

Water Losses
From
Watercourses

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a)

WATER LOSSES FROM WATERCOURSES

REPORT OF THE COMMITTEE CONSTITUTED

PLANNING AND DEVELOPMENT DEPARTMENT PUNJAB, LAHORE

Provincial Development Working Party (PDWP) in its meeting held on 19-10-1987 constituted a committee to determine the extent of water losses in the watercourses based on various field studies conducted by different organizations in the province from time to time.

TERMS OF REFERENCE.

The terms of reference of the committee was decided by the PDWP. The decision in this regard was as follows:-

“vii) A committee was constituted under the chairmanship of Chief Agri. With the representation of Irrigation Department and Agri. Department to determine/ estimate the extent of water losses in the watercourses based on various field studies conducted by various organizations in the province from time to time”.

Mr. Mushtaq Ahmad Gill, Director, OFWM, Training Institute, Lahore represented the Agri. Deptt. And Mian Abdul Rashid Executive Engineer, Command Water Management Division, Lahore represented Irrigation and power Department. Choudhary Mohammad Asharaff, Project Director, Command Water Management Project, Lahore, was co-opted as member by the committee itself.

REVIEW OF LITERATURE

A number of meetings of the committee were held to define the limits of the assignment and to review the reports of various research workers. Results of 23 studies are referred in the literature reviewed on the subject. Original reports, describing detailed methodology and results pertaining to 17, out of 23 studies, could be obtained from various resources. Brief description of methodology and results of these 17 studies are given in Annexure “A”. Results of remaining six studies were reported out of available reports or other literature related to the subject. Moreover, various national and international agencies have also quoted extent of water losses from the watercourses. Details of 21 such reports are given at annexure “B”.

DEFINATION OF LOSSES

It is observed that different studies refer different percentage of losses from the watercourses. The reason for reporting different rate of water losses by various agencies was investigated and the Committee found that water losses were defined differently by research workers. The main sources of water losses have been categorized as follows:-

- 1) Seepage/ infiltration.
- 2) Evaporation.
- 3) Vegetation (Transpiration)
- 4) Spillage.
- 5) Rodent holes.
- 6) Breaches/ cuts.
- 7) Dead Storage.

The studies and reports reviewed by the committee are spread over a period of over 100 years and their perusal reveals two district definitions of the watercourses losses as given below:-

a) **Seepage and Evaporation Losses**

These losses only indicate direct seepage losses from the wetted perimeter of the watercourses and evaporation losses from the free water surface. The techniques used for the measurement of such losses include the ponding method, well-log analysis and laboratory experiments.

b) **Operational Losses**

Most of the studies have used the approach of determining overall losses i.e. seepage and operational, measured from the system under operation condition by In-flow Out-flow Method. This technique takes into account the operational losses which include spillage, over-topping, leakage through rodent holes, dead storage, initial infiltration and evapotranspiration from the vegetation along the watercourse in addition to the direct seepage from the channel wetted perimeter. The committee is of the opinion that the channel losses measured through this method are better representative of the water losses from the watercourses.

SCOPE OF STUDIES.

Detailed review of the studies indicated that different studies covered different tiers of the Irrigation System at primary, secondary and tertiary level such as :-

- i) From head of main canal to off takes of distributaries and minors.
- ii) From distributaries and minors to watercourses head.
- iii) From watercourses head (Mogha) to the farmer's field.

Since the terms of reference of the committee were confined to find out losses from watercourse starting from mogha to the farmers' field, the reports referring the losses in this part of Irrigation System were thoroughly investigated. However, few studies carried out on watercourses of Tube wells were also considered.

ANALYSIS OF STUDIES

Review of the literature on the subject revealed that the studies can be divided into distinct groups based upon period and methodology as discussed below.

Period of Studies.

It was found that four distinct periods can be identified for studies carried out to evaluate the watercourse losses in the Province of Punjab. The first era was around the year 1880 (3 studies), the second one around 1935 (2 studies), the third was around 1965 (3 studies) and the fourth started from 1970 (15 studies).

It was observed from the perusal of the studies that average losses from the watercourses found around the year 1880 were 21%, around 1935 were 16.33%, around 1965 were 10.84% and since 1970 were 48.08%. Details are given in annexure-“C”. It is, however, interesting to observe that all the studies conducted prior to 1965 used the methods to determine seepage losses only through ponding method whereas the studies conducted after-wards determined the steady state and operational losses mainly through In-flow Out-flow method.

b) Methods Used For Water Loss Measurement.

A number of methods were used by different research workers which accounted for different types of water losses from the watercourses. The studies have been categorized based upon the method adopted and are given at annexure “D”. Brief description of the different methods adopted by various researchers is given in Annexure-“E”. The results are summarized in the following Table:-

Table:- **SUMMARY OF WATER LOSSES MEASURED THROUGH VARIOUS METHODS**

<u>S. No.</u>	<u>METHOD OF STUDY</u>	<u>STUDIES</u>	<u>WATER LOSSES</u>
1.	Well Log Analysis	1	21.25%
2.	Ponding Method.	9	23.00%
3.	In-flow Out-flow Method.	7	49.01%
4.	Operational In-flow Out-flow Methods	4	48.38%
5.	Interview Method.	2	50.50%

It has been observed that different methods cover different parameters of Watercourse losses as per details given in the following Table:-

Table:- **FACTORS ACCOUNTED FOR BY DIFFERENT METHODS FOR WATER LOSS MEASUREMENTS**

<u>Factors Affecting Losses</u>	<u>Well-log Analysis</u>	<u>Ponding Method</u>	<u>Steady State Inflow-outflow Methods</u>	<u>Operational Inflow-Outflow Methods</u>
Seepage/ Infiltration	*	*	*	*
Evaporation vegetation		*	*	*
Spillage			*	*
Rodent holes			*	*
Breaches/ cuts			*	*
Dead storage			*	*
Initial infiltration			*	*
Operational			*	*

CONCLUSION

The well log analysis counts for seepage/infiltration losses only which were measured up to 21.25% in the watercourse section while ponding method covers seepage and evaporation losses which have been reported to the extent of 23%.

The steady state In flow-Out flow method, Operational In flow-Out flow Method and Interview Method cover a wide range of losses and their results are almost same. 49.38% and 50.50%, respectively being 49.29% on an average. These three types of studies are scattered over a period of 12 years from 1974-75 to 1987.

The 21 reports quoted in Annexure-B actually have used either the studies referred to above or without referring the original studies. The average losses from the watercourses were reported to the extent of 46.83%.

It transpires from the above that only seepage losses are to the extent of 23.25%, seepage & evaporation losses are up to 23% and operational losses which account for seepage, evaporation spillage, breaches/ cuts, dead storage, rodent holes and begetation etc. are 49.29 percent on an average.

The over all losses i.e. 49.29 percent have also been widely accepted by the national and international agencies as is evident from their reports (Annexure-B). The committee concludes to following this figure for all practical purposes.

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SUMMARY OF STUDIES AND THEIR FINDINGS

STUDY: 1) **A STUDY OF LOSSES THROUGH WATERCOURSES AND MEANS FOR CONSERVATION-1965**

BY: **Dr. Nazir Ahmad, Principal Research Officer Irrigation Research Institute, Lahore (West Pakistan)**

Methodology:

Water losses from the watercourses has been estimated for the watercourse passing through Clayey Loam, Silty and Sandy soils for the assumed discharges of one and three cusecs for each soil type. Results of laboratory investigation for seepage through these soils have been based to evaluate the extent of water losses. Evapotranspiration from the weeds grown at watercourse banks, evaporation from free water surface and evaporation from bare soil have also been accounted.

RESULT: It is estimated that **2.75 to 14.5 percent** water is lost in the watercourses.

STUDY: 2) **STUDIES ON WATER LOSSES FROM WATERCOURSES AND THEIR LINING MEASURE-1972**

BY: **Irrigation Research Institute Punjab, Lahore.**

Methodology: The report deals with the estimation and testing of various lining to reduce seepage losses from the watercourses. 12 field watercourses located in different areas having varied soil textures and water table conditions were select in addition to the four watercourses constructed at Field Research Station Niaz Beg. Seepage and evaporation losses were measured on fest section of usually 500 feet length on each watercourse with ponding method.

RESULT: This study conducted on 16 watercourses reveals that water losses in the watercourses range from **8 to 19.8 percent.**

STUDY: 3) **WATER LOSSES IN WATER COURSES-1974-75**

BY: **Hassan Ali Director IRDP Punjab/ Project Director Punjab Water Management Project.**

Methodology: Study was carried out on watercourses located at shadab (Lahore) and Lar (Multan). One Watercourse at each site was studied to evaluate the extent of water losses from the watercourses. The data was collected by the Water Management Staff of IRDP.

In-flow Out-flow method was used to estimate the conveyance efficiency and cut-throat flumes were used as water measurement devices.

RESULT: The study conclude that watercourses delivery losses range from **30 to 69 percent**.

STUDY: **4) SEEPAGE LOSSES UN LINED AND LINED WATERCOURSES- 1975-76.**

BY: **Irrigation Research Institute Lahore.**

The study was conducted to monitor the brickcum-polyethylene lined watercourses. Designing and technical supervision work during the construction was provided by Punjab Irrigation Department. This study documents the finding of monitoring work carried out at seven watercourses lying in Multan, Faisalabad and Bahawalpur Irrigation Regions. Ponding tests were conducted on certain reaches of the watercourses to estimate the extent of water losses. Averagely 150 to 200 feet long test sections were selected on the watercourses and water loss measured through test sections was then calculated for a length of 5000 feet taken as standard. The water losses measured on seven watercourses located in various districts are given below:

<u>S.No.</u>	<u>Location</u>	<u>Water losses</u>
1.	Saraba, Faisalabad	14.3%
2.	Rajowal, Sahiwal	60.4%
3.	Chak 99, Fateh, B. Nager	82.0%
4.	Musafirkhana, B. Pur	10.3%
5.	Lar, Multan	4.96%
6.	Kotwah, Muzaffargarh	13.97%
7.	Kot Chutta, D.G.Khan	59.32%

RESULT: The perusal of above table reveals that water losses from **5 to 82 percent** were measured for unlined watercourse in this study.

STUDY: 5) **OPERATIONAL CONVEYANCE LOSSES ON TUBEWELL NO. 81-R WATERCOURSE-JULY, 1977.**

BY: **Thomas J. Trout et. 1, CSU in collaboration with Mona Reclamation Experimental Project of WAPDA.**

Methodology: The study was carried out on one watercourse bearing outlet No. 31574-R and tube well No. 81-R located at Fatehpur distributary in District Sargodha. This comprehensive study was undertaken in detail by measuring the discharge available at the head of the watercourse and the value of water delivered at each farm gate during the entire warabandi system of the outlet. The water conveyance efficiency was worked out by summing up the volume of water delivered at each farm nakka against that available at inlet.

RESULT: On the basis of these operational inflow and outflow measurements, the overall water losses to the extent of **56 percent** have been reported from the watercourse.

STUDY: 6) **WATERCOURSE IMPROVEMENT IN PAKISTAN, PILOT PROJECT STUDY ON COOPERATION WITH FARMERS ATA TUBEWELL NO. 56-L**

BY: **Jointly by the Experts of Colorado state university, USA & Mona reclamation Experimental Project, WAPDA.**

Methodology: The study was conducted on watercourse outlet No. 62395/L, tube well No. 56-L Chak No. 10-ML, Distt. Sargodha. The delivery efficiency was determined by measuring inflow-outflow discharge through flume installation at the watercourse head and the farm nakkas.

RESULT: The delivery efficiency has been worked out as 34.44 percent and the water losses accordingly ranged from **56.66 percent.**

STUDY: 7) **OPERATIONAL IRRIGATION EVALUATIONS OF THREE WATERCOURSE SYSTEMS- AUGUST, 1978.**

BY: **Jointly by the Directorate of Watercourse Chak Farming Survey Project, WAPDA and Experts of Colorado State University, USA.**

Methodology: Three watercourses on each Bhakkar, Bahawalpur (Punjab) and Moro (Sind) were selected to conduct the study. The flow rates were measured with cut-throat flumes placed at the watercourse head (below the mogha), at the tail end of the khal and at the field nakkas throughout the warabundi system of the three watercourses selected for the study.

RESULT: Water Losses to the tune of **40-51 percent** were determined in the watercourse conveyance system from mogha to field nakkas.

STUDY: **8) FARM IRRIGATION CONSTRAINTS AND FARMER'S RESPONSES COMPREHENSIVE FIELD SURVEY IN PAKISTAN-SEPTEMBER, 1978.**

BY: **Jointly by the Directorate of Watercourse Chak Farming Survey Project, WAPDA and Colorado State University, U.S.A.**

Methodology: The study was conducted on 40 watercourses commands located throughout Pakistan representing the major agro-climatic zones of the country. The discharge of the watercourses at the head and that available at teach from nakka was measured by installation of flumes. The conveyance efficiency was worked out by adding up the volume of water delivered in the watercourse command against that measured at inlet.

RESULT: **47 percent** water is lost in the watercourse from head to the farm gate.

STUDY **9) WATER DELIVERY EFFICIENCY ON MN-140 "UN-COMMAND WATERCOURSE"-JUNE, 1979.**

BY: **Jointly by Colorado State University, USA and Experts from Mona Reclamation Experimental Project, WAPDA.**

Methodology: The procedure followed was the measurement of losses by inflow-outflow method, where the cut-throat flumes were placed at the watercourse inlet and at the field nakkas throughout the warabundi system of the watercourse command. The water losses in the watercourse conveyance system have been calculated on the basis of difference between the volume of water. Delivered at the watercourse head and that reaches the field nakkas.

RESULT: It has been concluded through this comprehensive study that irrigation water to the tune of **58.4 percent** is lost during conveyance from watercourse inlet up to the field nakkas.

STUDY: **10) IMPACT OF WATERCOURSE IMPROVEMENT AT TUBEWELL NO. 56-R ON THE FARM ECONOMY-JUNE, 1980.**

BY: **Muhammad Siddique and Muhammad Aslam, Mona reclamation Experimental Project, WAPDA.**

Methodology: Survey on one watercourse bearing tube well No. MN-56-R was carried out during the study. The method of interviewing the farmers was followed and maximum factual information was obtained from twelve farmers at head, middle and tail. During interview the information especially concerned to water use efficiency in terms of time taken to irrigate one acre of land was collected from the farmers. It was observed that 85 percent more time is taken to irrigate one acre of land at the tail end than that of head reach.

Result: The water losses to the tune of **46 percent** have been worked out in this study.

STUDY: **11) OPERATION EVALUATION OF VILIAGE LEVEL IRRIGATION EFFICIENCY SYSTEMS, JUNE, 1980.**

BY: **Thomas J. Trout and S.A. Bowers, Assistant Professors of Colorado State University, USA with the assistance of USAID.**

Methodology: The methodology adopted for carrying out this study involved determination of total operational conveyance losses by measuring the inflow-outflow discharge of water on five village level watercourses systems located in District Sargodha and Faisalabad. This inflow outflow data was used to determine total operational conveyance losses by calculating the difference between the volume of water entering the irrigation fields during a complete rotation (warabundi).

Result: Total operational conveyance losses in the watercourse conveyance system have been worded out as **45 percent** on the basis of measurements made of five watercourses.

STUDY: 12) A PONDING STUDY OF FACTORS WHICH AFFECT WATERCOURSE WATER LOSSES-JUNE, 1980.

BY: Jointly by Colorado State University, USA and Mona Reclamation Experimental Project, WAPDA with the assistance of USAID.

Methodology: During the course of study, both the ponding as well as inflow-outflow measurement methods have been adopted for calculation of water losses on 18 water channels.

Result: The study concludes average conveyance losses of about **40 percent** in Pakistan's watercourses.

STUDY: 13) BENCH MARK SURVEY OF WATERCOURSE AT TUBEWELL NO. MN-22, NOVEMBER, 1980.

BY: G.M. Khokar et. Al, Mona Reclamation Experimental Project, WAPDA.

Methodology: The study was carried out on watercourse outlet No. 24030/TL, tube well No. NM-22, Distt. Sargodha. This methodology for determining the watercourse conveyance losses was based on the intensive interviewing of the farmers. The conclusion of the study reveals water losses to the extent of **50-60 percent** in the overall watercourse system.

STUDY: 14) WATERCOURSE LOSSES IN SAHIWAL TEHSIL. DECEMBER, 1981.

BY: On-Farm water Management Training Institute, Agriculture Department, Punjab.

Methodology: Seven survey teams were constituted to undertake the water loss measurements of the 66 randomly selected watercourses scattered throughout the Sahiwal Tehsil. The actual discharge measurements were made by adopting inflow-outflow method through installation of cut-throat flumes.

Result: Water conveyance losses in the watercourses were determined to be **32.20 percent** on an average in Tehsil Sahiwal.

STUDY: **15) MONITORING AND EVALUATION OF ON-FARM WATER MANAGEMENT PROGRAMME (PRE-IMPROVEMENT EVALUATION)-SEPTEMBER, 1984.**

BY: **Watercourse Monitoring & Evaluation Directorate, Planning Division, WAPDA.**

Methodology: The study was a pre-improvement evaluation of On-Farm Water Management Programme (IDA/IFAD assisted). A sample of 45 watercourses falling in different locations in NWFP, Sind and Punjab Provinces was selected for conducting the study. The procedure adopted was the measurement of delivery efficiency of the sample watercourse at head, middle and tail reaches by inflow-outflow method with the use of cut-throat flumes.

Result: Overall watercourse delivery losses **@ 45 percent** have been reported.

STUDY: **16) BASELINE SURVEY OF COMMAND WATER MANAGEMNT PROJECT, PUNJAB-NOVERMBER, 1987**

BY: **Punjab Economic Research Institute, Planning and Development Department, Lahore.**

Methodology: The main object of the study was to establish baseline data and information which could serve as basis for subsequent evaluation of performance of Command Water Management Project. During this baseline survey, the watercourse conveyance losses were also determined by adopting inflow-outflow measurements with the use of cut-throat flumes as well as broad-crested flumes. This comprehensive study was undertaken in the commands of 27 watercourses located in all the four sub-project units viz: Niaz beg, Shahkot, Vehari and Haroonabad.

Result: Water losses to the extent of **47-50 percent** have been reported on the watercourses in the Command Water Management Project areas.

STUDY: **17) TECHINCAL ECONOMIC FEASIBILITY REPORT FOR DHUSHAB SALINITY CONTOL AND RECLAMATION PROJECT DECEMBER, 1987.**

BY: **Copland & Co. , Consulting Economists to Asian Development Bank.**

Methodology: Inflow-Outflow measurements were conducted with cut-throat flumes installed at head, middle and tail sections. A sample of three watercourses were selected for inflow-outflow measurements. An additional three watercourses were **studied** on the basis of interview of the water-users, besides review of pertinent literature.

Result: The findings indicated deliver losses ranging from **38-62 percent** in the watercourses in Khushab District.

SUMMARY OF CONCLUSIONS/RECOMMENDATIONS OF VARIOUS TECHNICAL REPORTS, FEASIBILITY REPORTS, SRS, CONFERENCES AND SEMINARS REGARDING WATER LOSSES IN WATERCOURSES

<u>Sr. No.</u>	<u>Title</u>	<u>Prepared/Organized By</u>	<u>Conclusions/Recommendations</u>
1.	Review Report for On-Farm Water Management Project (World Bank Aided) -1984	Implementation and Progress Section, Planning and Development Division, Islamabad.	i) About 30% water is saved from watercourse improvement. ii) Expended Programme needs to be given priority.
2.	Monitoring & Evaluation of On-Farm Water Management Programme (IDA Assisted)-September 1984.	Planning Division WAPDA.	Pre-improvement overall delivery efficiency is 63% in sample watercourses.
3.	Socio-Economic Impact of Watercourse Improvement and Precision Land Levelling on Agriculture Production and Farmers' Income-November 1981	Economic Study Cell, Agriculture Department Punjab.	31-45% delivery losses in watercourses.
4.	On-Farm Water Management. An Approach to Modern Agriculture-November1977.	OFWM, Agriculture Department Punjab.	Watercourse delivery losses 40%
5.	Feasibility Report-Command Water Management Project-	WAPDA/UNDP	Average watercourse losses 40%

	August 1983.		
6.	Impact of watercourse Improvement on Farm Production-January 1979.	OFWM, Agriculture Department Punjab.	30-50% conveyance losses in watercourses.
7.	Evaluation of On-Farm Water Management Programme in Punjab-December 1985	Punjab Economic Res. Institute, Planning & Development Deptt. Punjab.	i) 30-50% water losses in watercourses. ii) Irrigation saving about 23% after watercourse improvement.
8.	Monitoring & Evaluation of On-Farm Water Management Programme (USAID Assisted).	Planning Division, WAPDA.	Water loss rate during conveyance in watercourse is 40-50%
9.	Monitoring & Evaluation of On-Farm Water Management Programme (USAID Assisted).	Planning Division, WAPDA.	Water losses rate during conveyance in watercourse is 40-45%
10.	Khushab salinity Control and Reclamation Report-Technical Economic Feasibility Report-December 1987.	Asian Development Bank Consultants.	Watercourse losses are very high and estimated at 43%
11.	S.A.R. of Command Water Management Project-April 1984.	World Bank.	Irrigation efficiency of watercourse system 40-50%
12.	Annual Research Plan 1985-86 Water Management Research and Training Programme for Rural Development-June 1985.	University of Agriculture Faisalabad.	Watercourse conveyance losses range from 40-47%
13.	Feasibility Study—Second On-Farm Water Management Project-August 1987.	Asian Development Bank Consultants.	Watercourse losses 44-47%
14.	Integrated Development of Watercourse Command Area-October 1986.	Mona Reclamation Experimental Project, WAPDA.	41% saving in irrigation time due to watercourse improvement.
15.	Watercourse Improvement Its Impact On-Farm Economy-October 1981.	Water Management Training Institute Agriculture Deptt.	33-65% watercourse losses.

		Punjab.	
16.	Appraisal of the Second On-Farm Water Management Project-Nov 1987.	Asian Development Bank.	Conveyance losses in watercourse from 31-67%.
17.	Feasibility study of On-Farm Water Management Project-August 1980.	Asian Development Bank Consultants.	Average 50% loss of water in project area.
18.	S.A.R. of On-Farm Water Management Project.	World Bank.	53% conveyance losses in watercourses.
19.	S.A.R. of Second On-Farm Water Management Project.	World Bank	53% Conveyance losses in watercourses.
20.	Report of the Committee on Water Resources Regarding Seventh Five Year Plan (1988-93) and perspective plan (1987-2000) Proposals-March 1987.	Planning and Development Division, Islamabad.	Delivery efficiency in watercourses average about 55% on unimproved watercourses.
21.	Project Benefit Monitoring and Evaluation Study of On-Farm Water Study of On-Farm Water Management Project (Asian Development Bank Funded)-October 1987.	Asian Development Bank Consultants/Ministry of food & Agriculture, Islamabad.	Overall conveyance efficiency is 55% on unimproved watercourses.

CATEGORIZATION OF THE STUDIES BASED UPON PERIOD OF RESEARCH STUDIES CARRIED OUT AROUND THE YEAR 1880

S. No.	Name of Study	Year	Water Losses	
1	Water Losses in Bari Doab Canal System. (\Punjab Irri. Diptt.)	1874	20-30%	Distys/Minors & Watercourses
2.	Water Losses in Irrigation Systems (By Kennedy)	1881	47%	Main canals & Branches 20%; Distys 6% & W/Cs 21%
3.	Seepage Losses on Bari Doab Canal System (By Kannedy)	1881	12.5%	

A total of three studies have been traced in the period around the year 1880. The first two confine the measurement of water losses to seepage and evaporation losses while the third one measured only seepage losses. In first and last study the researchers have taken into account the whole canal system for their measurements including main canals, distributaries, minors and watercourses. The second study have singled out losses in different parts of the water conveyance system and figured out that losses in watercourses are to the extent of 21%. The measurement of losses in these studies are confined to only two types i.e. seepage and evaporation. Therefore, these studies don't provide sufficient base to be counted for broader objectives i.e. total losses from the watercourses.

STUDIES CARRIED OUT AROUND THE YEAR 1935

<u>S. No.</u>	<u>Name of Study</u>	<u>Year</u>	<u>Water Losses</u>
1.	Water Losses in Canal System(By Blench)	1930-35	25%
2.	Water Losses in Canal System.	1935-36 to 1942	6.5%

Only two studies were found in this period. The methodology for measurement of water losses adopted in these studies were similar to those conducted in period around 1880. They have reported losses in the whole canal system for 6.5 to 25 percent i.e. on an average 16.33 percent. Due to limited scope of these studies they have also not been included for finalization of results for this report.

STUDIES CARRIED OUT AROUND THE YEAR 1965

<u>S. No.</u>	<u>Name of Study</u>	<u>Year</u>	<u>Water</u>
1.	A study of losses Through Watercourse and Means For observation. (Dr. Nazir Ahmed, Irrig. Res. Instt.)	1965	2.74% to 14.5%
2.	Indus Basin Studies (By Harza)	1968	10%
3.	Studies on Water Losses From Water Courses And Their Lining Measures. (Irrig. Res. Instt.)	1969 to 1972	8-19.8%

These three studies carried out around 1965 pointed out water losses ranging from 2.74 to 19.8 percent. However, simple average losses are to the extent of 10.84 percent which is nearly the same as Harza pointed out during 1968. It is, however, pointed out that these studies do not reflect the losses other than seepage and evaporation i.e. operational losses.

STUDIES CARRIED OUT AROUND AFTETR 1970

S. No.	Name of Study	Year	Water Losses
1.	Water Losses in Watercourses. (Hassan Ali, Dir. IRDP, Punjab)	1974-75	30-60 %
2.	Seepage Losses Un Lined and Lined Watercourses. (Irrig. Res. Instt)	1975-76%	4.96% to 82.04%
3.	Operational Conveyance Losses on Tubewell No. 81-R. (Thoma J. Trout et al. CSU and WAPDA)	1977	56%
4.	Watercourse Improvement in Pakistan, Pilot Project Study on Cooperation with Farmers at Tubewell No. 56-L. (CSU and MREP, WAPDA)	1977	56.66%
5.	Operational Irrigation Evaluations of three Watercourse Systems. (W/C Chak Farming Survey Proj., WAPDA & CSU)	1978	40-51%
6.	Farm Irrigation Constraints and Farmer's Responses Comprehensive Field Survey in Pakistan. (W/C Chak Farming Survey Proj., WAPDA & CSU)	1978	47%
7.	Water Delivery	1979	58.4%

	Efficiency On MN-140 “Un-Command Watercourse.” (CSU and MREP, WAPDA)		
8.	Impact of Watercourse 1980 Improvement at Tubewell No. 56-R on the Farm Economy. (M. Siddique & M. Aslam MREP, WAPDA)	1980	46%
9.	Operation Evaluation of village Level Irrigation efficiency Systems (Thomas J. Tout & S.A. Bowers, CSU)	1980	45%
10.	A Ponding Study of Factors which affect watercourse Water Losses. (CSU& MREP, WAPDA)	1980	50-60%
11.	Bench Mark Survey of 1980	1980	50 to 60%
12.	Watercourse Losses in Sahiwal Tehsil. (OFWM, Trg. Istt., Agri. Deptt. Punjab)	1981	33.20%
13.	Monitoring and Evaluation of On-Farm Water Management Programme (Pre- Improvement Evaluation). (W/C M& E Directorate, WAPDA)	1984	45%
14.	Baseline Survey of Command Water Management Project, Punjab. (Punjab, LHR.)	1987	47.54%

15.	Technical Economic Feasibility Report for Khushab Salinity Control and Reclamation Project. (Copland & Co. Consulting Economist to ADB)	1987	38-62%
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Since 1970, fifteen studies have been carried out by different agencies with different methodologies adopted for measurements of various types of losses from the watercourses. Some of the studies, however, accounted for seepage losses only (S. No. 2) while most of the studies have considered all types of losses. The overall average watercourse losses of these fifteen studies are 41.8 percent.

CATEGORIZATION OF THE STUDIES BASED UPON THE METHODS ADOPTED FOR MEASUREMENT OF WATER LOSSES.

I. MEASUREMENT OF SEEPAGE LOSSES ONLY THROUGH ANALYSIS OF WELL LOG DATA

<u>S. No</u>	<u>Name of Study</u>	<u>Year</u>	<u>Water Losses</u>
1.	Water Losses in Canal System (By Blench)	1930-35	25%-17.5%

II. MEASUREMENT OF SEEPAGE AND EVAPORATION LOSSES THROUGH PONDING TESTS

<u>S. No.</u>	<u>Name of Study</u>	<u>Year</u>	<u>Water Losses</u>	
1.	Water Losses in Bari Doab Canal System. (Punjab Irri. Deptt.)	1874	20-30%	Distys/Minors & Watercourses
2.	Water Losses on Bari Doab Canal System. (By Kennedy)	1881	47%	Main Canals & Branches 20%; Distys 6% & W/Cs 21%
3.	Seepage Losses on Bari Doab	1881	12.5% %	

	Canal System (By Kannedy)			
4.	Water Losses in Canal System.	1935-36 to 1942	6.5%	
5.	A Study of Losses Through Watercourse and Means for Conservation. (Dr. Nazir Ahmed, Irrig. Res. Instt.)	1965	2.74% to 14.5%	
6.	Indus Basin Studies	1968	10%	
7.	Studies on Water Losses From Water Courses And Their Lining Measures. (Irrig. Res. Instt.)	1969 to 1972	8-19.8%	
8.	Seepage Losses Un Lined and Lined Watercourses. (Irrig. Res. Instt)	1975-76	4.96 % to 82.04 %	
9.	A Ponding Study of Factors which affect Watercourse Water Losses. (CSU & MREP, WAPDA)	1980	40%	

III. MEASUREMENT OF WATER LOSSES BY IN-FLOW OUT-FLOW METHOD THROUGH FLUME INSTALLATION AT HEAD & TAIL OF SECTION.

<u>S. No.</u>	<u>Name of Study</u>	<u>Year</u>	<u>Water Losses</u>
1.	Water Losses in Watercourses. (Hassan Ali, Dir, IRDP, Punjab)	1974-75	30-60%
2.	Watercourse Improvement in Pakistan, Pilot Project Study on Co-operation with Farmers at Tubewell No. 56-L. (CSU and MREP, WAPDA)	1977	56-66%
3.	Water Delivery Efficiency on MN-140 "Un-Command Watercourse."	1979	58.4%
4.	Watercourse Losses in Sahiwal Tehsil. (OFWM, Trg. Istt.,	1981	33.20%

	Agri. Deptt. Punjab)		
5.	Monitoring and Evaluation of On-Farm Water Management Programme (Pre-Improvement Evaluation). (W/C M&E Directorate, WAPDA)	1984	45%
6.	Baseline Survey of Command Water Management Project, Punjab. (PERI, P& D Deptt., Punjab, LHR.	1987	47-54%
7.	Technical Economic Feasibility Report for Khushab Salinity Control and Reclamation Project. (Copland & Co. Consulting Economist to ADE)	1987	38-62%

IV. MEASUREMENT OF OPERATIONAL LOSSES BY COLLECTING IN -FLOW OUT-FLOW DATA FOR OMPLET WARABUNDI TURN

<u>S. No.</u>	<u>Name of Study</u>	<u>Year</u>	<u>Water Losses</u>
1.	Operational Conveyance Losses on Tubewell No. 81-R. (Thomas J. Trout et al. CSU and WAPDA)	1977	56%
2.	Operational Irrigation Evaluations of three Watercourse Systems. (W/C Chak Farming Survey Proj., WAPDA & CSU)	1978	40-51%
3.	Farm Irrigational	1980	47%

	Constraints and Farmer's Responses Comprehensive Field Survey in Pakistan. (W/C Chak Farming Survey Proj., WAPDA & CSU)		
4.	Operational Evaluation of Village Level Irrigation efficiency Systems (Thomas J. Trout & S.A. Bowers, CSU)	1980	45%

METHODS USED FOR MEASUREMENT OF WATERCOURSE LOSSES AND THEIR METITS / DEMERITS

The committee reviewed different studies and reports pertaining to irrigation water losses from the watercourses conducted since the construction of the present irrigation system. Various methods use for measurement and estimation of channel losses along with their merits and de-merits are described briefly in the following section.

Following five methods have been used for measurement of water losses in the studies reviewed by the committee.

1. Well log Data Analysis.

This technique was used for only one study referred in this report. The method involves monitoring of fluctuations in water table to asses the extent of seepage from the contributing channels. This method is rarely used for measurement of losses from particular channel as, many other factors are responsible for changes in the water table such as; rain, other channels in the area and soil geology etc. It generally indicates the direction of groundwater movement, and seepage rate of the soil.

This method only helps in understanding the groundwater conditions in terms of recharge and flow, and assessing seepage from large water reservoirs etc. Its use for calculation of losses from community watercourse losses is, however, limited due to the difficulties involved in isolating seepage from a particular channel in an irrigation system. Furthermore, the technique does not involve the determination of operational losses.

2. Ponding Method

This method is extensively used as a means for determining infiltration or seepage rates for different soil conditions. It involves filling a section of channel, closed at both ends, and determining the decrease in the volume of water over time. The loss rate is then expressed as discharge per unit distance (e.g. lps. Per 100 meters). The initial water level is usually higher than the operational level of the watercourse and measurements are made until it is well below the operational level. The resulting calculations reflect seepage losses only and can vary from one soil type to another. In addition, the seepage rates a direct function of the depth of water in the channel, a graphical representation must, therefore, be used to determine the loss rate at the operational level.

The primary advantage of this method is that accurate measurements of steady state seepage rates can be made for given soil characteristics. These losses do not represent the total losses occurring in the conveyance system under flowing conditions which involve different operating conditions. Another limitation involved in this method is the sample sections used tend to be relatively short and the results derived generally do not account for the variability in long watercourses, unless a large sample is taken. This method, also being limited in its utility, is not applicable to determine operational losses in the watercourses.

3. **Interview Techniques**

This method is generally used to evaluate socio-economic impact of the projects. The interview schedule is prepared to collect the required information. Generally interview schedule is pre-tested and necessary changes are made to improve its work ability in accordance with the objectives of the study. Qualitative information about pre and post or/and with and without project conditions is collected from the people through their interviews and the results are compared for assessment of change brought by the project. This technique is not generally used for technical evaluation of projects, however, a fairly good estimate can be made if the survey questionnaire is comprehensively designed and data is carefully collected.

4. **Steady State Inflow-outflow Measurements.**

The inflow-outflow method involves installation of water measuring devices such as flumes at the ends of a flowing channel. The losses are then taken as the difference in the measured flow rates and the loss rate per unit length is calculated as the flow loss divided by the distance between the measuring devices. The most commonly used device is the cut-throat flume, since it can be accurately calibrated under submerged conditions. This is necessary to prevent the rise in water level due to head-loss in the flume, as it will significantly alter the flow conditions.

The relative advantage of this method lies in the ability to monitor discharge rates under actual flowing conditions and can take into consideration losses which would otherwise be ignored in the ponding and well-log data methods. However, the man in assumption followed in this case is of

continuous steady state flow, which does not account for the many transient losses of the watercourse system when in actual operation.

5. Operational Inflow-Outflow Measurements.

This involves the inflow-outflow measurements of a watercourse while operating during a complete warabundi turn rotation. Flow measurements are made continuously with flumes installed at the watercourse head, the watercourse outlet and the field outlet. Consequently all the water entering the watercourse system and flowing into the fields during the complete warabundi is monitored. In this way the volume of water flowing, rather than just flow rates, is calculated and the additional transient losses such as initial infiltration, are determined.

This method is the most advanced and accurate of all water loss measurement techniques, since it is carried out under actual operating conditions and takes into account all the factors contributing to loss of water. It, however, requires appropriate expertise and know-how, especially in interpretation of flow hydrographs and their relevance to physical parameters.