delivery schedules, water quality
vi) Any problem	Salinity / alkalinity' high Sub-soil water level; Drainage

Irrigation Efficiency: Entire water applied for irrigation can never be stored in the root zone; even in the most versatile of application techniques; losses do occur due to non-uniform distribution over the field; waste at the end of borders and furrows ; some percolation below the root zone depth & in case of sprinkler irrigation; evaporation from the spray and retention on the foliage.

For selecting and evaluating performance of any Irrigation method; the three irrigation efficiencies i.e. application; storage & distribution have been kept in view.

Border Irrigation

Field experiments in sandy loam soils were conducted to select optimum length, width & slopes of border strips. It was observed that grain yield & WUE of wheat was 8.3 & 8.4 and respectively higher in 70 M long borders as compared to 50 M, but with regard to slope the level border gave higher yields than steeper slopes. The WUE decreased with increasing width & decreasing slope (Refer Table 4.5). In respect of width of borders, higher wheat yield was obtained in 8 M wide borders than in 10 to 12 M wide borders. Thus where water is scarce & considering WUE surface drainage needs in Kharif season & also keeping in view the land grading cost, border strips of 70 M long and 7.5 M width were found to be most suitable. However, where water availability is not a constraint level borders of same width & length result in better performance.

Border method is more suitable to soils having moderately low to moderately high infiltration rate; not used in coarse sandy soils with high infiltration rates because of stringent limitation in design; also not suited to soils with low infiltration rate; since to provide adequate infiltration time without surface runoff at the lowest end; the irrigation stream may be too small to completely cover the border strip.

The border strip is suitable to irrigate all close-growing crops like Wheat; Barley, Fodder crop and legumes. However, not suitable for crops like rice which requires standing water.

TABLE - 4.5

Wheat yield (q/ha) & water use efficiency (q/ha-cm) in border strip with different slopes & length.

Slope	Yield		WUE	
	70 m	50 m	70 m	50 m
0.2	30.5	30.3	1.28	1.11
0.1	32.3	28.3	1.07	0.93
Level (0)	34.2	30.2	1.00	0.86
Mean	32.3	29.6	1.08	0.97

TABLE - 4.6

Yield of Wheat (q/ha) in border strips of different border widths

Border Width (m)

Years	8	10	12
I	40.3	35.5	32.8
II	37.8	31.0	33.1
Mean	39.0	33.2	32.9
Irrigation Water Application (cm)	23.0	23.6	24.4

TABLE - 4.7

Recommended slopes, stream size & width of border strip for different soils

Soil Type	Infiltration (cm/hr)	Slope (%)	Width (m)	Discharge (Litre/Sec)	Irrigation depth (cm)	Irrigation Time (Minutes)
Heavy	< 0.5	0.05	7-8	10-12	7	50-55
Medium	0.5-1.0	0.05-0.10	6-7	12-15	6	30-35
Light	> 1.0	0.2-0.5	5-6	15-20	5	15-20

i) Border strip is more suitable for medium textured soils.

ii) Length may be 60-70 m.

iii) Inflow is to be stopped when water has advanced to 80 m length of the border.

iv) When available discharge is much more than required two or more strips may be watered simultaneously.

v) When land slope is more than recommended & obtaining design slope is difficult either reduce the discharge or increase the width.

Check Method of Application

Water is applied individually to small & relatively level plots surrounded by ridges so that required depth is impounded rapidly in the field. In rolling topography, plots follow contour & application called contour checks. Deep percolation is directly proportional to the water spread in the plot. Thus largest available non-erosive stream be adopted for irrigation so that spread time is shortest. In this method deep percolation losses can be estimated by an equation & also with help of monograph.

Rough rule being that water spread in the entire plot should be covered in one fourth of the time required so as to infiltrate the net depth of irrigation.

TABLE - 4.8

Recommended Check Sizes for different soils & size of stream

Soil Type	Stream size (litres/ Sec)	
	14.0	28.0
Heavy	200-240	350-400
Medium	100-125	150-180
Light	16-20	20-25

Plot size may be rectangular / square but ratio of length / width not more than 4:1.

Furrow Irrigation

This is used to irrigate row crops with furrows developed between the rows in the planting and cultivation process. Water in the furrow contacts only 1/2 to 1/5 of land surface thus reducing puddling and crusting of soils & renders early cultivation. It is more suitable to crops sensitive to ponded water. When salinity is a problem; double row beds alternate furrows avoiding salt accumulation near the young seedling. Furrows are most commonly made down the slope but when land slope exceed the safe limit of soil erosion they are made on contour. These are effective in area needing surface drainage. These also are effective when rain water is to be conserved. In scarcity areas of water; system of alternate/skip furrow burrow irrigation results in considerable saving of water.

Furrow stream : - Maximum non-erosive stream size is estimated by

Qm = 0.6 litres / sec

Qm = max^m non-erosive stream size in litres / sec

S = furrow slope

Sprinkler Irrigation

i) It is suitable for almost all crops except rice & Jute. One or more of following make it a better choice than surface irrigation

ii) Sandy soils or soils with very high infiltration rate (more than 7.5 cm / hr)

iii) Shallow soils; the topography of which prevents desired levelling

iv) Small stream & scarce water

v) Undulating topography, sand dunes, too steep to level

vi) Labour scarce & costly

In Western Yamuna Canal command areas in districts of Bhiwani, Mohindergarh, parts of Rohtak, Jhajjar, Hissar : Sprinkler Irrigation would be appropriate. This would add to savings in Water.

4.7 INCREASING WATER USE EFFICIENCY BY IMPROVING UPON CROP & SOIL MANAGEMENT PRACTICES

Water Use Efficiency (WUE), Crop yield, Evapotranspiration of crop area is influenced by crop and soil management practices. The numerator i.e. yield can be changed by management practice whereas denominator is more difficult to control. WUE is not closely dependent on the water available if the supply is within the evapotranspiration limit; even though the crop yields depend on the adequacy of water supply. Storage of more water in the soil profile increase greatly the WUE of grain crops grown under conditions of limited water. Allowing an irrigated grain crop like wheat or maize run out of water at the critical phases of its growing may reduce yield & WUE drastically without lowering appreciably the total seasonal evapotranspiration. Proposed cropping pattern is given at Annexure 4.10.

Selection of species

One of the basic approach of increasing crop yield & WUE in a particular growing environment can be selection of plant species adopted to the total amount and distribution pattern of water. Plants vary greatly in requirement of water.

Productivity of Cereal per unit of water (An experiment)

Crop Species	Water Requirement cm	Yield (Kg/ha)	Productivity of water kg/ha/cm
Rice	120	4500	3.7
Pearlmillet (Bajra)	50	4000	8.0
Maize	62.5	5000	8.0
Wheat	40.0	5000	12.5

The plant characteristics which influence water requirement are leaf area; extent of root system; length of growing season; number, distribution and size of stomata, inclination of leaves specis ; selection, Plant choice & breeding can enhance the WUE. Predictions on moisture availability, rainfall, ground water aid improving WUE.

Planting pattern i.e. density and row spacing; enabling the plant canopy more effective in intercepting radiant energy and shading weeds; reduction in rain drop impact on soil structures aid the process. Dwarf variety of row crops benefit more from narrow rows than tall late maturing varieties.

Planting dates are extremely important cultural practices in efficient use of irrigation water. Criteria being to choose date of sowing to ensure good germination by placing seed in the optimum moisture zone. This is so very true & essential in semi-arid / arid zones of Western Jamuna Canal .

WEED ELIMINATION

Weeds compete with crops for soil nutrients, water as well as light. Water requirement of weeds is greater than that of crop. Competition begins when root system of weed & crop overlap. Eradication & Control of weed is necessary to increase WUE of crop.

Efficient crop & Water management to increase WUE includes judicious use of Chemical pesticides in producing healthy crop plant.

Tillage - Principal effect of tillage are the preparation of seed bed conducive to the germination of seed and growth of seedling; conservation of soil moisture & providing adequate soil depth for optimum root growth.

Response of fertilizer to Irrigation : Soil moisture and nutrient availability have a close relationship. Maximum benefit from fertilizer application can be obtained under Irrigated agriculture. With adequate nutrient supply; plants which are limited in growth due to moisture stress would have a higher content of mineral nutrients than plant under comparable fertility but not limited in growth by moisture supply.

A detailed module of fertilizer application; after evaluating nutrient deficiency; calibration of dose; interval; control & variation should be available to the training & visit Staff to educate the farmer in enhancing overall WUE.

Annex. 4.1

COMPARATIVE STATEMENT OF LOSSESS BY VARIOUS STUDIES /EMPIRICAL FORMULA /ASSUMPTION & PERFORMANCE INDICATORS UGC

Losses on the system as per UPCIP report	Losses as per predet-ermined share	Losses as per empirical formula (Roorkee Research Institute)	Losses to envisages be saved on lining of canal as per World Bank Projects	Losses as per recorded gauge /discharge at control points (%)	Losses as per field observation (%)	Delta variation on various channels	20 km length loss on channels (% per cusecs of head Q)	Studies on Delta (1901)	Scope of improvement in efficiency if recommendation implemented for conveyance system & distribution network	Scope of increase in efficiency by change -over to modular outlets & rationalizing water allowance	Scope of increase in ≪ by PIM & supply at bulk in Tertiary system	Scope of overall increase in ≪
Lined System Main Canal 5% Branch Canal 10% Distributary and Minor 15% Efficiency upto outlet level 73% Overall Efficiency 51% Percolation rate in soil 1.0-5.0mm/day for soils suitable for rice cultivation Puddule/cash and 7.5 mm (unsuitable for rice)	Main/Branch 8.5 % Distributary system 7-10% No loss accounted for in tail reach of Mat branch as per revaluation by Ex. Engr., Mathura	8 Cs/million sq. feet of wetter perimeter (2.44 cumecs per million sq. meter of wetter perimeter)	6 Cs/million sq. feet of wetted perimeter (1.83 cumecs per million sq. meter of wetted perimeter)	Upper main canal 0.5-2.6% Main line lower 2.84-8.23% Branch 8.31-15% Disty. 10.5-16% Water Course 11.5-16.2%	Watercourse 11.5 to 16.29 (Main) & 9 to 11 % (Branch) field chak 15-20% loss calculated water courses 4% per 100 meter length	Jatwari 2.85 Kharif 4.43 Rabi 2.17-2.25 Baldeo 4.43-6.76 1.98 - 3.23 Dagheteri 3.43-6.66 2.38 - 5.07	Lined Loss Head Q 2.25cs - 0.22 60 cs -0.44 10.0 cs -1.18 0.6 cs -5.08 Unlined 2.25 cs -1.02 60 cs - 1.21 10 cs - 5.56 0.6 cs -24.30	Head reach UGC Kharif-2.92 Rabi -1.50 Anupshahar Branch Kharif - 2.41 Rabi- 2.50 Meerut circle Kharif - 2.66 Rabi-1.60 Bulandshahar Divn. Kharif - 2.58 Rabi-1.83 Aligharh Division Kharif-2.60 Rabi-1.50	10-15%	10%-20%	10%	15-35%

Overall WUE(excluding plant transpiration and unavoidable use-up) ; 33 to 38 %

UPPER GANGA CANAL SYSTEM
WATER ACCOUNT & IRRIGATION ON
DISTRIBUTARY & MINOR SYSTEM OF JEWAR DISTRIBUTARY

S.No.	Name of Channel (Minor)	CROP SEAON RABI				Delta	CROP SEASON KHARIF				Delta	CROP SEASO	
		Discharge	Days Run	Irrigation			Discharge	Days Run	Irrigation			Discharge	Days Run
		A	B	C	A X B		A	B	C	A X B		A	B
1	Jewer	300.00	83.00	3344.00	24900.00		290.00	105.00	3588.00	30450.00		289.00	74.00
2	Talra	14.00	81.00	246.00	1134.00	3.68	10.00	76.00	226.00	760.00	2.69	14.00	67.00
3	Sunpera	2.50	57.00	14.00	142.50	8.00	2.00	10.00		20.00		2.50	67.00
4	Hasrana	2.00	81.00	39.00	162.00	3.32	1.50	80.00	33.00	120.00	2.90	2.00	67.00
5	Alipura	1.07	71.00	15.00	75.97	4.04	1.00	41.00		41.00		1.07	67.00
6	Bailane	1.06	67.00	10.00	71.02	5.68	1.00	10.00		10.00		1.06	67.00
7	Gadhana	2.00	81.00	30.00	162.00	4.32	1.50	89.00	23.00	133.50	4.64	2.00	67.00
8	Shairg	5.00	77.00	99.00	385.00	3.11	3.00	56.00	45.00	168.00	2.98	5.00	40.00
9	Kherli	3.00	77.00	53.00	231.00	3.48	1.50	68.00	35.00	102.00	2.33	3.00	33.00
10	Chandpur	4.00	77.00	140.00	308.00	1.76	2.00	45.00	44.00	90.00	1.63	4.00	54.00
11	Raunikha	5.00	77.00	144.00	385.00	2.13	3.00	43.00	56.00	129.00	1.84	5.00	42.00
12	Ravupra	3.00	63.00	127.00	189.00	1.19	2.10	74.00	160.00	155.40	0.80	3.00	56.00
13	Nand Kishore Pura	4.00	77.00	51.00	308.00	4.83	2.80	73.00	45.00	204.40	3.63	4.00	57.00
14	Amerpur Palaka	3.60	53.00	70.00	190.80	2.18	3.00	-	-	0.00		3.60	50.00
15	Right Phalda	5.00	53.00	157.00	265.00	1.35	4.00	81.00	167.00	324.00	1.55	5.00	53.00
16	Karauli	6.00	70.00	146.00	420.00	2.30	4.00	104.00	115.00	416.00	2.90	6.00	63.00
17	Dayanatpur	23.00	76.00	264.00	1748.00	5.29	15.00	104.00	259.00	1560.00	4.91	23.00	53.00
18	Veerumpur	7.00	61.00	220.00	427.00	1.55	5.00	87.00	197.00	435.00	1.77	7.00	55.00
19	Ruhera	4.00	62.00	195.00	248.00	1.02	3.00	98.00	77.00	294.00	3.05	4.00	44.00
20	Kishorepur	5.50	62.00	125.00	341.00	3.18	3.00	93.00	47.00	279.00	4.70	5.50	30.00
21	Varnota	52.00	69.00	999.00	3588.00	2.87	40.00	108.00	1109.00	4320.00	3.12	52.00	63.00
22	Khawajupur	5.00	69.00	37.00	345.00	7+	2.00	95.00	36.00	190.00	4.22	5.00	60.00
23	Chaureeli	15.00	59.00	195.00	885.00	3.60	8.00	95.00	228.00	760.00	2.66	15.00	62.00
24	Shivarau	8.00	67.00	284.00	536.00	1.50	4.00	97.00	225.00	388.00	1.38	8.00	48.00
25	Vaina	8.50	61.00	427.00	518.50	0.97	4.20	104.00	503.00	436.80	0.70	8.50	58.00
26	Gopalgarh	7.00	61.00	138.00	427.00	2.47	3.50	104.00	107.00	364.00	2.72	7.00	55.00
27	Sikarpur	15.00	69.00	509.00	1035.00	1.63	7.00	103.00	402.00	721.00	1.43	15.00	22.00
28	Jaitari	40.00	59.00	661.00	2360.00	2.85	20.00	94.00	349.00	1880.00	4.30	40.00	35.00
29	Karanpur	5.80	6.00	65.00	34.80	0.42				0.00		5.80	16.00
30	Gadak	16.00	34.00	170.00	544.00	2.56	5.00	6.00	27.00	30.00	0.80	16.00	7.00
31	Untasani	25.00	25.00	111.00	625.00	4.50	8.00	18.00	10.00	144.00	11.50	25.00	20.00
32	Malab												
33	Gaurola												
34	kolana												

DATA NOT RECEIVED

Annex. 4.2

N RABI		Delta	CROP SEASON				Delta
Irrigation			Discharge	Days Run	Irrigation		
C	A X B		A	B	C	A X B	
3145.00	21386.00		270.00	126.00	3390.00	34020.00	
445.00	938.00	1.69	10.00	108.00	220.00	1080.00	3.92
12.00	167.50	11.00	2.00	8.00	13.00	16.00	0.99
38.00	134.00	2.82	1.30	82.00	30.00	106.60	2.84
16.00	71.69	3.57	0.80	48.00	6.00	38.40	5.13
5.00	71.02	10+	0.85	2.00	3.00	1.70	0.45
60.00	134.00	1.78	1.00	80.00	24.00	80.00	2.67
148.00	200.00	1.08	3.00	109.00	118.00	327.00	2.21
121.00	99.00	0.63	1.50	105.00	81.00	157.50	1.55
236.00	216.00	0.73	2.00	101.00	104.00	202.00	1.55
218.00	210.00	0.77	2.50	74.00	107.00	185.00	1.38
334.00	168.00	0.40	1.80	97.00	181.00	174.60	0.76
98.00	228.00	1.86	2.00	82.00	38.00	164.00	3.45
33.00	180.00	4.36	1.80	12.00	11.00	21.60	1.56
198.00	265.00	1.07	2.50	69.00	185.00	172.50	0.75
136.00	378.00	2.22	3.00	100.00	88.00	300.00	2.72
244.00	1219.00	3.99	12.00	102.00	152.00	1224.00	6.44
193.00	385.00	1.59	4.00	59.00	163.00	236.00	1.15
176.00	176.00	0.80	3.00	4.00	22.00	12.00	0.44
71.00	165.00	1.86	Nil	0.00	0.00	0.00	
987.00	3276.00	2.65	40.00	116.00	1244.00	4640.00	2.98
61.00	300.00	3.93	4.00	107.00	34.00	428.00	10+
208.00	930.00	3.57	10.00	112.00	230.00	1120.00	4.85
285.00	384.00	1.08	6.00	98.00	171.00	588.00	2.75
378.00	493.00	1.04	6.00	118.00	623.00	708.00	0.90
159.00	385.00	1.94	5.00	117.00	113.00	585.00	4.10
371.00	330.00	0.71	10.00	65.00	461.00	650.00	1.12
514.00	1400.00	2.19	20.00	44.00	247.00	880.00	2.35
115.00	92.80	0.60	Nil			0.00	
40.00	112.00	2.24	Nil			0.00	
48.00	500.00	8.33	Nil			0.00	

Annex. 4.3

DISCHARGE TABLE OF CONTROL POINT AT BELARA (UGC)

GAUGE (ft)	DISCHARGE (Cusecs)	GAUGE (ft)	DISCHARGE (Cusecs)	GAUGE (ft)	DISCHARGE (Cusecs)
2.0	1923	4.7	4592	7.4	8534
2.1	1996	4.8	4656	7.5	8718
2.2	2069	4.9	4720	7.6	8902
2.3	2142	5.0	4786	7.7	9086
2.4	2215	5.1	4924	7.8	9270
2.5	2288	5.2	5062	7.9	9454
2.6	2361	5.3	5200	8.0	9638
2.7	2434	5.4	5338	8.1	9822
2.8	2507	5.5	5476	8.2	10006
2.9	2580	5.6	5614	8.3	10190
3.0	2654	5.7	5752	8.4	10374
3.1	2802	5.8	5890	8.5	10558
3.2	2950	5.9	6028	8.6	10742
3.3	3099	6.0	6166	8.7	10926
3.4	3148	6.1	6329	8.8	11110
3.5	3297	6.2	6492	8.9	11294
3.6	3546	6.3	6655	9.0	11478
3.7	3695	6.4	6818		
3.8	3843	6.5	6981		
3.9	3991	6.6	7144		
4.0	4140	6.7	7307		
4.1	4205	6.8	7471		
4.2	4270	6.9	7635		
4.3	4335	7.0	7798		
4.4	4400	7.1	7982		
4.5	4464	7.2	8166		
4.6	4528	7.3	8350		

Annex. 4.4

DISCHARGE TABLE OF CONTROL POINT AT NIWARI (UGC)

GAUGE (ft)	DISCHARGE (cusecs)	GAUGE (ft)	DISCHARGE (Cusecs)	GAUGE (ft)	DISCHARGE (Cusecs)
2.0	1380	4.7	2965		
2.1	1450	4.8	3020		
2.2	1510	4.9	3080		
2.3	1570	5.0	3157		
2.4	1630	5.1	3210		
2.5	1700	5.2	3280		
2.6	1760	5.3	3350		
2.7	1820	5.4	3420		
2.8	1870	5.5	3500		
2.9	1940	5.6	3580		
3.0	2000	5.7	3670		
3.1	2060	5.8	3760		
3.2	2110	5.9	3850		
3.3	2170	6.0	3930		
3.4	2230	6.1	4030	1.1	840
3.5	2280	6.2	4108	7.5=5400	
3.6	2340	6.3	4200	7.6=5500	
3.7	2400	6.4	4300	7.7=5600	
3.8	2460	6.5	4380	7.8=5700	
3.9	2520	6.6	4480	7.9=5800	
4.0	2570	6.7	4590	8.0=5900	
4.1	2620	6.8	4700		
4.2	2680	6.9	4800		
4.3	2740	7.0	4900		
4.4	2785	7.1	500	0	
4.5	2840	7.2	5100		
4.6	2900	7.3	5200		
		7.4	5300		

Annex. 4.5

DISCHARGE TABLE OF CONTROL POINT AT DHANAURI (UGC)

GAUGE (ft)	DISCHARGE (Cusecs)	GAUGE (ft)	DISCHARGE (Cusecs)	GAUGE (ft)	DISCHARGE (Cusecs)
4.0	3400	6.7	5690	9.4	8440
4.1	3480	6.8	5790	9.5	8550
4.2	3560	6.9	5880	9.6	8660
4.3	3640	7.0	5980	9.7	8770
4.4	3720	7.1	6075	9.8	8880
4.5	3800	7.2	6175	9.9	8990
4.6	3880	7.3	6265	10.0	9100
4.7	3960	7.4	6360	10.1	9210
4.8	4040	7.5	6460	10.2	9320
4.9	4125	7.6	6560	10.3	9430
5.0	4200	7.7	6660	10.4	9540
5.1	4280	7.8	6760	10.5	9650
5.2	4360	7.9	6860	10.6	9760
5.3	4440	8.0	6960	10.7	9870
5.4	4520	8.1	7060	10.8	9980
5.5	4610	8.2	7160	10.9	10090
5.6	4700	8.3	7265	11.0	10200
5.7	4790	8.4	7370	11.1	10310
5.8	4880	8.5	7475	11.2	10420
5.9	4970	8.6	7580	11.3	10530
6.0	5060	8.7	7685	11.4	10645
6.1	5150	8.8	7790	11.5	10760
6.2	5240	8.9	7895		
6.3	5330	9	8000		
6.4	5420	9.1	8110		
6.5	5510	9.2	8220		
6.6	5600	9.3	8330		

Annex. 4.6

Some Earlier Studies & observations (1901)

On UGC

Showing variable duty in different tracts of same UGC System

Tarct — Delta

☚ = depth of water (feet)

	Kharif	Rabi
Northern part Ganga	2.92	1.50
Anupshahr	2.41	2.50
Meerut	2.66	1.60
Bulandsharhr	2.58	1.83
Aligarh	2.60	1.50

Some earlier studies & observations

Duty of Water (Kharif 1901) - A Comparison

Canal	Average utilisation in cusecs at the head of canal during season	B=base i.e. No. of days canal was in flow	☚ = Duty of discharge utilised	☚ = equivalent aggregate depth of water on the fields on the basis of utilised discharge (feet)	V=Volume utilised per acre irrigated (Cuft)
Upper Ganga Canal	5152	127	73	3.41	150,320
Lower Ganga Canal	3133	141	67	4.16	181,830
Eastern Jamuna Canal	1310	169	120	2.75	121,680
Western Jamuna Canal	4200	181	64	5.58	244,350

Annex. 4.6.1

Duty in Rabi Season

(Study Carried out by R.G. Kennedy)

Canal	Number of acres of crops matured from one cusec of the utilised discharge		
	1899-1900	1900-01	1901-02
Upper Ganga Canal	170	160	159
Lower Ganga Canal	198	199	191
Eastern Jamuna Canal	237	172	196
Western Jamuna Canal	141	98	115

Annex. 4.7

ESCAPE ON UPPER GANGA CANAL SYSTEM

A. UPPER GANGA CANAL

S.No	Name of Escape	Milage of UGC M-F-FT	Bank	Length of Escape	Capacity (Cusecs)
1.	Mayapur	Head	Left	1-4-0	81132
2.	Silt Ejecter	1-3-0	Left	0-7-0	2200
3.	Ratman level crossing at Dhanauri	13-10-123	Left	9-3-0	80000
4.	Khartauli	61-1-220	Right	3-6-0	2000
5.	Jani	84-1-160 87-0-360	Two heads		
6.	Mundan Khera	142-0-89	Left		1500
7.	Rachua	172-6-195	Left		2000
B. ESCAPES ON DEOBASED BRANCH					
1.	Banhera	11-5-379	Right	0-2-280	
2.	Baghra	38-1-474	Right	-	
C. ESCAPES ANUPSHEHR BRANCH					
1.	Siana	56-2-280	Left	6-0-0-	1000
2.	Makhena	82-0-0	Left	2-2-0	
3.	Pesri	99-6-530	Left	0-6-546	
D. ESCAPES ON MAT BRANCH					
1.	Kot	10-5-330	Right	7-0-0	700
2.	Balaupur	33-0-0	Right	3-1-1	700
3.	Sofa	37-2-614	Left	4-5-495	200
4.	Harnaul	58-0-280	Right	4-0-0	633

Annex. 4.8

Chachura Down Kharif 1407 Crop Gauge & Discharge

(Gauge in ft. and discharge in cusecs)

Date	April	May	June	July	Aug	Sept
1	4.7.=1180	4.1-940	3.9.=692	4.4.=901	4.6.=969	4.4.901
2.	4.7.-1180	4.01=940	3.9=692	4.6=969	4.6=969	4.55=952
3.	4.0=900	3.9=865	4.1=752	4.8=1041	4.7=1003	4.65=981
4.	4.0=900	4.1=940	4.2=784	4.95=1092	4.75=1020	4.65=981
5.	3.5=700	4.1=940	4.0=720	4.9=1075	4.8=1041	4.7=1003
6.	-	4.1=940	4.2=784	3.0=471	4.8=1041	4.7=1003
7.	-	4.1=940	4.3=816	4.7=1003	4.75=1020	4.5=935
8.	-	4.1=940	4.3=816	4.6=969	4.75=1020	4.5=935
9.	-	4.3=1020	4.3=816	4.2=833	4.75=1020	4.4=901
10.	-	4.2=980	4.3=816	4.7=1003	4.6=969	4.5=935
11.	-	4.3=1020	4.3=816	4.8=1041	4.5=935	4.5=935
12.	-	4.3=1020	4.35=832	4.95=1092	4.5=935	4.0=765
13.	-	4.3=1020	4.2=784	4.9=1075	4.3=867	4.0=765
14.	-	4.3=1020	4.3=867	4.3=867	4.4=901	4.0=765
15.	3.2=620	4.4=848	4.45=918	4.2=833	4.4=901	4.0=765
16.	3.2=620	4.4=848	4.3=867	4.1=799	4.2=833	3.7=671
17.	4.2=980	4.4=848	4.3=867	4.0=765	4.2=833	3.7=671
18.	4.4=1060	4.6=912	4.3=867	4.4=901	4.2=833	3.7=671
19.	4.25=990	4.5=880	4.1=799	4.75=1022	4.5=935	3.5=603
20.	4.4=1060	4.4=848	4.2=833	4.8=1041	4.6=969	3.5=603
21.	4.4=1060	4.1=752	4.2=833	4.8=1041	4.6=\969	3.5=603
22.	4.1=940	4.4=848	4.3=867	4.7=1003	4.6=969	3.5=603
23.	4.1=940	4.4=848	4.3=867	4.5=935	4.5=942	3.5=603
24.	4.1=940	4.55=896	4.3=867	4.8=1041	4.6=969	4.3=867
25.	4.0=900	4.55=896	4.3=867	4.5=935	4.6=969	4.4=901
26.	4.0=900	4.55=896	4.1=799	4.3=867	4.7=1002	4.4=901
27.	4.2=980	4.2=784	4.1=799	4.5=935	4.6=969	4.2=833
28.	4.1=940	4.2=784	4.1=799	4.6=969	4.7=1003	4.2=833
29.	4.1=940	4.0=720	4.1=799	4.6=969	4.5=935	4.2=833
30.	4.2=980	4.0=720	4.2=833	4.6=969	4.5=935	4.2=833
31.		4.2=720	4.4=902	4.6=969	4.0=765	

Chachura Down Kharif 1407 Crop Gauge & Discharge

Date	OCT	NOV	DEC	JAN	FEB	MAR
1	4.4.=901	-	4.9=1075	2.8=365	4.8=1041	4.3=867
2.	4.2=833	-	4.7=1003	4.0=765	4.8=1041	4.8=1041
3.	4.2=833	-	4.75=1020	4.0=765	4.8=1041	4.6=969
4.	4.2=833	-	4.75=1020	4.4=901	4.6=969	4.7=1003
5.	4.2=833	-	4.8=1045	4.4=901	4.8=1041	4.7=1003
6.	4.2=833	-	4.8=1045	4.3=867	4.8=1041	4.6=969
7.	4.2=833	-	4.8=1045	4.0=765	4.9=1075	4.6=969
8.	4.2=833	-	4.1=799	1.5=nil	4.9=1075	4.5=939
9.	4.1=799	-	4.8=1045	1.3=nil	5.0=1114	4.7=1053
10.	4.0=765	-	4.7=1003	1.5=nil	5.0=1114	4.6=969
11.	4.0=765	-	4.85=1058	1.5=nil	5.1=1152	4.2=831
12.	4.0=765	-	4.85=1058	1.5=nil	4.2=833	3.8=697
13.	4.0=765	-	4.85=1085	3.8=705	4.9=1075	3.9=731
14.	4.0=765	-	4.85=1058	2.0=nil	4.9=1075	3.9=731
15.	4.0=765	-	4.85=1058	3.6=641	4.9=1075	3.9=731
16.	4.0=765	-	4.8=1045	4.2=833	5.0=1114	4.2=833
17.	4.0=765	-	4.8=1045	4.2=833	5.0=1114	4.2=833
18.	4.0=765	-	4.8=1045	3.8=705	5.0=1114	4.6=969
19.	3.9=735	-	4.75=1020	3.8=705	5.0=1114	4.6=969
20.	3.9=735	4.75=1020	4.75=1020	3.8=705	5.0=1114	4.3=867
21.	3.9=735	5.0=1114	4.75=1020	4.2=833	5.0=1114	4.3=867
22.	3.9=735	5.0=1114	4.75=1020	4.2=833	5.0=1114	4.3=867
23.	-	4.6=968	4.75=1020	4.4=901	5.0=1114	4.2=833
24.	-	4.45=918	4.5=935	4.2=833	5.1=1152	4.0=765
25.	-	4.45=918	4.75=1020	3.5=603	5.1=1152	-
26.	-	4.4=901	4.8=1045	-	5.1=1152	-
27.	-	4.6=969	4.8=1045	4.2=833	5.0=1114	-
28.	-	4.9=1075	4.8=1045	4.4=901	4.9=1075	-
29.	-	4.9=1075	4.5=935	4.6=969	4.9=1075	-
30.	-	4.9=1075	4.8=935	4.8=1041		-
31.	-		4.8=935	4.8=1041		-

Chachura Down Kharif 1407 Crop Gauge & Discharge

Date	April	May	June	July	Aug	Sept
1	-	4.8=1041	4.9=1075	4.1=799	4.0=765	5.1=1152
2.	-	4.8=1041	5.0=1114	4.1=799	4.5=935	5.1=1152
3.	-	4.9=1075	4.4=901	4.1=799	4.7=1003	5.1=1152
4.	-	4.8=1041	4.6=969	4.3=867	4.6=969	5.1=1152
5.	-	4.5=935	4.9=1075	4.5=935	4.5=935	5.1=1152
6.	-	4.65=986	4.8=1041	4.5=939	4.5=935	5.1=1152
7.	-	4.65=986	4.8=1041	4.6=969	4.6=969	5.1=1152
8.	-	4.65=986	4.8=1041	4.6=969	4.7=1003	5.1=1152
9.	-	4.65=986	4.7=1003	4.5=935	4.7=1003	5.1=1152
10.	-	4.65=986	4.6=969	4.5=935	4.7=1003	5.1=1152
11.	-	4.8=1041	4.5=935	4.5=935	4.8=1041	5.1=1152
12.	-	4.9=1075	-	4.7=1003	4.8=1041	5.1=1152
13.	-	-	4.4=901	4.7=1003	4.8=1041	5.1=1152
14.	-	-	4.4=901	4.7=1003	4.8=1041	5.1=1152
15.	-	-	4.4=901	4.5=935	4.8=1041	5.1=1152
16.	-	-	4.5=935	4.6=969	4.8=1041	5.0=1113
17.	4.75=1025	-	4.5=935	4.6=969	4.8=1041	4.7=1113
18.	4.7=1003	-	4.5=933	4.6=969	4.4==901	4.7=1003
19.	-	-	4.5=933	4.6=969	4.8=1041	4.9=1075
20.	-	4.5=935	4.5=933	4.6=969	5.0=1113	4.9=1075
21.	3.0=467	5.0=1114	4.5=933	4.6=969	5.0=1114	4.7=1003
22.	4.2=833	4.9=1075	4.5=935	4.6=969	4.9=1075	4.6=969
23.	4.7=1003	4.9=1075	4.5=935	4.6=969	5.0=1113	4.7=1003
24.	5.0=1114	4.9=1075	4.3=867	4.6=969	5.0=1114	4.8=10
25.	5.0=1114	4.9=1075	4.6=969	4.6=969	4.9=1075	4.5=93
26.	4.5=935	4.9=1075	4.6=969	4.6=969	4.9=1075	4.8=10
27.	4.8=1041	4.85=1058	4.7=1003	4.6=969	5.0=1114	4.9=1075
28.	4.8=1041	4.85=1058	4.7=1003	4.6=969	5.0=1114	4.9=1075
29.	4.9=1075	4.85=1058	=4.7=1003	4.7=1003	5.0=1114	5.0=1114
30.	5.0=114	4.9=1075	4.7=1003	4.7=1003	5.0=1114	4.8=1041
31.		4.9=1075		4.7=1003	5.0=1114	

Chachura Down Kharif 1407 Cop Gauge & Discharge

Date	OCT	NOV	DEC	JAN	FEB	MAR
1	4.8=1041	-	5.1=1152	4.8=1041	-	4.3=724
2.	4.8=1041	-	5.1=1152	4.9=1075	-	4.2=696
3.	4.8=1041	-	5.1=1152	4.7=1003	3.9=735	-
4.	4.8=1041	-	5.1=1152	5.0=1114	3.7=671	-
5.	4.4=901	-	5.1=1152	5.0=1114	3.8=705	-
6.	4.0=765	-	4.8=1041	4.9=1075	4.0=765	-
7.	4.5=935	-	5.0=1114	5.0=1114	4.0=765	-
8.	4.4=901	-	5.0=1114	5.0=1114	3.6=604	-
9.	4.4=901	-	5.1=1152	5.1=1152	3.5=497	-
10.	4.5=935	-	5.1=1152	5.1=1152	3.9=735	4.1=667
11.	4.5=935	4.0=765	5.1=1152	5.2=1190	4.0=765	3.6=536
12.	4.0=765	4.3=867	5.1=1152	5.0=1114	401=799	3.6=536
13.	-	4.9=1075	5.1=1152	4.7=1003	4.3=867	3.6=536
14.	-	4.9=1075	5.1=1152	4.75=1017	4.6=969	3.3=465
15.	-	4.6=969	4.9=1075	4.8=1041	4.5=935	3.3=465
16.	-	4.7=1003	-	5.15=1170	4.5=935	3.1=418
17.	-	4.0=765	-	5.2=1190	4.7=1003	3.6=535
18.	-	3.9=735	-	5.2=1190	4.5=935	3.9=614
19.	-	3.9=735	-	4.5=969	4.5=935	3.8=589
20.	-	3.8=705	-	3.5=497	4.5=935	3.8=614
21.	-	4.4=901	-	3.2=434	4.5=935	3.7=560
22.	-	4.4=901	-	3.2=434	4.4=901	3.2=440
23.	-	4.4=901	-	3.0=388	4.6=969	3.9=614
24.	-	4.5=935	-	3.2=434	4.3=867	4.2=696
25.	-	4.9=1075	-	3.2=434	3.95=626	4.4=752
26.	-	4.9=1075	-	2.8=339	4.0=639	4.5=781
27.	-	5.0=1114	-	-	4.6=795	4.4=752
28.	-	5.0=1114	-	-	4.8=870	4.3=724
29.	-	5.1=1152	-	-	4.5=781	4.5=781
30.	-	5.0=1114	5.2=1192	-	-	4.3=724
31.	-	-	4.8=1041	-	-	3.5=504

Annex. 4.10

CROPPING PATTERN PROPOSED
% CCA

Zone	SC	WHEAT	OR	PADDY	O/C
1	**2**	**3**	**4**	**5**	**6**
I Sugar Cane	50	31	14	25	18
II Partial Sugarcane Zone	25	41	14	25	23
III Non-Sugarcane zone	5	41	14	25-30	23
Overall	17	40	14	26	22

Annex. 4.13

UPPER GANGA CANAL IRRIGATION PROJECT

ATTAINABLE FIELD APPLICATION EFFICIENCIES
(Per cent)

FURROW METHOD

Soil	Slopes (Percent)			NET APPLICATION DEPTH (Cm)				
				5.0	**7.5**	**10.0**	**12.5**	**15.0**
Clay *	0.1	-	0.2	75	70	70	70	70
	0.4	-	0.75	70	70	70	65	60
	1.25	-	2.00	65	65	65	60	60
Loam	0.1	-	0.2	75	75	75	75	75
	0.4	-	0.75	70	70	70	70	70
	1.25	-	2.00	65	65	70	70	70
Sand	0.1	-	0.2	70	75	80	80	80
	0.4	-	0.75	65	70	75	75	75

CHECK OR BASIN METHOD

Clay[2]	80	80	85	85	85
Loam	80	80	85	85	85
Sand	65	70	75	80	80

BORDER STRIP METHOD

Clay [1]	0.1	0.2	65	65	65	65	65
	0.4	0.75	55	-	-	-	-
Loam	0.1	0.2	65	65	70	70	70
	0.4	0.75	60	65	65	70	70
Sand	0.1	0.2	65	65	70	70	70
	0.4	0.75	55	60	60	65	65

1. On expanding types of clays - that crack when dry and swell and swell when wet - use 80% efficiency
2. On expanding types of clays - that crack when dry and swell when wet - use 90% efficiency

* Not recommended.

GOI, Ministry of Irrigation, 1984 Tech Series No. 2

Annex. 4.14

Weighted Average ET_o for the I Agroclimatic Zones and Weighted Average Rainfall for the 3 Agroclimatic Zones

(in mm)

Month	Fortnight	Sugarcane		Partial Sugarcane		Non Sugarcane	
		ET_o	Rainfall	ET_o	Rainfall	ET_o	Rainfall
Jan.	I II	35 38	9 12	40 45	6 8	38 42	5 6
Feb.	I II	41 52	11 10	47 58	8 8	46 57	6 5
Mar.	I II	67 87	8 6	74 94	6 5	73 90	5 3
Apr.	I II	94 109	3 3	98 112	3 3	95 108	3 3
May	I II	119 129	5 8	124 130	5 8	119 127	3 5
June	I II	122 111	26 47	130 117	17 30	128 119	14 27
Jul.	I II	96 85	94 131	101 86	70 108	106 92	67 103
Aug.	I II	80 75	116 95	77 74	119 103	80 75	103 89
Sep.	I II	76 73	78 44	82 81	73 41	80 79	69 40
Oct.	I II	73 61	12 6	80 67	13 7	81 68	14 7
Nov.	I II	49 39	2 2	52 43	2 2	53 42	1 1
Dec.	I II	36 34	3 5	39 37	3 4	38 36	2 3
Total		1776	736	1888	652	1872	584