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TRIP REPORT

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3860467

NAME G. L. Corey TITLE Water Management Specialist DIV./UNIT DS/AGR

PERIOD OF TRAVEL (inclusive dates) 15 March - 14 April, 1979

ITINERARY Rajasthan and N. Delhi, India
(Use attachment for details, including time schedule)

PURPOSE Participate on project development team for Rajasthan Medium Irrigation Project.

ORGANIZATIONS AND PERSONS CONTACTED: 000064
(Use attachment for details.)

See attached list

RESULTS/ACCOMPLISHMENTS:

1. Negotiated with Rajasthan Irrigation Dept. over technical aspects of proposed project.
2. Prepared, for GOI and USAID, a report describing team recommendations and 7 annexes describing technical details.

FOLLOW-UP ACTION REQUIRED:
(Indicate what, by whom, when.)
Preparation of final Project Paper by USAID/N. Delhi.

OTHER REMARKS:
(May include other information, observations, and impressions of general interest.)
See attached report.

Attachments:
(List) 1. List of People contacted
2. Trip report
3. The Medium Irrig. Project
4. Special Water Mgt. Studies
Water Mgt. Systems of Rajasthan

Distribution:
(List) DAA/FN/DS, TBabb
DS/PO, RSimpson
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ASIA/PD, BODell
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ASIA/TR/ARD, CMartin

AGF Form No. 2

CONTACTS MADE

USAID
John Withers, Director
Fletcher Riggs, Rural Development
Peter Bloom, Capital Development
Jeff Malick, Capital Development

CENTRAL GOVT. OF INDIA
Mrs. Shraff, Joint Sec. Irrigation
Mr. Padhye, Member Central Water Commission
Mr. Cana, Member Central Water Commision
Mr. J. K. Jain, Chairman, Central Ground Water Board

GOVT. OF RAJASTHAN
Mr. Bim Singh, Commissioner and Secretary of Irrigation
Mr. Kapoor, Chief Engineer Irrigation Dept.
Mr. Bivani Singh, Director Surveys and Investigations, Irrigation Department
Mr. Mukerji, Deputy Chief Engineer, Irrigation Department
Mr. Singhri, Special Assistant to Commissioner
Mr. Dhanda, Superintending Engineer Jaipur District
Mr. B. L. Sharma, Registrar Cooperatives
Mr. K. P. Sharma, Deputy Registrar Cooperatives
Mr. R. L. Verma, Chief Statistical Officer, Department of Agriculture
Several Executive and Asst. Engineers on the Morel and Juggar Projects

DS/AGR/TSWM:GLCorey:kb 5/7/79

TRIP REPORT
INDIA
March 15 - April 15, 1979
G. L. COREY

The purpose was to participate on a team study of the proposed Rejasthan Medium Irrigation Project. Other team members included Dean Peterson, Garret Argento, Fred Tileston, AID/W and Sherry Plunkett, USAID/Pakistan.

The team prepared a report with several technical annexes. These reports should suffice for all technical aspects of the Project Paper. The report with annexes has not been typed finally and is not included here. The Washington Based team members held a review of findings and recommendations during the last week in April. Attached is a copy of two small reports I prepared. They are included because they are in general valid for irrigation projects anywhere and may be of use elsewhere.

It was interesting and pleasing to me to learn of all the various developments in India in the water management area. It is obvious that the Central Government of India has recognized the problems and constraints past irrigation system management has placed on farmers. They are attempting various measures to improve the situation. Most of these include lining watercourses downstream closer to the farmer. Regardless of short term economics and regardless of seepage losses, in my opinion, these measures will provide much better control of the irrigation system and the water to each farm, and in the long term will be highly successful. I believe it to be a necessary step in such irrigation systems before good management of water and high production is achieved.

All of these efforts in India need to be watched closely because, if successful, they can be duplicated in many other LDC irrigation systems, and if they are not we should be in a position to know why.

Another important aspect of India's irrigation development is the so called small scale irrigation projects where small wells are utilized as supplemental irrigation. Such conjunctive use of water provides the farmer with a degree of freedom on when he can irrigate—not possible in a government operated irrigation system. Water management on the farm is always better in such systems.

It was a distinct pleasure and a learning experience for me to serve on this team.

DS/AGR/TSWM:GLCorey:kb 5/7/9

G.L. Corey
4-5-79

THE MEDIUM IRRIGATION PROJECT/ WATER MANAGEMENT SYSTEMS OF RAJASTHAN

It is common throughout much of Asia to design and build irrigation systems which cannot always supply sufficient water to meet crop needs if all of the area under the command is planted to crops. In other words the canal system is not large enough to deliver water, during peak demand periods, to all the land it serves. Therefore farmers adjust acreages planted in accordance with anticipated water supplies. Cropping intensities under any given canal system almost never reach 100 percent during any cropping season.

Such systemsare common and, in fact, logical where water and not land is the limiting resource. A feature of these systems is the fact that any water saved within the system can be effectively used because there is always land to put the saved water on. For example, the commonly used demand of one cusec per 200-250 acres would supply sufficient water for most crops if the entire irrigation system from reservoir to the crop were 100 percent efficient. Of course, no system approaches such efficiency so, in fact, the basic irrigation system is water short by design and planted acreage must be adjusted to meet available water.

Irrigation systems world-wide are notoriously inefficient due to several physical, design, and operational factors. An ideal system would supply water in precise quantities to plants as they use it. Since water is liquid and must be moved in a conduit it is not practical to

consider such efficiencies. The soil must be used as a reservoir to store water which is supplied to it at some reasonable interval. Usually the supply line is a quite complicated system whose various parts are operated and maintained by government institutions, farmers and/or groups of farmers. With evaporation, seepage, non beneficial use, and operational wastes all taking their toll it is not possible to expect any system, no matter how sophisticated, to operate at greater than 75 percent overall efficiency.

IRRIGATION SYSTEM DESCRIPTION

The Indian canal systems are designed and operated such that extensive distribution of water over the command area is accomplished with very little operator attention required. The system of main canals, minor canals, distributaries and water courses carry water from a storage source through the network of canals out to a water course where the farmers take the water and apply it to their fields. The system has no gates so when the canal system is operating there is water in all its various branches. Therefore, a properly designed and maintained canal system will deliver an equitable amount of water to each water course area and it will do it without an operator's attention because it is designed to occur automatically.

The water course area is the production end of the irrigation system. It is where the farms are and where the farmer becomes involved with the irrigation process. The water is delivered from the canal system to

each farm through the water course sub-system. Water is taken from the canal through a control structure which permits a specified fixed quantity to flow whenever there is water in the canal. The water course in turn delivers water to several farms. In Rajasthan the usual practice is to provide a water course outlet for each 40 hectares of land. This is an average value however and the watercourse area (chak) sizes seem to vary widely from as low as 4 hectares to more than 200 hectares. Obviously, then there are a varying number of farmers who irrigate from the common watercourse.

The current practice in Medium Irrigation projects in Rajasthan is for the Irrigation Department to construct the canal system down to and including the outlet structure which provides water to the watercourse or chak area. At that point, the farmers are responsible for constructing, operating, and maintaining the sub-system within the chak. The usual practice is for an intricate and rather extensive ditch system to be built along farm boundaries with each farmer then getting his water from the watercourse through his own field ditch system. When one considers that the basic field irrigation unit on the farm is usually no larger than one-eighth acre it is apparent that there is a very complicated, tortuous, and lengthy system of channels carrying water from the canal outlet to each irrigation plot.

On Medium Irrigation projects the division of water among farmers on the chak is left entirely to the farmers. They manage this in various

ways and usually divide the water among several watercourse branches and pass the water among themselves on some pre-arranged turn basis. Since it is their own responsibility there probably is no set pattern of distribution and use among farms and fields although there is obviously a high probability that inequitable distribution occurs.

On Major Irrigation projects, formal irrigation scheduling among farms is arranged for by the Irrigation Department. This system called "warabandi" schedules each farm with a specific time of use of all the water in the watercourse. The length of time per farm is dependent on the size of farm. It is arranged that all farms on a chak will receive water once each week at precisely the same time.

Prior to each winter irrigation season a Water Distribution Committee plans the operation of the irrigation system for the next irrigation season. This essentially involves decisions about when water flow will begin and when it will be closed for cleaning and when the season will end. At the time of this meeting, the Executive Engineer know the amount of water available in the reservoir so this information weighs heavily on how the system will operate during any given season. The Water Distribution Committee is chaired by the Executive Engineer, Irrigation Department. Other members include representatives from the Collector's office, the Legislative Assembly from concerned constituencies, the Heads of the Panchayats in the command area, and influential farmers.

IRRIGATION SYSTEM CONSTRAINTS

Any irrigation system has design and operational constraints which limit its effectiveness or lowers the efficiency of water use within it. Several such problems are apparent in the present Medium Irrigation schemes and some of them can be corrected or at least reduced.

Water Availability

The availability of water in the storage facility at the beginning of each irrigation season is a real constraint which is practically uncontrollable. Prolonged periods of drought can create shortages of water supply even in large reservoirs where carry-over storage space is available. It is possible in some cases to increase the volume of storage by increasing dam heights or building other storage or holding facilities within the irrigation system.

Design and Construction

There are design constraints which affect irrigation efficiency adversely. The fact that the entire canal and watercourse system is essentially ungated creates excessive use of water at certain periods of time. For example, it is not possible to provide water to only a portion of the command area; when water is flowing in the system it is flowing throughout all the system. At the beginning and ending of the cropping season unless all fields are planted and/or mature at the same time the irrigation demand will not be the same throughout all project areas. For example, a chak where

all wheat is ripe might be receiving water because some other chaks have unripe wheat which still need water. In this case the water delivered to the chak with ripe wheat has a negative value because it can only be a detriment in such cases.

The design and construction of outlet structures to each chak also provide some built in inefficiencies. Each chak area, size and shape, is defined by topography, farm size, and property boundaries. Therefore it is impossible to precisely "lay out" each chak to a pre-designed uniform size and shape. Therefore, chak sizes vary over a considerable range. The common construction practice on Medium Irrigation projects is to use a concrete pipe for the outlet structure. Since standard concrete pipes are available only in discrete sizes, it is not possible to apportion flow exactly according to the acreages under each chak. For example it appears that the 4-inch concrete pipe is used for chaks as small as 4 hectares and/or a large as 8-10 hectares. This obviously does not provide the same amount of water to each hectare even though some variations in flow can be achieved by altering the design hydraulic head operating across the outlet.

Water Losses

By far the greatest inefficiencies in Medium Irrigation schemes, however, occur through the losses encountered in getting the water from the reservoir to the root zone on a timely basis. There are several types of losses.

i) Evaporation and consumption use by non beneficial plants is not normally considered to be excessive. Some watercourse areas appear to be totally covered with weeds, however, most of them are edible and are grazed by livestock.

ii) Seepage losses are excessive on several existing Medium Irrigation schemes. Seepage occurs not only downward below canals and watercourses but a far greater amount in the case of watercourses occurs as horizontal seepage through the banks. This seepage not only is wasteful of water but it also creates waterlogging (high water tables) near the channel to the point that no crops can be grown in such areas. Examples of seepage problems are on the Morel Project where over most of the length of the main canal there is an area at least 100 feet wide on either side of the canal which cannot be farmed because the water table is essentially at the ground surface. The area occupied by watercourses on the same project are very wide for the same reason. The poorly constructed watercourses allow excessive horizontal seepage therefore creating the wide land of "wet" soil along each watercourses.

On the Juggar Project the canal seepage is so great that large areas (over 2000 hectares) have become totally waterlogged and out of production.

iii) Operational wastes also occur on each canal and chak system. These losses can be considerable and result from leaks at structures or

divisions on the watercourse, and the irrigation system operating when there is no demand for water. Examples include a watercourse outlet flowing into an area totally abandoned from waterlogging and a minor canal operating in an area where all the crops were being harvested. It carried water because there was irrigation need on the main canal system. Since there are practically no permanent structures on watercourses, at every junction farmers have to build earthen dams and, over time, excavation for soil to build the dams causes large areas to be inundated most of the time. Watercourse bifurcations practically become small ponds where much loss occurs.

Similarly the watercourse itself, having been constructed by farmers who have practically no knowledge of hydraulics, is usually underdesigned and exhibits many leaks throughout its length.

iv) Finally, there are significant water losses within the cropped fields or irrigation units. The basis method of irrigation is universally used and the farmer realizing that the irrigation units must be level has resorted to very small units because he has no facility to level larger units. Even so, each unit is not absolutely level and in filling it until the highest point is covered to a depth of 2 or 3 inches results in excessive water in all the lower areas of the unit. The time required to move water from one bunded unit to another is also an operational problem which causes waste.

Summary

All of these opportunities for losses and the design supply, and operationa constraints inherent in the system causes the farmer to reduce the acreage he plants in order to be assured that he will have adequate water. Undoubtedly he errs on the safe side so in actuality there is almost always ample water in any given system for the acreage actually in crop. The farmer undoubtedly also plants drouth tolerant crops along with those he wants to irrigate carefully as a hedge against short water. An example would be growing gram and wheat on the same farm. Gram does nicely with 2 irrigations while wheat is usually irrigated at least 4 times.

IMPROVEMENT TECHNOLOGIES

The design and operation of Medium Irrigation Schemes in Rajasthan can be greatly improved with increased agricultural production as the direct result. System constraints inefficiencies, and water losses not only cause excessive waste of precious water but much of this waste results in raising the water table to the point that the soil becomes salinized or in severe cases the land becomes completely waterlogged and must be abandoned. So there is a double-edged benefit in favor of

techniques to reduce losses. Three things should be kept in mind when considering improvements:

(a) There is presently excessive wastage of water within Medium Irrigation Projects due to seepage, operational, application, and other losses;

(b) There are built in inequities within the design and operation of MIPs i.e. chak outlets are not precisely designed to match acreages served and the system supplies water to each farmer on a time basis rather than on a demand basis.

(c) The design hydraulic capacity on all MIPs is not sufficient to permit all culturable land to be adequately irrigated during any particular crop season.

The following technologies would improve water management aspects on MIPs. In most cases each one would cause its own benefit in saved water and in several cases there are definite synergetic effects by combining several practices. In all cases, the benefits would derive from extending existing water supplies over more land; but no attempt is made to analyze the respective benefits and/or costs of each.

1. Increase the availability of water. - About the only way to increase the quantity of water available to an MIP is to increase storage capacity of the existing tank or build additional tanks upstream from the projects. In some cases, these activities can be economically justified.

2. Add flexibility to the water delivery system - Presently designed and operated MIP systems are quite rigid as regards water supply. There are several things that could be done to add flexibility. More gates could be provided on canal mains, minors and distributaries such that supplies could be varied among branches according to demand. Ultimately water-course outlets could be gated so that when no water was needed on a particular chak it could be closed. Such a gated system would also need a rapid and accurate communication system throughout so that as demands changed signals could rapidly trigger a change in the supply line. Other possibilities for flexibility could be a program of farmer owned tube or dug wells to be incorporated into the MIP irrigation system. This would give supply flexibility to farmers and also provide the possibility of lowering water tables in the proximity of canals. Another possibility would include small tanks or ponds within an MIP to provide temporary storage which can be used to draw from or add to according to demand variance.
3. Permanently line channels - Undoubtedly one of the most economic techniques to add water to the system is to line the channels where seepage is excessive. This is an activity which is widely practiced in India so standard designs and techniques are known. Aside from the usual benefits, lining also provides for much better and positive control of the water and maintenance costs are significantly reduced.

4. Improve the design and layout of watercourses - The distribution system below the canal outlet is designed and constructed by farmers. It is institutionally a "no mans land" where neither the Irrigation nor Agricultural Department offer assistance any yet it is actually the "working" end of the irrigation system. Certainly the Irrigation Department is capable of giving design, layout, and construction assistance to farmers. If this was done, much more effective channels could result from better alignment, better grades, and better hydraulic design. Many present watercourses are not at all well constructed, being very wide and leaky and thus occupy an excessively wide strip of land.

5. Install permanent structures on watercourses - The locations where watercourses branch and places where farmers withdraw water from the watercourse (nakas) presently have no structures whatsoever. These locations cause enormous quantities of wasted water especially when the user is located at the end of a watercourse and there are dozens of such leaky earth dams upstream from his point of use. Permanent (perferably concrete) structures in many irrigation systems worldwide have proven economically sound. Quality control on construction is not a severe problem because they can be prefabricated at a central location.

6. Install Adjusted Proportionate Modules (APMs) at all canal/watercourse outlets - The APM is a standardized outlet structure for watercourses. It is constructed to deliver precisely any given quantity of water. Therefore when they are used each chak area can

be issued precisely the same amount of water as every chak depending on acreage. In other words, installation of APMs instead of concrete pipes would eliminate the present inequitable distribution among chak areas.

7. Provide assistance to farmers with precise land leveling - Without doubt the basin method of irrigation is not efficient unless the basis is precisely dead level. It is also true that without instruments and mechanization it is practically impossible to level large basins precisely. The farmer therefore resorts to very small irrigation sub-units (basins). Most of those observed in Rajasthan were no larger than one-eighth acre. Moving water over the surface from basis to basin also adds to the inefficiency even if basins are level because of the time it takes to move water through the long and tortuous path to each basin. Land leveling programs however are major undertakings if done correctly. Proper machines (soil scrapers and land planes) are not available in significant numbers in India and a great deal of training is necessary for operators, engineers and farmers to make a land leveling program economically justifiable. Land leveling improperly accomplished offers no economic benefit and could be a detriment.

8. Improve the Warabandi - No one really knows how the farmers presently divide water among themselves in chak areas on MIPs. Undoubtedly, whatever exists, could be improved upon because inequities are almost sure to occur. The Irrigation Department is

empowered to establish a warabandi on any chak and, if the farmers so desire, its establishment should lead to better water management within the chak.

9. Improve control in the chak area - Establishment of the warabandi could be sufficient within itself to improve water use within a chak. However, it is likely that the establishment of an institution (person or committee) to inforce procedures, provide farmer/Irrigation Department linkage, report problems, and otherwise police the chak operation would go a long ways toward increasing the operational efficiency of the total irrigation system. The farmer/Irrigation Department linkage presently available appears to be next to inoperable.

10. Provide better drainage facilities - In many areas there are insufficient surface drains to remove rain or excess irrigation water before it causes damage to crops. Provision of adequate drainage in such cases is usually highly economic because the alternative is no crop and in fact a reduction of the value of the land to practically nil.

RECOMMENDATIONS

There are obviously funding and technical limits to the amount of technology and degree of sophistication which should be attempted in an improvement program. It seems reasonable and technically sound that the following should be adopted as components of the GOR/USAID Medium Irrigation Project.

1. Where economically and technically feasible tanks and/or reservoirs should be enlarged by raising the dam height.

2. Where seepage is sufficient to economically justify it, canals (mains and minors) should be lined down to the chak outlets.
3. Adjustable Proportionate Modules (APM) should be installed at all chak outlets.
4. Sufficient surface drainage should be supplied in all project areas to insure that irrigation waste water and rainfall does not accumulate in low areas and inundate agricultural lands.
5. On all projects (new, on-going, and modernization) the Irrigation Department should design and construct the watercourses down to a point where, on the overage, each 8 hectare area will be served with this improved watercourse. Since farm boundaries and topography restrict watercourse location this recommendation is not feasible for every 8 hectare block; but in no case should areas larger than 12 hectares be removed from the improved watercourse.
6. On all projects, the Irrigation Department should install permanent structures (division boxes and farm outlets) on all the watercourses it designs and builds.
7. On all <u>new</u> and <u>on-going</u> projects, the Irrigation Department should line the entire watercourse down to the level described in 5 above.

   Note: MIP project feasibility studies should include plans and estimates for the work to be accomplished under 5,6 and 7. The work can either be paid for from project funds or if GOR chooses the farmers can be charged for the work. However, if the farmers are

to pay, 75% of them should be signed up before the project is approved.

8. The Irrigation Department should assist with the operation of the newly constructed watercourse by providing a person who would, at least, on a weekly basis tour each watercourse to observe its operation, note its condition and report any problems to the next higher authority.

9. If after construction it is determined that warabandis are needed, the Irrigation Department should establish them on all water courses under the Project.

10. Special watercourse/water management studies should be conducted during the life of the project. These would be designed to provide information to GOR and GOI on the benefits of the various technologies and also feed back to the Irrigation Department relative to any operational problems developing within the project. The studies should be grant funded from the USAID funds and contracted to a research/evaluation agency. (Attached is a description of the study.)

G. L. Corey
4-9-1979

SPECIAL WATER MANAGEMENT STUDIES

A significant problem associated with implementation and adoption of any new technology is collection of valid information regarding the effect, positive or negative, the new technology is having on the users. Baseline information and later evaluations usually provide gross effects of the total project. However, careful monitoring before and during implementation can provide feed back which can continually serve to improve the process. Also in the final analysis data would be available to evaluate the true benefits of project components and implementation constraints can be identified. This is especially true of water management improvement projects where complicated institutional, procedural, and technical aspects operate in combination to produce the benefits.

The water management aspects of irrigation projects are often ignored in collection of baseline and evaluation data. This is not surprising because water is illusive, and , although easy to measure at a point in space and time, it is difficult to quantify over space and time. Nevertheless, it should not be ignored especially in India where the Government is initiating many programs to create more efficient delivery of water down to the farm level.

It is suggested that, as a part of the Rajasthan Medium Irrigation Project, a program of special water management studies

be initiated and carried out throughout the life of the project. This program should undoubtedly be grant funded from the AID portion of project funds and it should be contracted to a qualified Indian Institution. The Indian Institute of Management at Ahmedabad has exhibited good qualifications for such work in their "assessment of the Chambal project" and there undoubtedly are several others including the University at Udaipur, and other State and Federal research agencies.

The GOI and USAID might find it desireable to combine these studies with other projects such as the Gujarat Medium Irrigation Project. The World Bank assisted projects in Punjab and Rajasthan could also be included. In any case, there are many technologies, procedures, and techniques being tried to improve water management and it will be imperative to quantify implementation problems and specific benefits, if the processes are to be improved. Cost/benefit analyses in future projects will be dependent upon hard data from such studies.

Studies should be initiated to collect and analyze the following information on a continuing basis: water table levels, seepage losses, operational losses, application losses, cropping intensities, and institutional and farmer techniques used in management of the water. The organization doing these studies must work closely with the Evaluation Organization of the Department of Agriculture, and the Irrigation Department so that data on yields, fertilizer and pesticide use, extension, operation and maintenance constraints etc. can

be combined with the water management data to clearly identify problems and quantify effects.

Obviously the data will need to be collected on a sampling basis. It would be physically impossible to account for the disposal of all water over an entire project throughout an irrigation season. Much of the technique for measurement will have to be developed during the process of collection. Discussions of each set of measurements follows:

1. Water table levels - Water tables should be monitored in each Minor Irrigation Project. This does not mean a precise mapping of the levels throughout the project area; but a few well placed observation wells can be used to define major changes in the water tables. This is especially important in modernization schemes where the improvements should cause a lowering of the water table over time. In this case, the water table can be moniotred by augering observation holes at specific intervals of time.
2. Seepage Losses - Seepage losses should be measured by ponding method. Representative sections of lined and unlined channels could be used for sampling points. It would not be necessary to measure very many lined sections as they should all be similar.
3. Operational Losses - These losses are much more difficult to measure, yet they undoubtedly are much more

important on a watercourse area. Although sampling is the only way to accomplish these measurements over broad areas, it is suggested that the researchers start by fully monitoring one chak area. This means instrumenting the entire chak so that at any given time the disposition of the water going to that chak is known. This can best be done by Parshall Flumes or other sutiable measuring devices. Operation losses can only be determined by measuring water at different points within the chak area.

The experience gained by working in one chak area, at the outset, can be used to develop sampling techniques and as a location to train data takers. At least one chak area on each MIP should be completely monitored during one entire warabandi period. Information gathered during that 7-10 day period gives much information relative to the operational losses within the chak and also an indication of how the warabandi operates and the irrigation techniques used by the farmers. Without information gathered during a complete warabandi turn, it is difficult to explain just where and how losses are occuring.

With good data on one chak during one warabandi turn during each cropping season, supplemental sampling data can be added. There are several techniques to get reliable information which can be extended over larger areas if one has some complete data to correlate it with. An example of learning much about operational efficiency is to determine the chak outlet discharge and the cropped acreage. With this information, one needs only to

determine the total time water flows into the chak to get a gross irrigation efficiency for the chak. These types of measurements should be made on several chaks within each MIP as they can be done with very little manpower.

Operational losses are important enough to quantify and to understand how they are occuring, that the research group should undoubtedly have at least 3 teams of data collectors who collect such data on a full time basis.

4. Application Losses - These losses refer to the losses due to excess water being placed in an irrigated unit (field) during a given irrigation. To measure is simply a matter of estimating the soil moisture before irrigation, determining how much water is needed, and then measuring how much was applied.

   Sufficient samples of application efficiencies should be taken so that for each crop an average value for such losses is known. Experts disagree as to the amount of this loss. Some feel that due to the fact that there is no run-off in each field the efficiency is high but others feel that unlevel fields and the rigidness of the delivery system causes these efficiencies to be very low. Therefore measurement is important to learn the true picture.

5. Cropping Intensity - In order to finally summarize

data on water flow and disposition within a chak or a project one must know exactly the acreages of each crop. Therefore, cropping intensities will need to be determined each season. This may already be done routinely but specifically on the chaks where operational losses are being monitored it will be necessary to precisely know the acreage of each crop. It serves no purpose to measure the water and not quantify the use to which it was intended.

6. Analyses - Sufficient chak area water measurement data should be taken to make comparative analyses to determine the extent and marginal benefits among the various types of improvements being implemented. These include unimproved watercourses, unlined watercourses with permanent structures, and completely lined watercourses. These analyses should specifically define the economic viability of each alternative. Therefore, the data on water losses will need to be combined with information on the use to which the saved water was put and on the costs of implementing and maintaining each alternative. These analyses will be the most important product of the studies as they should provide sound recommendations on the best alternative for improving water management practices down to the farm and field level.