PERFORMANCE EVALUATION OF CHANDRA CANAL IRRIGATION PROJECT IN NEPAL

A DISSERTATION

submitted in partial fulfillment of the
requirements for the award of the degree
of
MASTER OF TECHNOLOGY
in
WATER RESOURCES DEVELOPMENT

By
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CANDIDATE'S DECLARATION

I hereby declare that the work which is presented in this Dissertation entitled, "**PERFORMANCE EVALUATION OF CHANDRA CANAL IRRIGATION PROJECT IN NEPAL**", in partial fulfilment of the requirement for the award of the degree of MASTER OF TECHNOLOGY IN WATER RESOURCES DEVELOPMENT (Civil), submitted in Water Resources Development Training Centre, Indian Institute of Technology, Roorkee, is an authentic record of my own work, carried out during the period from July 16th, 2001 to December 7th, 2001 under the supervision of **Prof. Raj Pal Singh**, Emeritus Fellow, WRDTC, and **Dr. Deepak Khare**, Associate Professor, WRDTC, Indian Institute of Technology, Roorkee (India).

The matter embodied in this dissertation has not been submitted by me for the award of any other degree or diploma.

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Dated : December , 2001

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December, 2001 **(BINOD KUMAR JHA)**

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ABBREVIATIONS AND NOTATIONS

ADB/N	Agricultural Development Bank / Nepal
ADO	Agricultural Development Office
APM	Adjustable Proportional Modules
ASCE	American Society of Civil Engineers
BOD	Biochemical Oxygen Demand
C.A	Catchment Area
C.C.A	Cultivable Command Area
CCIS	Chandra Canal Irrigation System
DAP	Di-Ammonium Phosphates
DIO	District Irrigation Office
DOI	Department of Irrigation
e_a	Field Application Efficiency
e_c	Conveyance Efficiency
EC	Electrical Conductivity
e_d	Distribution Efficiency
EO	Evaporation Losses
e_p	Overall or Project Efficiency
e_s	Irrigation System Efficiency
ETc	Crop Evapotranspiration
ETo	Reference Crop Evapotranspiration
e_u	Tertiary Unit Efficiency
FAO	Food and Agriculture Organization
FIR	Field Irrigation Requirement
G.C.A	Gross Command Area
GA	General Assembly
GIR	Gross Irrigation Requirement
H/W	Head Works
ha	Hectare

HH	Household
HMG/N	His Majesty's Government / Nepal
ICID	International Commission on Irrigation and Drainage
IIMI	International Irrigation Management Institute
ILRI	International Institute for Land Reclamation and Improvement
IQR	Interquartile Ratio
IR	Irrigation Requirement
K	Potassium
Kc	Crop Coefficient
m	Meter
M/C	Main Canal
MO&M	Management, Operation and Maintenance
MoP	Murate of Potash
N	Nitrogen
NIR	Net Irrigation Requirement
O&M	Operation and Maintenance
P	Phosphorous
RAP	Regional Office for Asia and the Pacific
RID	Royal Irrigation Department
RWS	Relative Water Supply
SFDP	Small Farmers Development Programme
Sq. Km	Square Kilometer
VC	Village Channel
WAI	Water Availability Index
WC	Water Course
WUA	Water Users' Association

SYNOPSIS

Performance evaluation is a subject of great interest in the irrigation sector. The call for performance assessment is most prevailing in the developing countries where it is strongly advocated by the external support agencies who see it as an important tool for instilling more service orientation and accountability in the public organizations which dominate the irrigation sector in most of these countries.

The issue of performance in irrigation is of increasing concern to investors, managers and water users alike. Performance is viewed as having two dimensions: the attainment of a specified set of relevant objectives, and doing so with efficient resource use.

Chandra Canal Irrigation System is the oldest public irrigation system in Nepal. This system was constructed between 1923-1927 A. D. It was designed to irrigate 9900 hectares of land during monsoon season.

The "Performance Evaluation of Chandra Canal Irrigation Project in Nepal" has been undertaken in the command area of the project to examine whether the project is servicing its purpose or not using the relevant data on the physical system, cropping system, socio-economic system and operation and maintenance system.

This study may provide the necessary information about the present status of the project and it can as well be helpful for the further improvements of the system.

INTRODUCTION

1.1 GENERAL

Despite continuous increase in global food production during this century, a number of developing countries are facing chronic food insecurity. Increased and more reliable food production generated close to where it is consumed, in an important pre-requisite for household and national food security. However, a number of developing countries have failed to achieve steady progress and some of them have even suffered setbacks.

Humanity today is faced with stark reality that some 800 million people in developing countries, about 20 percent of their total population, suffer from chronic malnutrition.

It is now well recognized that poverty and malnutrition are inter-related. Failure to alleviate poverty has led to hunger and malnutrition. At the same time, in developing countries, increasing agricultural production is a major means of overcoming poverty. Most of the world's poor live in rural areas and it is here that the most intractable poverty problems are to be found.

During this century there has been a dramatic increase in the are irrigated. Most of this expansion has occurred through capital investments in infrastructure for the capture, storage and distribution of water, and in the conversion of rein-fed areas into irrigable land. This type of development has created a number of groups who have a direct concern on the performance of the irrigation system; investors, policymakers, planners, managers and users. Each of these groups has to be able to assess the effectiveness of the systems in which it has a stake. To do this these groups require not only basic information about the inputs and outputs of the system, but also a framework within which this information can be processed and evaluated. This frame work has to be capable of allowing assessment of the performance in individual systems and permit comparisons with other systems and even other sectors of the economy to determine the relative utility of the initial investments and operational inputs.

1.2 DIFINITIONS OF PERFORMANCE AND PERFORMANCE INDICATORS

Abernethy (1989) defines **performance** as: the performance of a system as represented by its measured levels of achievement in terms of one, or several, parameters which are chosen as indicators of the system's goals

Performance indicators: do more than measure the value of a particular item such as yield or canal discharge. They have to include a measure of quality as well as of quantity, and be accompanied by appropriate standards or permissible tolerances. If the value of the indicator falls outside a particular range of values then performance is presumed to be unsatisfactory.

1.3 OBJECTIVE AND TARGET

Objective: An objective is a broad goal that reflects the overall purpose of the irrigation system or the sector within which the irrigation system falls. Typically, objectives are not precise, exemplified by such purposes as crop diversification, equity, adequacy, or sustainability.

Target: A target is a specific value of something that can be measured: it provides operational staff with information on the desired conditions that should be met if the objective is to be fulfilled.

1.4 OBJECTIVE OF PERFORMANCE

The performance of a irrigation system can only be measured in terms of its objective. Irrigation schemes have multiple and sometimes-conflicting objectives and perception about performance will vary depending upon the value attached to different goals by person or organization making the assessment. These are different aspects of project performance, which may relate to financial, institutional, design construction and operation of the system.

In engineering terms, the ultimate objectives of performance assessment may be given as follows:

- Profitable land use based on high crop yields, wide crop choice and good Conditions for timely and efficient farm operations;
- Sustainable land use and environmental protection;

- Contribution to the regional/national socio-economic development.

It would generally be difficult, often impossible for irrigation, to assess performance on the basis of these ultimate objectives as they are generally not readily measurable and are influenced also by many non-irrigation factors.

1.5 IRRIGATION SYSTEMS IN ASIA

The role of irrigation in increasing agricultural production is well recognized. About 240 million hectares or 17% of the world's croplands are irrigated. This land produces one third of the world's food. At present, almost three-quarters of the world's irrigated area is in developing countries. Increased irrigated area and the technological innovations brought along with the Green revolution Asia to achieve food self-sufficiency.

Since the 1950s, the total irrigated area in the world expanded rapidly. Between 1961 and 1990, the area under irrigation increase by almost 100 million hectares. The annual growth rate of irrigated area exceeded 2% during the 1960s and 1970s. Today, the growth rate worldwide has slowed has slowed down to a moderate 0.8%. Between 1961 and 1990, the irrigated area in Asia expanded by 70 million hectares.

All the countries of the region have irrigation systems varying in type and extent. The categorization of the irrigation projects varies from country to country. The projects are categorized as large, medium, or small scale depending upon the command area, the project costs, the storage capacity of reservoirs developed, or sometimes the irrigation water sources.

The performance of irrigation systems, however, has become a subject of considerable criticism. The relatively larger systems have been subjected to more criticism, while the smaller ones appear to have performed better. Adverse performance parameters in the large irrigation systems include economic factors like inadequate returns from investments, low water-use efficiencies, social factors like failing to achieve equitable water distribution, and environmental factors like soil salinization, contamination of groundwater resources, and adverse public health effects.

1.6 CONSTRAINTS IN IRRIGATION

Many irrigated areas have a lower productivity than originally planned due to low cropping intensities and due to inefficient water use which reduces the originally designed command area. Furthermore part of the irrigated area goes out of production due to lack of maintenance of problems of waterlogging and salinity. It is estimated that at present 10 to 15% of the irrigated area, mainly in arid region, is to some extent degraded due to waterlogging or salinization. The shortcoming in many irrigation systems requires additional investment in forms of costly rehabilitation and drainage projects, necessary to sustain productivity under irrigation.

The introduction of irrigation in particular to new areas may have other negative effects notably on the environment. These are often overlooked in the planning stage and include: large scale clearing of natural lands, pollution from high fertilizer and pesticide use, introduction and spread of water-borne diseases and environmental degradation of surrounding land due to increases population in the irrigated areas (fuel, wood, overgrazing). As the productivity of many irrigation schemes is disappointing, the financial viability of the irrigation infrastructure is threatening the sustainability of many schemes. Public schemes often rely on limited government funds for operation and maintenance, while revenues from taxing farmers for irrigation water prove very difficult to impose and to collect.

These problems and high costs in new irrigation development have led to a growing concern both from government and financial institutes, and as a consequence there is a tendency to overscrutinize new investments in irrigation.

1.7 IRRIGATION PERFORMANCE OF EXISITNG SYSTEMS

When the irrigation systems were planned and constructed; the main goal was to deliver water at the farm level. Many of the problems that later arose were not fully visualized nor appreciated. The main causes for the disappointing performance of the irrigation systems in the Asian region could be listed as follows:

- under utilization of the available irrigation potential,
- non-responsive performance of the irrigation administration,
- poor system management, and
- inadequate maintenance.

In some large irrigation systems, the available irrigation potential is not being used for reasons like farmers attitudes, lack of on-farm development etc. Most of the irrigation systems were constructed by agencies, which also continued to manage the systems. The engineers who constructed the projects also continued to manage the systems. The engineers who were responsible for construction did not have the aptitude or in some cases the experience required for the management of the system. The irrigation system management in some cases could not come close to the farmers and be responsive to their needs. Required drainage facilities could not be established and also adequate budgetary provisions were not available for the maintenance of the system.

Irrigation systems operated under these constraints, developed over a period of time, several adverse conditions effecting the whole system operation. Some of these can be listed as follows:

- deterioration of structures both at the main system level and at on-farm level;
- silting of main, secondary and tertiary canals;
- aquatic weeds in the canal system;
- rise in water tables creating waterlogging and salinity situation; and
- clogging of open drains due to siltation and aquatic weeds.

In addition to these structural factors, inequitable and untimely water deliveries affected the overall productivity of the systems.

1.8 OBJECTIVE AND SCOPE OF THE STUDY

The exploitation and utilization of water for irrigation require that there are periodic evaluation of its utility and efficiency of use. This concern with performance within the irrigation sector is increasing as pressure grows on water resources in all parts of the world, and as concerns increase regarding the sustainability of irrigated agriculture systems. Any enterprise requires feedback on the management of resources and the end result in terms of increased output.

There is need of not only basic information about the input and output of system, but also a frame-work within which this information can be processed and evaluated. This frame work has to be capable of allowing assessment of performance in individual systems and permit comparisons with its defined objective or global standards.

In view of the importance of the performance evaluation of project, the present work is undertaken with following objectives:

i) To study the Chandra Canal Irrigation System of Nepal which includes the entire physical system,

ii) To study the cropping pattern of the study area,

iii) To study the agricultural and social aspects,

iv) To study the operation and maintenance, and

v) Finally to conduct the performance evaluation of the project.

PERFORMANCE INDICATORS

2.1 GENERAL

During earlier work on performance assessment (Murray – Rust & Snellen 1993; Bos et al., 1993) three levels of organization, having different objectives, were distinguished:

- irrigation and drainage system level,
- agency level, and
- planning and policy environment at sector level.

Despite the differences in objective sets for each level of organization, a common definition of performance was proposed:

- the degree to which an organization's products and services respond to the needs of their customers or users, and
- the efficiency with which the organization uses the resources at its disposal.

Recognizing that there are different customers or users, makes it easier to distinguish between objectives of such diverse groups as donors, politicians, system managers and farmers.

2.2 THE PROCESS OF PERFORMANCE ASSESSMENT

The process of performance assessment hinges around the capacity of the managers of an organization to answer two simple questions:

- "Am I doing things right?", which asks whether the intended level of service (that has been set and agreed upon) is being achieved. This is the basis for good operational performance.
- "Am I doing the right thing?", a question that aims at finding out whether the wider objectives are being fulfilled, and fulfilled efficiently. The latter is part of the process of assessment of strategic performance.

Operational performance is concerned with the routine implementation of the agreed (or preset) level of service. It specifically measures the extent to which intensions are being met at any moment in time, and thus requires that actual inputs and outputs are measured on a regular basis.

Strategic performance is a longer term activity that assesses the extent to which all available resources have been utilized to achieve the agreed service level efficiently, and weather achieving this service also meets the broader set of objectives. Available resources in this context refers not merely to financial resources: it also covers the natural resource base and the human resources provided to operate, maintenance and manage irrigation systems. Strategic management involves not only the system manager, but also higher level staff in agencies and at national planning and policy level.

At all levels, performance must be assessed using a combination of targets. Each of these targets have an acceptable range of values around that target. Neither targets nor the range are likely to be uniform.

Targets reflect the objectives of managers at different levels. A system manager is most likely to base targets on the outcome of the annual or seasonal planning process. Higher level agency managers are more likely to use design criteria as their targets, because these were the basis for initial investment decisions. Policy makers concerned with very broad objectives may think in terms of potential performance with respect to the use of natural resources.

2.3 THE AGREED SERVICE LEVEL

The intended service (or product) being delivered by an (irrigation) organization to its customers (water users) depends on the 'agreed service level'.

$$\text{Agreed Service Level} = \frac{\text{Intended Level of Delivered Resource}}{\text{Required Level of Considered Resource}}$$

For each of the considered disciplines, the agreed service level quantifies the intended value of a considered sub-set of parameters. It may differ from month to month. It is recommended to define the agreed service level for all sub-command areas on a monthly basis.

If the 'intended level of delivered resource' cannot be determined, there will be no yardstic against which performance can be measured ! As such, the description of 'the agreed service level' has priority. The agreed service level does not remain constant in time. It is due to be revised with a change in the availability of resources (eg. Water, energy, manpower, funds).

2.4 GENERAL FEATURES OF PERFORMANCE INDICATORS

A true performance indicator includes both an actual value and an intended value that enables the assessment of the amount of deviation. It further should contain information that allows the manager to determine if the deviation is acceptable. It is therefore desirable wherever possible to express indicators in the form of a ratio of the actually measured versus the intended situation. Hence.

$$\text{Performance Indicator Level} = \frac{\text{Actual Level of Delivered Resource}}{\text{Intended Level of Considered Resource}}$$

It is important to ensure that the indicators selected for a system will describe performance in respect of the objectives established for that system. It is this process that links the use of indicators to the overall performance assessment framework (Bos et al. 1993). Failure to take this into account may lead to managers being assessed in terms of activities that were not included in their initial brief.

In general, it is not recommended to use all described indicators under all circumstances. The number of indicators will depend upon the level of detail with which we want to quantify performance and on the number of disciplines.

2.4.1 Water Balance Indicators

Water balance performance indicators are concerned with the assessment of the water supply function of the irrigation system. They cover the volumetric component that is primarily concerned with matching water supplies to irrigation water demand, as well as the rather more subjective concept of reliability that may affect the users' capacity to manage water efficiently, and the socially oriented aspects of equity'. These three aspects all represent facets of the concept of the level of service being provided to water users.

(a) Water Delivery Performance

The simplest, and yet probably the most important, hydraulic performance indicator is

$$\text{Water Delivery Performance} = \frac{\text{Actually Delivered Volume of Water}}{\text{Intedned Volume of Delivered Water}}$$

This measure enables a manager to determine the extent to which water is delivered as intended during a selected period (may range from second to year) and at any location in the system. The primary utility of the water delivery performance ratio is, that it allows for checking of whether the flow at any location in the system is more or less than intended. Over a sufficiently long time frame (e.g., monthly, or over three or four rotational time periods) it can be assumed that; if the water delivery performance ratio is close to unity, then the management inputs must be effective.

(b) Water Balance Ratios

In general, the water balance indicators deal with the volume of water delivered within a set time period (in m^3/period), rather than the instantaneous flow rate (in m^3/s). the ratios quantify components of the water balance in a spatial context over a specific time period.

(c) Irrigation Efficiency

Bos and Nugteren divide the overall project efficiency into various components so that the efficiencies associated with different components of the water delivery system – conveyance, distribution, and field application – can be separately stated. The following terms are used in the definitions:

V_c = Volume of water diverted or pumped from river,

V_d = Volume of water delivered to the distribution system.

V_1 = Inflow from other sources.

V_2 = Non-irrigation deliveries from the conveyance system,

V_3 = Non-irrigation deliveries from the distributary system,

V_f = Volume of water delivered to the fields, and

V_m = Volume of water needed, and made available, for evapotranspiration by the crop to avoid undesirable water stress in the plants throughout the growing cycle.

(i) Conveyance Efficiency (e_c)

Conveyance is the movement of water from its source through the main and lateral or secondary canals or conduits to the tertiary off-take. The conveyance efficiency e_c is the efficiency of canal and conduit networks from the reservoir, river diversion, or pumping station to the off-take of the distribution system. It can be expressed as:

$$e_c = \frac{V_d + V_2}{V_c + V_1}$$

(ii) Distribution Efficiency (e_d)

Distribution is the movement of water through the tertiary (distributary) and quaternary (farm) canals or conduits to the field inlet. Distribution efficiency e_d is the efficiency of the water distribution canals and conduits supplying water from the conveyance network to individual fields. It can be expressed as:

$$e_d = \frac{V_f + V_3}{V_d}$$

(iii) Field Application Efficiency (e_a)

Field application is the movement of water from the field inlet to the crop. The field application efficiency e_a is the relationship between the quantity of water furnished at the field inlet and the quantity of water needed to maintain soil moisture at the level required by the crop. This is an indirect way of establishing the field application efficiency, since the water used by evapotranspiration of a crop equals the amount of water needed to maintain the required soil moisture for the crop. The field application efficiency can be expressed as :

$$e_a = \frac{V_m}{V_f} = \frac{ET_p - P_e}{V_f}$$

where,

ETp = evapotranspiration by the irrigated crops, and

P_e = effective precipitation.

(iv) Tertiary Unit Efficiency (e_u)

The tertiary unit efficiency e_u is the combined efficiency of the water distribution system and of the water application process. In other words, it is the efficiency with which water is distributed and consumptively used within the tertiary unit. The tertiary unit efficiency can be expressed as:

$$e_u = \frac{V_m + V_3}{V_d}$$

If the non-irrigation deliveries are insignificant compared with the volume of water delivered to maintain soil moisture at the required level for the crop, we may write :

$$e_u = e_d \cdot e_a$$

The tertiary unit efficiency expresses the efficiency of water use downstream of the point where the control of water is turned over from the water supply organization to the farmers.

(v) Irrigation System Efficiency (e_s)

The irrigation system efficiency e_s is the combined efficiency of the system of water conveyance and distribution.

$$e_s = \frac{V_f + V_2 + V_3}{V_e + V_1}$$

If the non-irrigation deliveries are insignificant compared with the volume of water delivered to the fields, which is often true, we may write.

$$e_s = e_c \cdot e_d.$$

(vi) Overall Or Project Efficiency (e_p)

The separate assessments of conveyance, distribution, and field application efficiencies will indicate if and where remedial measures are required to improve the efficiency of water use in the project as a whole. The data used to assess the separate efficiencies can also be used to assess a project's overall irrigation efficiency.

The overall (or project) efficiency can be expressed as :

$$e_p = \frac{V_m + V_2 + V_3}{V_e + V_1}$$

This volume represents the efficiency of the entire operation between river diversion or source of water and the root zone of crops. If the volumes of V_1, V_2 and V_3 are negligible compared with V_c and V_m, which is often true, the following relation holds.

$$e_p = e_c \cdot e_d \cdot e_a$$

Various efficiencies of irrigation water use are shown in Figure 2.1.

(d) Equity and Dependability

The word, equity and equality as defined and explained in the Spanish context are described as follows:

Equity means fair distribution of water to the water users. The mechanism for determining equity comes through the water allocation process. The canal officers, wherever they have discretionary authority, should be guided by a general sense of fairness, apart from specific provisions of the ordinances. The design of the system has to be compatible with the water allocation principle: if it is not, then it is unlikely, if not impossible, to achieve the equity principle implicit in the water allocation plan.

Equality: The irrigation schemes can be viewed for the purpose of ensuring that all members enjoy the benefits of irrigation water with equality and equity. Equality in reference to the quantity of water provided to farmers means proportionate equality, whereas absolute equality is meant for one man, one vote. Equality in water allocation process is intended to guarantee that all users are favoured equally in case of abundance and that all suffer equally in drought; but equal in this sense means in fixed proportion to the relative needs of crops in the farms and service areas of the served laterals and canals.

The pattern in which water is delivered over time, is directly related to the overall efficiency (or ratio) of the delivered water, and hence has a direct impact on crop production. The rationale for this is that water users may apply more irrigation water if there is an unpredictable variation in volume or timing of delivered water, and they may not use other inputs such as fertilizer in optimal quantities if they are more concerned with crop survival than crop production.

The primary indicators proposed for use in measuring dependability of water deliveries are concerned with the duration of water delivery compared to the plan and the time between deliveries compared to the plan.

$$\text{Dependability of Duration} = \frac{\text{Actual Duration of Water Delivery}}{\text{Intended Duration of Water Delivery}}$$

and

$$\text{Dependability of Irrigation Interval} = \frac{\text{Actual Irrigation Interval}}{\text{Intended Irrigation Interval}}$$

In addition to dependability in terms of timing, it is strongly recommended that the predictability of discharge or water level be included in this part of the assessment. For many irrigation activities the flow rate must be near the intended flow rate for water use to be effective.

2.4.2 Environmental Sustainability and Drainage

2.4.2.1 Sustainability of Irrigation

Aspects of physical sustainability that can be affected by irrigation managers relate primarily to over-or under supply of irrigation water leading to water logging or salinity. The simplest measure of sustainability is therefore :

$$\text{Sustainability of Irrigable Area} = \frac{\text{Current Irrigable Area}}{\text{Initial Total Irrigable Area}}$$

The initial area refers to the total irrigable area in the design of the system or in the latest rehabilitation to specifically refer to water logged or saline areas as a percentage of the total irrigable area.

2.4.2.2 Depth to Groundwater

The sustainability of irrigation is determined by the ratio

$$\text{Relative Groundwater Depth} = \frac{\text{Actual Groundwater Depth}}{\text{Critical Groundwater Depth}}$$

The critical groundwater depth mostly depends on the (effective rooting depth) of the crop. If the actual ground water depth is near the critical depth, the time interval between readings of the ratio should be near one month. One year is suitable for most other purposes.

2.4.2.3 Pollution of Water

Within the context of (irrigation) water performance assessment we distinguish between the consumption and the use of water

- If water is consumed by (the crop) it leaves the considered part of the system, and cannot be consumed or reused in an other part of the considered system. For example, if the field application ratio (efficiency) for a considered field is 56% , this means that 56% of the applied water is evapo-transpirated and that the other 44% either becomes surface run-off or recharges the aquifer. Part of this 44% may have been used to serve other purposes, e.g. simplify farm management, leaching etc.

- During the irrigation process water can be used for a variety of other purposes. These may be directly related with irrigation (facilitate management silt flushing, leaching, seepage, etc.), or be related with other user groups (energy production, shipping, urban and industrial use, recreation, etc.). As a general rule we may assume that the quality of water decreases upon its use. The indicators, therefore quantify the effect of user activities on water quality.

2.4.2.4 Salinity

The relative change of salinity at considered locations within the irrigated area can be quantified by:

$$\text{Relative Electrical Conductivity (EC) Ratio} = \frac{\text{Actual EC Value}}{\text{Critical EC Value}}$$

The critical EC - value depends on the salt tolerance of the irrigated crops. If we want to quantify the effect of a certain user (or group of users) on the salinity of the irrigation water in the canal system, it is advisable to measure EC upstream and downstream of the user.

2.4.2.5 Organic Matter

The (rate of change of the) concentration of organic matter in irrigation water mainly results from two sources;

- The natural fall of leaves and branches from frees and vegetation along the canal, and
- The disposal of trash by humans along the canal.

It is recommended to measure total dissolved organic matter (vol. %), floating matter (vol. %), colour and smell. An equivalent ratio as shown for the EC value should be used.

2.4.2.6 Chemicals

The major sources of chemical pollution may have either a non-agricultural or an agricultural source; urban and industrial sewage water flowing into the canal, and pesticides plus fertilizer leached from the root zone.

Mainly the concentration of nitrates (NC_3^-) and phosphorous (P) in meq/l are measured. Measurement of other concentrations may be needed for specific locations. Equivalent ratios as shown for the EC value should be used.

2.4.3 Maintenance Indicators

Maintenance is designed to accomplish three main purposes : safety, keeping canals in sufficiently good condition to minimize losses and sustain designed discharge - head relationships, and keeping water control infrastructure in working condition.

2.4.3.1 Sustainability of Head - Discharge Relationship

Indicators that give practical information on the sustainability of the intended head - discharge relationship of flow division structures are :

The effect of this ratio on the water distribution depends on the hydraulic flexibility of the division structures.

2.4.3.2 Maintenance Cost

The cost of maintenance depends on the volume of silt and weeds that must be removed from the canal and by the size of the canal. An indicator that can be used to quantify this cost per unit (metre) length of canal is

$$\text{Maintenance Area Ratio} = \frac{\text{Volume of (Silt + Weed) per Unit Length}}{\text{Constructed Area of Canal}}$$

To establish the cost of canal and conduit cleaning, information should be available on the:

- Length of irrigation (and drainage) canals and conduits per unit irrigated or drained area (e.g. in m/ha) and

- Maintenance cost per meter canal or conduit.

To quantify the maintenance performance; hence, to assess the extent to which control structures can be operated as intended, the following ratio will be used:

$$\text{Effectivity of Infrastructure} = \frac{\text{Number of Functioning Structures}}{\text{Total Number of Structures}}$$

This approach immediately indicates the extent to which the manager is able to control water. For the analysis to be effective, however, it must divide structures up into their hierarchies importance (main, lateral, tertiary and quaternary) and the analysis completed for each level.

2.4.4 Economic, Social and Environmental

2.4.4.1 Economic Viability

Each of the primary participants in the irrigation sector, i.e., planners and policy makers, agency personnel and farmers, has a different perspective on what is meant by economic performance. Each therefore requires a separate set of indicators that reflects these different objectives. The system manager is most likely to be concerned with the financial resources available at system level and the source of those funds, possibly rather less concerned with the overall profitability of agriculture, and least concerned about the overall profitability of the irrigation project that created the system (unless it is owned by a private firm in which he is a share holder).

2.4.4.2 Financial Viability of Irrigation Systems

One set of indicators concerns with efforts to raise revenues from water users that help support management, operation and maintenance (O&M) costs, and often some or all of the capital costs of individual irrigation systems. The first of these indicators describes the overall financial viability of the system:

$$\text{Total Financial Viability} = \frac{\text{Actual O \& M + Allocation}}{\text{Total O \& M Requirements}}$$

This indicator says nothing about where the Management, Operation and Maintenance (MO&M) allocation comes from: it may be from Central Government or from user fees. A modified indicator is proposed that looks at the extent to which a system generates sufficient income to be self-supporting:

$$\text{Financial Self Sufficient} = \frac{\text{Annual Income}}{\text{Total O \& M Requirement}}$$

To quantify the effectiveness of the irrigation agency with respect to the actual delivery of water (operation) and the maintenance of the canals (or pipelines) and related structures, the O & M fraction is used.

$$\text{O \& M Faction} = \frac{\text{Cost of Operation} + \text{Maintenance}}{\text{Total Agency Budget}}$$

This indicator deals with the salaries involved with the actual operation (gate men, etc.) plus maintenance cost and minor investments in the system (replacement of canal or pipe sections and of damaged structures).

In many irrigated areas, water charges are collected from farmers. The fraction of the annual fees due to be paid to the WUA and (or) the irrigation district is an important indicator for level of acceptance of irrigation water delivery as a (public) service to the customers (farmers). The indicator is defined as:

$$\text{Fee Collection Performance} = \frac{\text{Irrigation Fees Collected}}{\text{Irrigation Fees Due}}$$

The ratio should be quantified for all Water Users Associations in the considered irrigated area.

2.4.4.3 Profitability of Irrigated Agriculture

Two indicators are proposed that address different aspects : profitability in terms of land, and profitability in terms of water delivered.

$$\text{Yield Vs Water Cost Ratio} = \frac{\text{Added Value of Crop}}{\text{Cost Applied Irrigation Water}}$$

$$\text{Yield Vs Water Supply Ratio} = \frac{\text{Added Mass of Marketable Crop}}{\text{Mass of Irrigation Water Delivered}}$$

From the perspective of the farmer the (socio-) economics of irrigation can also be quantified by the relative cost of irrigation water:

$$\text{Relative Water Cost} = \frac{\text{Total Cost of Irrigation Water}}{\text{Total Production Cost of Major Crop}}$$

The total production cost includes cost of water (including fees, energy for pumping), seeds, fertilizer, pesticides, labour, etc. If critical values of this ratio are exceeded, farmers tend to abandon irrigation.

2.4.4.4 Viability of Irrigation Investments

The primarily economic concern for planners and policy makers is the economic performance of investments, or the return to capital employed. A typical indicator used for this purpose is :

$$\text{Gross Return on Investment} = \frac{\text{Gross Value of Output}}{\text{Investment on Irrgation System}}$$

2.4.4.5 Social Capacity

Social capacity refers to the social capacity of people and organizations for managing and sustaining the irrigated agriculture system. The two indicators are:

$$\text{Technical Knowledge Staff} = \frac{\text{Knowledge Needed for Job}}{\text{Actual Technical Knowledge of Staff}}$$

and

$$\text{Users Stake on Irrigation System} = \frac{\text{Active Water Users Organiqations}}{\text{Actual Techical Knowledge of Staff}}$$

Actual technical knowledge of staff could be ascertained through tests, while required knowledge is inherent in the job description. "Activeness" of water users associations can be measured using acquired data, such as percentage of WUA's holding regular (or the minimum required) meetings, percentage of water users participating in meetings, or number of organizations fulfilling agreed upon tasks, such as fee collection, maintenance, or distributing water.

2.4.4.6 Social Viability

Irrigation manager's actions have direct social impacts, though managers are often unaware of these. This gap in perception leads many irrigation managers to feel that "social viability" issues are not relevant to them. However, if the long term sustainability of irrigation is an objective, and if improving and maintaining social well being is ultimately important, then social viability is relevant, particularly from a strategic management perspective.

2.4.4.7 Irrigation Related Labour

$$\text{Irrigation Employment Generation} = \frac{\text{Annual Day / ha Labour by Scheme}}{\text{Annual Number Official Working Days}}$$

$$\text{Relative Prosperity} = \frac{\text{\% Scheme Population above Poverty Level}}{\text{\% National Population above Poverty Level}}$$

2.5 PROPERTIES OF PERFORMANCE INDICATORS

(i) Scientific Basis

The indicator should be based on an empirically quantified, statistically tested causal model of that part of the irrigation process it describes. Discrepancies between the empirical and theoretical bases of the indicator must be explicit. It should be comparable with international standards.

(ii) The Indicator must be Quantifiable

The data needed to quantify the indicator must be available or obtainable (measurable) with available technology. The measurement must be reproducible.

(iii) Reference to a Target Value

It implies that relevance and appropriateness of the target values and tolerances can be established for indicator. These target values (and their margin of deviation) should be related to the level of technology and management.

(iv) Provide Information without Bias

Ideally, performance indicators should not be formulated from a narrow ethical perspective. This is, in reality, extremely difficult as even technical measures contain value judgments (small 1992).

(v) Provide Information on Reversible and Manageable Processes

This requirement for a performance indicator is particularly sensible from the irrigation manager's point of view. Some irreversible and unmanageable processes could provide useful indicators although their predictive meaning may only be indirect. For example, the frequency and depth of rainfall is not manageable, but information from a long time series of data may be useful in planning to avoid water shortage; and information on specific rainfall events may allow the manager to change water delivery plans.

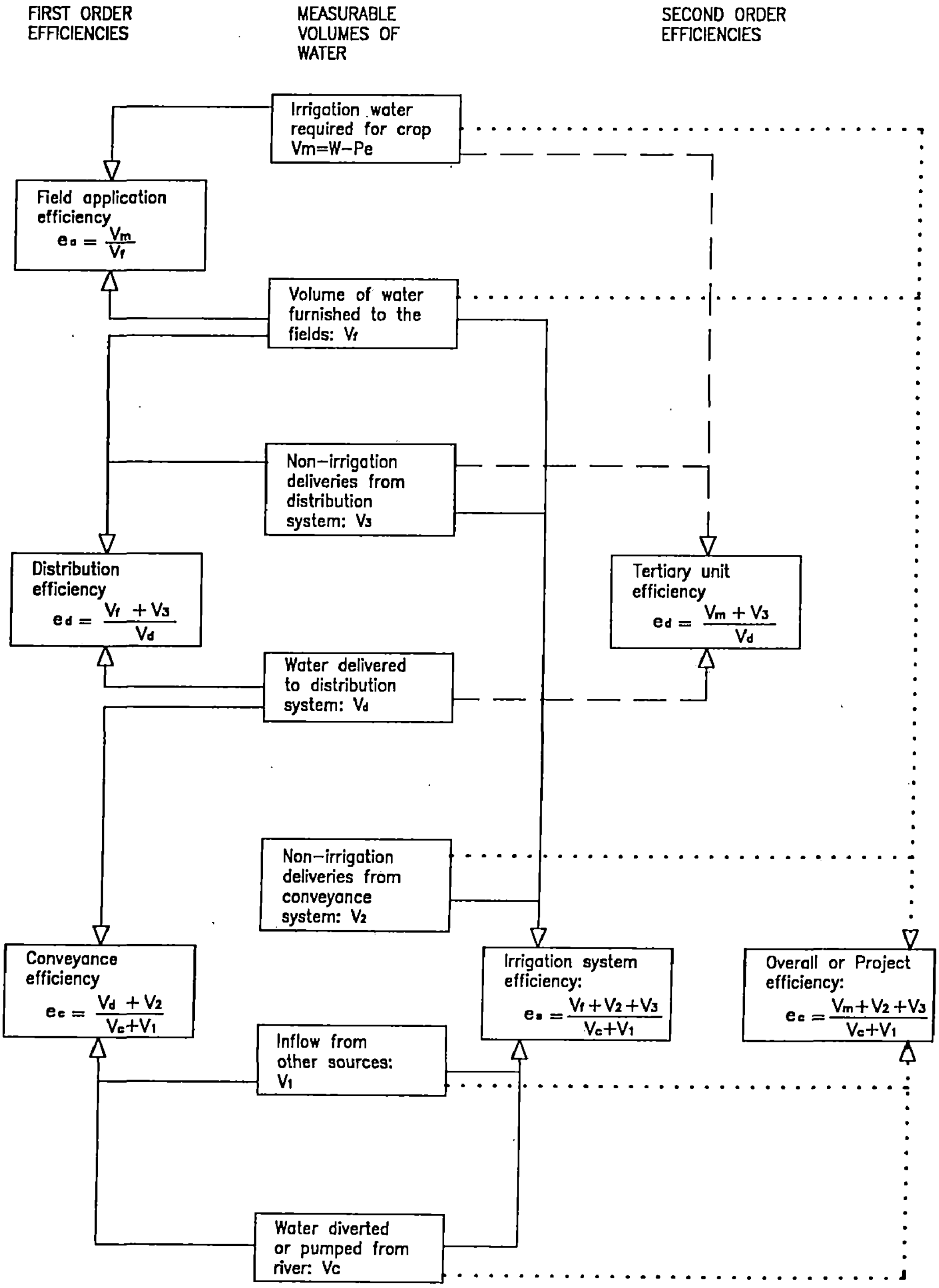
(vi) Nature of the Indicator

An important factor influencing the selection of an indicator has to do with its nature: the indicator may describe one specific activity or may describe the aggregate or transformation of a group of underlying activities. Indicators ideally provide information on an actual activity relative to a certain target value.

(vii) Ease of Use and Cost Effectiveness

Particularly for routine management, performance indicators should be technically feasible and easily used by agency staff given their level of skill and motivation. Further, the cost of using indicators in terms of finances, equipment, and commitment of human resources, should be well within the agency's resources.

Figure 2.1– Various efficiencies of irrigation water use.



LITERATURE REVIEW

3.1 GENERAL

In this section we review much of the irrigation management literature on performance indicators. Meaningful performance appraisal is possible only with a clear understanding of how we define an irrigation system, its management and objective for which it has been created.

Performance is viewed as having two dimensions: the attainment of a specified set of relevant objectives, and doing so with efficient resource use. The performance framework distinguishes between operational performance, primarily the concern with water delivery and agricultural output, and strategic performance that addresses issues of how well decisions are made, given the particular level of physical, financial and human resources available.

An indepth critique of the objective of irrigation is given in Small and Svendsen (1990) who stated that goals were crucial to performance assessment and their clear specifications and classification as to whether they were related to inputs, outputs or efficiency were needed. They conceptualized irrigation purposes within a nested means and end framework in which a narrow purpose in seen as a means of achieving some specified end. In the hierarchical order of objectives, the end of first level of objective becomes the means of next higher level of objective (Table 3.1). At each level of assessment of whole system view is required because the constraints at different levels influence, the performance of other levels.

If we limit our discussion to technical performance at the hydraulic level of water distribution system then the success of an irrigation system can be measured by how it supplies, the required quantity of water at the right time in an equitable manner to users served by the system.

The water delivery system can have many objectives by there is a broad agreement that most of them can be included in adequacy, equity and timeliness. In cases where water quality is a problem, a fourth dimension of quality will have to be added. Water delivery management is not an end in itself but it is a means of increasing agricultural productivity in a sustainable manner and ultimately improving the quality of life. It is therefore necessary to establish linkage between the secondary or intermediate objectives and ultimate objectives. Abernethy (1987) has shown how all the objectives could be combined into a single objectives of productivity.

Table 3.1: Irrigation Purpose as Nested Means and Ends

Level	Means	Ends
Proximate	Operation of irrigation facilities	Supplying water to crops
Intermediate -1	Supply water to crops	Sustained increases in agricultural productivity
Intermediate -2	Sustained increase in agricultural productivity	Increased incomes in rural sector
Intermediate -3	Increased income in rural sector	Rural economic development
Ultimate	Rural economic development	(i) Improved livelihoods of rural people (ii) Sustained socioeconomic development for entire economy

Source: Small and Svendsen (1990)

We must also give careful consideration to the type of productivity that we are going to use in making our analysis. Productivity means production per unit of input. So we may have a land productivity (tonnes/hectare), which is usually called yield; or we may have a water productivity (kg of crop/m^3 of water), which in the United States literature is usually called water us efficiency; in some circumstances labour productivity will be a more important feature and so on. The land productivity tends to receive the greatest emphasis in the literature, but in cases where management of water is focus of concern, there is at least a prima facia case for saying that water may be the dominant constraint on output, and that water productivity ought to our primary criteria for good performance. A way or resolving, the point is to ask whether in case any water so saved by good management, it can be put to alternative use, or whether it will simply be wasted. If there is not alternative demand for it, then water productivity is not an important objective.

Abernethy (1986) deals with performance measurement in canal water management and makes two important contributions regarding measurement of equity and relative potential yield. He defines two measures of equity, I_1 and I_2. Figure. 3.1 illustrates the difference between I_1 and I_2. The interquartile ratio (IQR) I_1 is defined as h_{75}/h_{25}, h_{25} being the depth of water such that one quarter of all the land receives less than this, and h_{75} is the lower limit of the most favoured quarter. However, when there is a relatively small set of available values of h (which is usually the case) then h_{25} and h_{75} are not sharply defined, and I_1 becomes rather volatile. For this reason, he prefers to take the average depth of water received by all land and in the best quarter, divided by the average depth received in the poorest quarter, (i.e. the average for the shaded area in the Figure 3.1), which he terms I_2, modified interquartile ratio. The virtue of the ratios I_1 and I_2 is that they are easily understood by almost anybody and hence are easily communicated to agency personnel.

The concept of relative potential yield is illustrated by using some observations from Kaudulla to quantify the effects of irregular water delivery upon crop yield and water productivity. First a water demand curve is developed (Figure 3.2). This should be done on a daily basis, using data from climatic observations to construct an evapotranspiration curve, say, through the Penman formula. Next, some form of soil storage and percolation model is used to calculate a pattern of intermittent water inputs that will maintain sufficient water in the root zone to satisfy crop needs, downward percolation, and direct evaporation to atmosphere. (Holmes, 1983 describes these steps for the case of a rice system). Then, the actual history of water issues to the field is compared with this ideal requirement. Using crop-water response tables such as those of Doorenbos and Kassam (1979), calculations can be made of how much yield is lost due to the occasions when water deliveries fall below requirements. The excess supply of water at other periods implies a waste of water, and therefore, a reduction of the productivity of the water used. Taking all these things together, Abernethy calculates (for the particular patterns of crop demand and water delivery shown in Fig. 3.1) and the relative yield Y_r (that is, yield relative to what would be achieved if the delivery and demand curves matched precisely) as 88 percent, and the relative water productivity, P_r, similarly defined as 66.8 percent.

This means (without any consideration of how the farmer uses the water in his field) the system is supplying water to him in such a way that the best productivity he can achieve will be 33.2 percent less than it could be under a water delivery system that accurately matched crop requirements. Abernethy suggests that this seems to be a meaningful way of quantifying the effect of a water delivery schedule. It enables the interpretation of scheduling in output terms, but without the distortion of extraneous factors (fertilizers, pests, prices, etc.) that make it unsafe to use actual production as the measure.

C. L Abernethy extract-two salient numbers that indicate the overall effectiveness of the water management arrangements, and their fairness among the many users of system facilities. These numbers are (1) median potential productivity, P_{50}, and (2) inter-quartile ratio of productivity I_P.

The use of potential productivity parameter P_{50} and I_P opens the way to analyses of several key questions concerning irrigation management. Before considering some of these, it is worth examining briefly what the parameters tell us, and what they do not. P_{50} is superior, as an indicator of irrigation performance, to irrigation efficiency, because it reflects not just the amounts of water delivered, but also their relationship to the requirements of crop production. It does, however, contain the effects of conveyance losses, which are one of the principle constituents of irrigation efficiency. In a leaky system adequacy deteriorates as we move down stream, and equity also deteriorates, so we see these effects in lower P_{50} and higher I_P.

On the other hand, although P_{50} is designed to represent the effects of water supply on output, it avoids the problems that arise if we attempt to adopt actual out-put as a performance. The difficulties of doing that are well known: statistics of output are not highly reliable, and there are too many other influences upon output (pests, diseases, prices, equipment, etc.) among which it is difficult to isolate the influence of a single one. The use of potential productivity enables us to evade these difficulties.

Figure 3.1 illustrates one way in which we can use these concepts in diagnosis of the management defects in a system. Here the single S-shaped distribution curve of Figure 3.1 is replaced by a family of five such curves (Fig 3.3), labelled P_0 to P_4. P_0, the extreme case, represents the ideal; water productivity under optimally controlled conditions, with uniform distribution of water, at times closely matched to crop need and with comprehensive lining for seepage control.

In any real system, the actual set of physical facilities for water delivery and control will be insufficient to enable us to manage water so perfectly. We have instead some maximum attainable performance level, which depends upon the available set of canals, regulators, etc. This is represented by the curve P_1, whose values can be determined by use of a numerical model of the irrigation network. As systems age, we expect the curve P_1 to be regressing to the left, due to the deterioration of canals and structures.

The curve P_2, is the most difficult to determine at present, but it is useful to include it here as part of the conceptual framework. Given a particular set of facilities, we cannot in practice operate them as perfectly as a mathematical model might assume: there are many practical constraints: the numbers of staff, their hours of working, the distances between structures and much else. These constraints will usually be reflected, more or less., in the operating rules that are supposed to guide field staff actions. So we can conceive of the curve P_2 as representing the potential productivity that could be achieved, if we operate the available facilities in full accordance with the operating rules.

Below this again is P_3, which is the curve that we find from direct measurement of the water distribution, as it actually occurs in the system, and below this again is P_4, which represents, no longer a potential productivity but the actual crop production obtained in the field, as a proportion of the theoretically available output of the same crop (s), under the same levels of inputs and agricultural practices, but with perfect water supply.

The intercepts between these curves indicate the influences of different aspects of the management process. The are between P_4 and P_0 represents the total gap between crop potential and achievement. The diagram enables us to resolve this "loss" into four components. The are P_0 -P_1 is attributable to the set of physical facilities; P_1-P_2, to the constraints upon operational rules P_2-P_3, to the execution of those rules in the field; and P_3 -P_4 to the water application activities of individual farmers. Such information can be used diagnostically, especially in the case of projects that are candidates for rehabilitation of work. At that stage it is of high importance to distinguish the major causes of deficient performance, in order that rehabilitation funds can be applied to greatest effect.

D.Hammond. Murray-Rust and W. Bart Snellen state that an generic process of performance assessment cannot be solely, out-put oriented. To be sure, outputs are integral to the assessment, but they are used to determine opportunities for improvement within the entire management cycle, not merely in raising the level of outputs as a single goal.

Fig. 3.4 presents a summary of the paths by which a diagnosis could be undertaken by asking a series of questions that help to identify some of the causes of poor performance, possible ways in which management performance could be improved are identified. The diagnosis falls into two activities that require priority attention if performance is to be improved.

At the outset, it is obvious that elements of management control, the process by which the effectiveness of the various management functions of planning, organizing, originating and implementing is reviewed and adjusted, relies on having good information. If good data are not available, then there is no possibility of making a careful analysis of the problem.

If, and only if the appropriate data are available, it is possible to undertaken a logical and analytical process of performance assessment. Personal experience at field and system level suggest that many irrigation agencies do not keep good record of field-level conditions; indeed, most of the case studies are based on research activities specially designed to measure real life performance.

3.2 SPECIFIC CASE STUDIES

Several case studies on performance indicators of irrigation system has been carried out by different experts. The case studies demonstrate the importance of clearly understanding what the users themselves feel to be equitable before an assessment can be made of distribution of water. The evidence form the case studies are that little systematic measurement of performance is made by system managers.

CASE STUDY I: SIX FARMER-MANAGED SYSTEMS IN NEPAL

In the case of six small systems (Murray-Rust and Snellen), the stated equity objective was an equal share of water per unit area of irrigable land.

The three systems in hills were Baretar, Bandarpa and Jamune and in Terai were Tulsi, Parwanipur and Laxmipur. It was found that there was little variation in average water availability between head and tail of the systems. In the largest system (Parwanipur) there was a slight but insignificant decline in the Water Availability Index (WAI) from head to tail of the system. In all other systems no difference existed in terms of WAI between head and tail of the system. The Interquartile Ratios for the nearest and furthest 25 percent of sample plots are remarkable low.

Fixed overflow designs provide little opportunity to manage reliability below the head gate controlling flow into the canal. The systems are highly depended on the water conditions upstream of the head gate. In this six-small systems it is clear that weekly Relative Water Supply (RWS) at the head of the system varies greatly (Figures 1 and 2 of Annex. A), so that in any week it is difficult for farmers to predict how much water they will obtain.

Because adjustments cannot be made to flows in the canal system, farmers have to either irrigate only a portion of their holding when water is in short supply or come to sharing arrangements with neighbours. None of the case studies provided information on tertiary-level management arrangements in this regard.

Adequacy in run-of river systems is dependent on river discharge. There is little farmers can do if the river discharge falls below total demand for water, although excess water can readily be passed down the river rather than being diverted into the system where it is not needed. In the systems there are efforts to regulate discharges into the system to accommodate changes in both water availability and demand. Calculation of the Relative Water Supply (RWS) at the intake into each system (Fig. 1 and 2 of Annex. A) shows that supply and demand are well-adjusted at system level, with weekly averages being normally in the range of 1.0 to 2.0. In none of the systems is RWS very high, suggesting that over time the farmers have learned to estimate how much very high, suggesting that over time the farmers have learned to estimate how much land can be irrigated with reasonable safety in a normal year and do not divert excess water into the canal. Smaller systems in the hills tend to have lower RWS values, suggesting that farmers are able to work together well to share scarce water supplies. Although there is land available for potential expansion of the irrigated area the RWS levels suggest that farmers are unlikely to expand the total area for risk of water shortages in drier years.

Within the systems, however, adequacy shows a distinctly different pattern. The variation of WAI between adjacent farms is high, irrespective of whether the plots are near to or far from the head of the system. The Interquartile Ratios for the best 25 percent and worst 25 percent of sample plots (i.e., independent of distance) were much higher than head-tail differences.

Yields in all of the Terai systems are closely correlated with the actual value of WAI (Figure 3, Annex. A) and it appears that there is potential for improving overall output from the system, and of individual farmers, if water at tertiary level is shared more equally. In the hills the same relationship is not found (Fig. 4, Annex. A). It is not clear from the data presented whether WAI variations are due to unequal access to water or because of differences in soil-water requirements. Increases in agricultural output will only come from improvements to management of agricultural inputs, not from improvements in water distribution at system level.

CASE STUDY 2: CIPASIR, WEST JAVA, INDONESIA

Cipasir represents a typical farmer – managed system in West Java. The system relies on a simple off-take in the Cipasir river and irrigates 39 ha. Most water control is by overflow weirs placed in the main canal. Water rights within the system are complex, and do not divide water equally by irrigable area. Instead each farmer has a certain right that reflects the length of time the family has been a member of the system. Families involved in the initial development of the system, primarily those near the head are entitled to a greater share of water and are thus able to cultivate two or three crops a year, depending on their location in the system. Farmers in more recent extensions to the system have fewer rights. Thus, it is a good example of a system that does not provide equality but is still seen as equitable by water users.

In the steeper upper parts of the system, however, water deliveries are provided by a series of bamboo pipes leading directly out of the canal to avoid erosion. Government staffs operate the gate at the head of the main canal whereas other operations and maintenance are undertaken by farfmers.

CASE STUDY 3: THE FAYOUM, EGYPT

The Fayoum Depression, southwest of Cairo, has a gross irrigated command area of 150,000 ha. The main canal diverts water from the Nile 284 km upstream of the head of the system. Each rotational unit, ranging in size from 8 to 200 ha is scheduled to receive continuous irrigation deliveries, with a maximum designed supply of 7.1 mm/ day.

Water distribution in the main canal system is through a set of gated regulators with undershot gates at each of the main bifurcations in the system. However, below these regulator gates, water distribution is achieved through overflow weirs (each known as a nasbah) where all crest levels are the same, and the width of each weir is proportional to the area served. The upper 20% receives somewhat more than its fair share for the sub-command both because of post construction changes to fixed structures and the use of pumps from the canal that cannot be easily controlled by irrigation agency. The remaining 80% of the area water distribution is controlled by ungated division structures more or less in proportion to the command area. This system shows in good uniformity of water distribution.

In this system there is no intention to meet the total potential crop water demand. Water rights represent an allocation of a share of total water available, and is intended to be less than farmers might require to cultivate all their lands under the most water – demanding cropping pattern. With water effectively rationed by the system demand, adequacy is controlled by the farmers' cropping pattern choices and is not included in the system managers' set of operational objectives. In the system, discharges into each subsystem will be reliable as long as discharges into the main canal are uniform.

CASE STUDY 4: LOWER CHENAB CANAL, PAKISTAN

The Gugera Branch canal is a major part of the Lower Chenab Canal Irrigation System constructed from 1900 to 1910. The head of the canal, at Sagar headworks, where the Upper Gugera Branch starts, serves a total command of at least 1.2 million ha and has 176 distributary canals totaling at least 2,800 km, and a Full Design Discharge of 310 m^3/sec.

The total length of the canal is over 250 km, terminating at Bhagat Head Regulator in the Lower Gugera Division. Along this length there is one major regulator at Buchiana where Burala Branch take-off. Otherwise there are virtually no gated cross-regulators but there are several drop structures that serve to stabilize water levels. Most drop structures are associated with scouring on the downstream side.

The high sediment load of the canal means that design velocities are normally more than 1.0 m / sec. This makes it difficult to regulate flows through using stop logs, although it is undertaken on the upstream side of some bridges. The bed level of the canal is, in many areas, much higher than designed, and free board has had to be sacrificed to get full discharge along the canal. Breaches are not uncommon particularly in the Lower Gugera Branch and required major and rapid attention when they do occur. For most of the year the canal is operated at or near Full Supply Discharge, but is closed down for two or more weeks in the winter season for essential maintenance and repairs. The time involved in refilling the canal means that irrigation is effectively stopped for several weeks at the tail although crop water requirements are very low at this time of the year.

In the system, sedimentation is a major problem. The changed cross-section results in a failure to meet target discharges into offtakes. In head ends, the increased bed level means that the head upstream of orifices is higher than designed, even when the target discharge into the secondary is achieved. Discharges through head end orifices are typically 150 – 200 percent of design. In extreme cases no water reaches the tail of the secondary even though the discharge at the head of the secondary met the target.

After desilting work, tail-end water conditions improved significantly, even though they did not achieve target discharges. Before desilting in Lagar Distributary, the IQR was 5.03 when discharges were at or close to design, a highly inequitable situation. Following desilting the IQR was reduced to 1.24.

There is an enormous spatial variation in access to reliable canal supplies. Tail-end farmers get not only less water, but less reliable water deliveries as well. The cause of this lack of reliability are the same as those for equity: canals are poorly maintained so that tail end areas are deprived of water, and there is weak management that permits discharges to be delivered far below the minimum stated in operational guidelines. Figures 5 (a) and 5 (b) of Annex. A show the water distribution equity before and after desilting in this case.

CASE STUDY 5: MUDKI AND GOLEWALA DISTRIBUTARIES, INDIA

Goldsmith and Makin (1991) describe a recent field study of the performance of a warabandi system in the Indian Punjab and illustrate some of the practical aspects of carrying out a rapid performance assessment.

The study area included the command areas of two distributaries, Mudki (30,894 ha) and Golewala (28,727 ha). Both distributaries are lined. Measurements were made of flows, losses and water levels in order to give estimates of equity of supply, adequacy of supply, and seepage and conveyance losses at both distributary and water course levels.

The study quantifies the performance of the distributaries in terms of water control objectives and conveyance efficiency. For example, the measured interquarrtile ratio (IQR) of 1.35 for Golewala Distributary is considered very good in terms of the equity in water distribution; the conveyance efficiency was found to be 53 percent at the time of the study but it was expected that this might fall to 42 percent without improved maintenance of lining. These results are reported to have had an effect on the watercourse lining and maintenance policy in the state.

CASE STUDY 6 : HAKWATUNA OYA IRRIGATION SCHEME, SRI LANKA

Bird (1991) reports the results of the collaborative research between Hydraulics Research Wallingford and the Irrigation Department of Sri Lanka in Hakwatuna Oya Irrigation Scheme in Sri Lanka. The paper supports the view that the introduction of monitoring and evaluation of water distribution systems as a part of the day to day management activity is a desirable step in the improvement process and can be done at little cost.

One aim of the study was to improve the standards of main system management within the constraints of the existing physical infrastructure through the provision of timely performance data. A microcomputer was installed at the project office to store and analyze rainfall, flow and field wetness data, and to provide performance reports on a regular basis. Early results suggested that the timely processing of an increased level of data collection was effective for both the identification of problems and the quantification of problems and the quantification of potential for improvement.

The paper makes a good contribution to the analysis of issues involved in deciding on the start and finish dates of the maha (wet) irrigation season in the irrigation scheme; that is, the preseason planning storage in the reservoir at the end of September and the occurrence of rainfall in September and October are two important factors in the preseason planning. There is generally a trade-off between waiting for sufficient rain to start land preparation and the penalty of waiting too long thus pushing the end of the season into the warmer and drier months of February and March. Delaying the start of land preparation until the beginning of November would take advantage of the rainfall to "wet up" the system and possibly reduce the land preparation issues by 50 percent. This would, however, be at the expense of additional issues at the end of the season.

The paper uses coefficient of variation as an indicator to study variability of flows in the Right Bank Canal. It also uses the interquartile ratio (IQR) to express the inequity of water issues from the Right Bank Canal.

CASE STUDY 7: KRASEIO PROJECT, THAILAND

Makin et al (1991) describe the results of a research project initiated in 1987 by the Royal Irrigation Department (RID) in Thailand and Hydraulics Research Wallingford to investigate methods to improve water management at the Kraseio Project in Thailand. The introduction of computer-assisted irrigation scheduling to this 20,000 ha small holder rice and sugarcane irrigation project has provided an opportunity for continuous performance assessment.

The Kraseio Project has been operated for two seasons, incorporating simple performance indicators, namely : actual versus targeted supply, and equity, reliability and adequacy measures. Over these two seasons, the value of regular feed back of performance information has been demonstrated, in terms of increased awareness by project staff of operating constraints and their ability to quantify project performance. The provision of weekly information on performance is exerting an influence on the management of the system thus enabling timely response to operational problems.

One of the contributions of the paper is the analysis of reliability of flows at the head of one of the canals Irrigation Water Supply (IR) as shown in Figure 6 of Annex. A. The observed flow is considered reliable if it lies between ± 10 percent of the target flow. It will be seen that only 55 percent of the observed flows were found to be reliable. The reliability index at the head of the canal is thus defined as 55 percent.

LESSONS LEARNED FROM THE CASE STUDIES

(i) Lack of Evidence of an Effective Performance Assessment Framework:

None of the case studies contained any evidence of an effective assessment framework which would help managers improve over the levels of performance. That does not mean to say that none of the systems have such a framework: it might be there, but is unreported.

Further, most of the case studies are reports of specific research activities that were themselves instrumental in collecting the data presented. This indicates that the operating personnel and the managers do not have access to data of sufficient quantity or reliability to assess performance and diagnose ways of improving it. Which of these two conditions needs to be addressed first if performance is to be improved is difficult to determine: data collection programs without a framework appear doomed to die through lack of relevance; a framework is of little value unless there are good data to be used.

(ii) Lack of Clearly Stated Objectives:

Most of the case studies did not identify the objectives for which the systems were being managed. This reflects in part the lack of a framework that stresses the importance of having clearly stated objectives, but it is also because outsiders impose their own understanding of what the objectives out to be on the systems being studied.

This highlights a particular dilemma for observers attempting to make judgements about performance. The most commonly cited objectives, including many of those used in this study, are more universal in nature: equity, reliability and adequacy to the evaluation of water delivery performance. System managers may have an entirely different set of local objectives. Unfortunately, if they are not clearly expressed, they will be ignored in external assessment, and a different set of objectives used in any evaluation of the level of performance actually achieved.

The combination of the lack of an effective performance assessment framework and a set of relatively short term research–oriented case studies means that there is little information on the long – term trends of performance in any of the systems studied. Short-term studies give little opportunity to see if performance is improving or declining, and the lack of long – term performance indicators in the assessment process mans that adverse and even irreversible changes are simply not being monitored.

(iii) Target and Objective Mismatches

In the majority of case studies shortfall is reported either in achieving targets, in fulfilling objectives, or in both. It is obvious that without accurate data such shortfalls are inevitable, but it may be precisely because of adverse institutional pressures than system operators do not wish to report bad news.

It is essential that data collection be undertaken openly and objectively if realistic assessment of performance is to take place. The fact that short falls in meeting targets or objectives are reported should not initially be any cause for alarm or discrimination; it is when whose shortfalls are viewed as persistent that evaluation must become more critical.

Assuming data exist, and this is not the situation in all of the case studies, then the diagnosis can proceed to assessing whether the defined targets if met, would actually meet the objectives. It is obvious that there is little concern with better matching the system level objectives with operational targets. At this stage of the diagnosis it may not be possible to say which should be modified in the future, but it is clear that the system is inherently out of synchrony and this can only perpetuate the situation where performance is lower than it could be.

The worst case, and regrettably the one that seems to typify most of the case studies is that neither objectives nor targets were met to any great degree of precision. It may be that in most cases the managers are neither "doing things right" nor "doing the right thing". This does not mean to say the systems are catastrophes, but it does mean that there is tremendous potential to improve performance.

(iv) Assessment of Operational Performance

When neither objectives are fulfilled nor targets achieved, then any remedial action is going to take a lot anger. It will require a much more detailed assessment of the management process in regard to the organization for management, the mobilization of resources, the utilization of those resources for operations and maintenance, and the management control process itself, if objectives or targets are not being fulfilled nor targets being achieved.

In many cases the critical issues may be in the field of operational implementation, while in others management of maintenance may be of greater significance.

A management-oriented approach does not rule out the need under some circumstances either to make physical changes in the system design or to increase the level of financial and human resources.

Rehabilitation and modernization, for example, are legitimate strategies to improve output from a system, but should only be advocated under a specific set of conditions. This condition is when evaluation determines that the operational targets were appropriate to fulfill objectives, but were not feasible because of a deficiency in the physical condition of the system. Assuming that rehabilitation will automatically improve output is not appropriate if current management is deficient and is not addressed as a competent of rehabilitation.

Assessment of operational performance is in large measure a site-specific activity. What is being assessed is the degree of achievement of specific hydraulic and other targets, and their capacity to meet the system specific objectives.

Therefore, the primary motivation of a manager will be to increase performance in absolute terms for that system, based on a time series view of actually achieved performance. A good example would be the improvement of equity of water distribution: if this is a system objective and the manager consistently improves the achieved level of equity this is good performance irrespective of the situation encountered in any other system.

(v) Assessment of Performance between Systems

It is more difficult and perhaps impossible to make many definite conclusions about the relative performance of different systems. Nevertheless, the overall environment in which an individual system is being operated must be taken into account when decisions have to be made in respect of where to invest for improved performance in the future.

The case studies are too diverse in both physical design and managerial environment to be definitive. Nevertheless, in respect of certain objectives that concerns decision-makers at levels higher than the individual system: the equity, reliability and adequacy can be made based on the available evidence.

SIGNIFICANT FEATURES OF THE CASE STUDIES

(i) In case of six farmer-managed systems in Nepal, over the passes of time farmers have learned to estimate how much land can be irrigated with reasonable safety in a normal year and they are able to work together, well to share scarce water supplies. With the involvement of farmers in management of irrigation water there has been an overall improvement in the service and it led for them greater satisfaction among farmers.

(ii) The case study of Cipasir, West Java, Indonesia is a good example of a system that does not provide equality but is understood as equitable by water users (because of good sharing arrangements of water among themselves). Except the operation of the gate at the head of the main canal all other operations and maintenance are undertaken by farmers.

(iii) In the case of Hakwatuna Oya Irrigation Scheme, Sri Lanka; the study results suggested that the timely processing (on a regular basis) of an increased level of data collection was effective for both the problems identification and for improving the performance of the system.

(iv) In the case of Kraseio Project, Thailand; the regular feedback of information was able to make more awareness of the project staffs in operating constraints and thus enabling timely response to operational problems.

(v) The concept of potential productivity (Abernethy C. L.) can be appropriately used in irrigation system management. It provides a good understanding for the scheme of rehabilitation of the irrigation system in use, specially giving a better information on the existing deficiencies and relative priorities and expenditure in the process of rehabilitation of the system.

3.3 OTHER IMPORTANT ASPECTS OF WATER RESOURCES DEVELOPMENT PROJECT

In this section we outlines some of the important aspects of Water Resources Development Project as follows:

- Sustainability of Water Resources Development Project
- Modernization of Irrigation System
- Privatization and Turn-over of Irrigation Schemes
- Irrigation Efficiencies
- Conjunctive Use
- Yield Response to Water
- Appropriate Water Management

3.3.1 Sustainability of Water Resources Development Project

Development is sustainable if,

"........it meets the needs of the present without compromising the ability of future generations to meet their own needs".

Sustainability criteria force us to consider the long-term future as well as the present. The actions that we as a society take now to satisfy its own needs and desires should not only depend on what those actions will do for us but on how they will affect our descenders as well. This consideration of the long-term impacts of current actions on future generations is the essence of sustainable development.

The concept of environmental and ecological sustainability has largely resulted from a growing concern about the long-term health. There is increasing evidence that our present resource use and management activities and actions, even at local levels, can significantly affect the welfare of those living within much larger regions in the future. Water resource management problems can not be justly viewed as purely technical, rather they must be seen closely related to broader societal structures, demands and issues.

Management decisions can be viewed as experiments, subject to modification but with goals clearly in mind. Adaptive management recognizes the limitations of current knowledge and experience and that we learn by experimenting. It helps us move toward meeting our changing goals over time in the face of this incomplete knowledge and uncertainty.

Changes in the social and institutional components of water resource systems are often the most challenging because they involve changing the way individuals think and act. Sustainability requires that public and private institutions change over time in ways that are responsive to the changing demands of individuals. Understanding how institutions are structured and function can help one understand better how water resource system development policies and operating rules might be altered when they become deficient, and who has the authority to change such rules, and in what ways.

To be sustainable, a project must perform reliably during process of change. The transition to new technologies, new management practices, and new institutions (or institutional leadership) must proceed in an orderly and equitable manner. Continuity and confidence in the new systems are prerequisites for sustainability, as are a proper respect for operation rules and for maintenance of the physical infrastructure.

3.3.2 Modernization of Irrigation System

Modernization is the process of improving and enhancing an existing project to meet new performance criteria. The process includes changes in existing facilities, operational procedures, management, and institutional aspects. Changes are designed to enhance economic and social benefits of the users and the region. Unlike rehabilitation, modernization is not renovation of project features in need of repair.

Reasons for Modernization of Irrigation Schemes

i) The traditional agricultural systems based on the cultivation of rice, mainly for house consumption, have to be transformed into a more diversified systems with higher agricultural inputs and to be market oriented. To feed growing population and support farmers' welfare and rural development, these objectives should be more encouraged and supported.

ii) Considering the constraints regarding availability of cultivable lands, there is no other way than to make water use more efficient in already irrigated areas, shifting its pattern from seasonal to year-round supply.

iii) Due to the rapid urbanization and industrialization, competition of water use between irrigation and other water users will become a focal point because they have to share limited water resources.

iv) One major task of the irrigation sector will therefore be to reduce water losses and to achieve equitable water delivery. Modernization of irrigation schemes will therefore be an essential part of the solution. Thus, it will make farmers able to control water at minimized losses. Modernization also includes institutional reforms to sustain their performance.

v) It has been recognized that human capacity building is a key prerequisite for better operation and maintenance. When water scarcity occurs, intensive management takes place.

vi) Water Users Associations should be strengthened so that they will be accountable for management of the irrigation system. Modernization will make it possible to introduce adequate water fees for not only O&M but also for some parts of capital cost recovery because modernization of irrigation systems results in remarkable returns to farmers including equitable and rational water delivery, water security and labour saving for operation.

3.3.3 Privatization and Turn-Over Of Irrigation System

Increasingly Governments in many countries are turning to privatization and turnover of irrigation schemes to farmers as a means of reducing government involvement in irrigated agriculture. The move towards privatization and turnover is driven by changing political, economic and social forces within many societies, and a need by governments to reduce ongoing expenditure on irrigation system management, operation and maintenance.

Privatization and turnover places increased burdens for management, operation and maintenance of irrigation and drainage systems on the farmers whilst in some communities farmers are able to shoulder the additional responsibilities, in others they are not, and farmer training and government support are required during the transitional period.

Training for farmers and farmer groups to enable them to cope with privatization and turnover has, by necessity, a different focus to the more traditional aspects of farmer training. It outlines some of those different aspects and details how they might be addressed.

Issues:

There are variety of issues that need to be considered in relation to farmer training for privatization and turnover of irrigation schemes. Therefore it is necessary to outline some of the issues which will strategically affect the approach to be adopted to farmer training and the training content and methods namely:

- Scheme history
- Environment
- Financial viability
- Political, economic and social structure of society
- Farmer attitude to government, government agencies and government staff
- Perception of purpose for privatization and turnover
- Asset management
- Farmers' management capability
- Who will carryout the training?

Training Needs

In the context of privatization and turnover some of the key training needs are:

- Water users association formation,
- Water users association management,
- Farmers' rights and responsibilities,
- Role of women,
- Water management.

To cover these needs the training content needs to cover:

- Committee functions and responsibilities,
- Finance, accounting and auditing,
- Setting and collecting irrigation service fees,
- Managing farmers' meetings,
- Conflict resolution,
- Organizing system maintenance,
- Facilitating community participation and co-operation,
- Establishing rights and responsibilities,
- Negotiating with water supply agencies,
- Lobbying politicians and government agencies,
- Establishing required levels of service provision,
- Legal and institutional aspects,
- Measuring and paying for provision of water.

3.3.4 Irrigation Efficiencies

Generally, overall water-use efficiency has been understood as the ratio of irrigation water that has been made available to the cop out of the total water mobilized for irrigation at the headworks (e.g. at river diversion). Considering economic, as well as environmental impacts we might have to be more precise and also more explicit.

Effective water is to be understood as the ratio (out of the total amount of water taken at the source) which finally contributes to biomass or yield formation.

Relating farm yields currently obtained in large irrigation schemes, to the amount of irrigation water taken at the source, we must acknowledge that overall water use efficiencies in major irrigation schemes can hardly be beyond 20-30% (ICID, 1994). Or, in other words, at higher water use efficiencies, substantially higher yields could be observed. So far, no scientific approach has been initiated in this respect (e.g. through water management at different stages, assessment by lysimeter etc.).

Achtnich (1980) correctly points out, that a series of sectorial ratios do subsequently multiply, as to result in the overall efficiency of a project. Numbers given below reflect a typical situation

$$E_p = E_{mc} \times E_d \times E_f = (\approx 0.28)$$

Where,

E_p = project overall efficiency

E_{mc} = main conveyance efficiency

E_d = distribution efficiency

E_f = field application efficiency

J. M. Verma (1992) has estimated that in India E_p of major project might be on the order of 0.3, thus slightly above what might be called a "world average". China, as one of the largest irrigators in the world did not release any estimate in this respect.

As a long-term vision, in rehabilitated irrigation schemes, feasible minimum requirements regarding irrigation water use efficiencies could be targeted as given here after:

$$E_p = E_{mc} \times E_d \times E_f = (\approx 0.50)$$

Where

$E_{mc} \approx 0.95$ (in lined canals or with interceptor pumping)

$E_d \approx 0.85$ (in partially lined distribution system)

$E_f \approx 0.65$ (improved irrigation methods)

(The estimated values originate from informal discussions at the occasion of ICID Den Hague, 1993)

3.3.5 Conjunctive Use

Conjunctive use implies coordinated and harmonious development of surface and ground water for meeting the water requirements by optimally utilizing the total available water resources.

The concept recognizes the unified nature of water resources as a single natural resource, although the method of exploitation may involve both surface and groundwater structures. The process takes advantage of the interactions between the surface and groundwater phases of the hydrological cycle and also the natural movement of ground water in planning the use of water from the two phases.

The conjunctive use of surface and ground water sources may be practiced in order to attain one or more of the following objectives:

(i) A higher total amount of supply,

(ii) Better regulation of the combined system using storage volume of aquifer,

(iii) Savings in evaporation losses from surface reservoirs,

(iv) Higher flexibility in supply according to the demand curve, by evening out peaks in stream flow and pumping ground water as and when needed,

(v) Use of augmentation tubewells discharging directly into the canal, and there by supplementing the supplies,

(vi) Mixing of different quality water, either in the supply system or in the aquifer to reduce salinity,

(vii) Augmenting low flows in rivers by artificially recharging the aquifer.

3.3.6 Yield Response to Water

The yield of crops in response to varying proportions of their theoretical water requirement is discussed in FAO Irrigation and Drainage paper 33. In essence, for many crops it is possible to achieve higher total yields by under watering crops and cultivating a larger area than meeting the full crop water requirement in a lesser area. This assumes the same quantity of water is applied during each period of crop growth.

For example, with paddy rice it is not essential to have continuous submergence of the paddy in order to achieve high yields. Indeed, according to FAO paper 33 it is possible to achieve 110% of the yield of rice grown under continuous submergence of the paddy while applying only 75% of the water needed for continuous submergence. This, however, requires highly competent irrigation management which generally has not developed in Nepal. Nevertheless some reduction in water application is achievable to allow extension of the irrigation area and an overall increase in yield. If such an approach is adopted, the following points specific to paddy (rice) should be observed:

(i) When moisture content of the soil decreases to about 80% of the saturation value (100% saturation occurs when the paddy is flooded to any depth) yields are reduced by about 5%;

(ii) The two periods when rice is most sensitive to water deficit are flowering, and to a lesser extent during the second half of the head development period;

(iii) Alternative wetting and drying during yield formation and ripening periods can cause grain to crack;

(iv) At certain periods it may be possible to draw down the level of water in the paddy to meet evapotranspiration demands thus supplementing a limited water supply. This is, of course, only possible as a short term measure.

3.3.7 Appropriate Water Management

Appropriate Water Management can be defined as "those cultures" methods, systems and techniques that provide a socially and environmentally acceptable level of service or quality of product at the least economic cost.

Irrigation Agencies should give top-down leadership to the implementation of appropriate water management.

Needs for appropriate water management can be listed as follows:

(i) To sustainably increase crop-production,

(ii) To significantly reduce the irrigation water used; and

(iii) To avoid/ reverse new contamination and further degradation of our land and water resources.

Figure3.1– Definition of interquartitle ratios

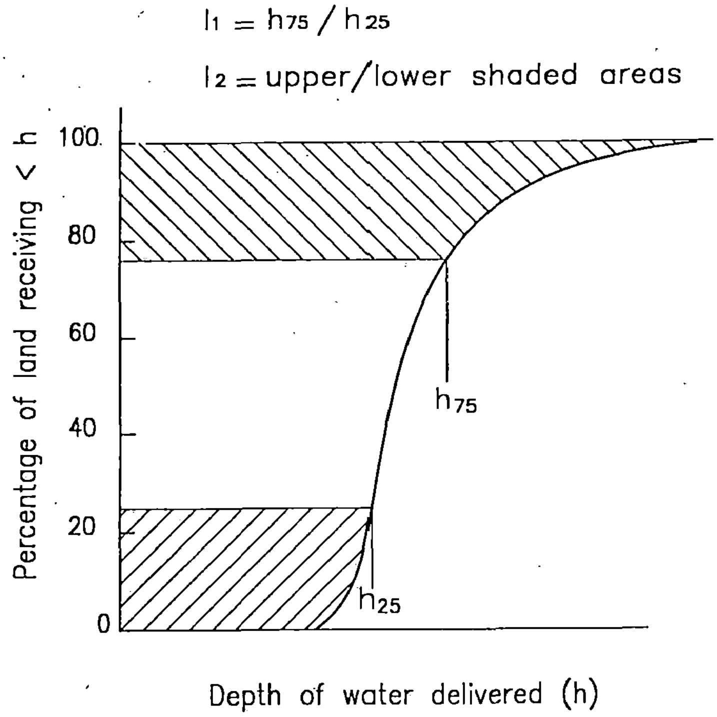


Figure3.2 – Effect of irregular water delivery upon crop yield and water productivity

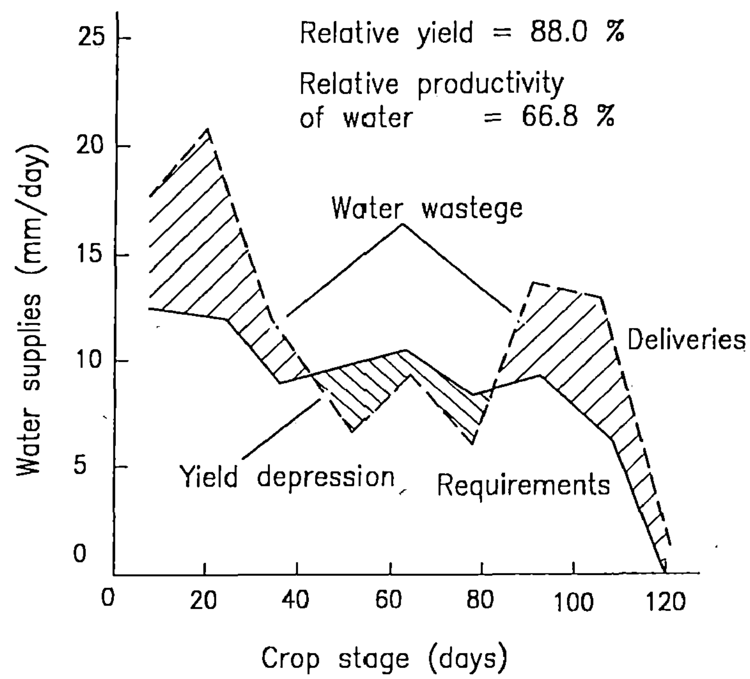


Figure 3.3 – Effect of different constraints upon the potential productivity of water

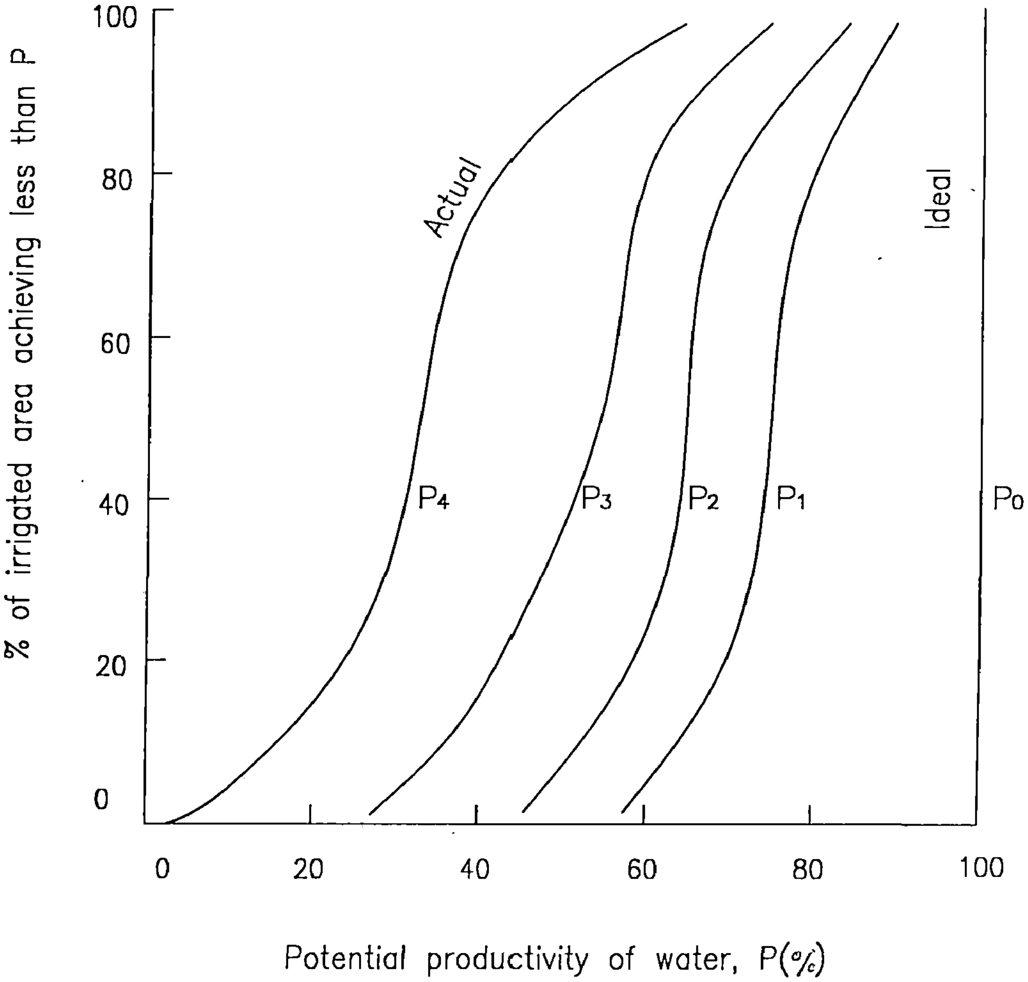
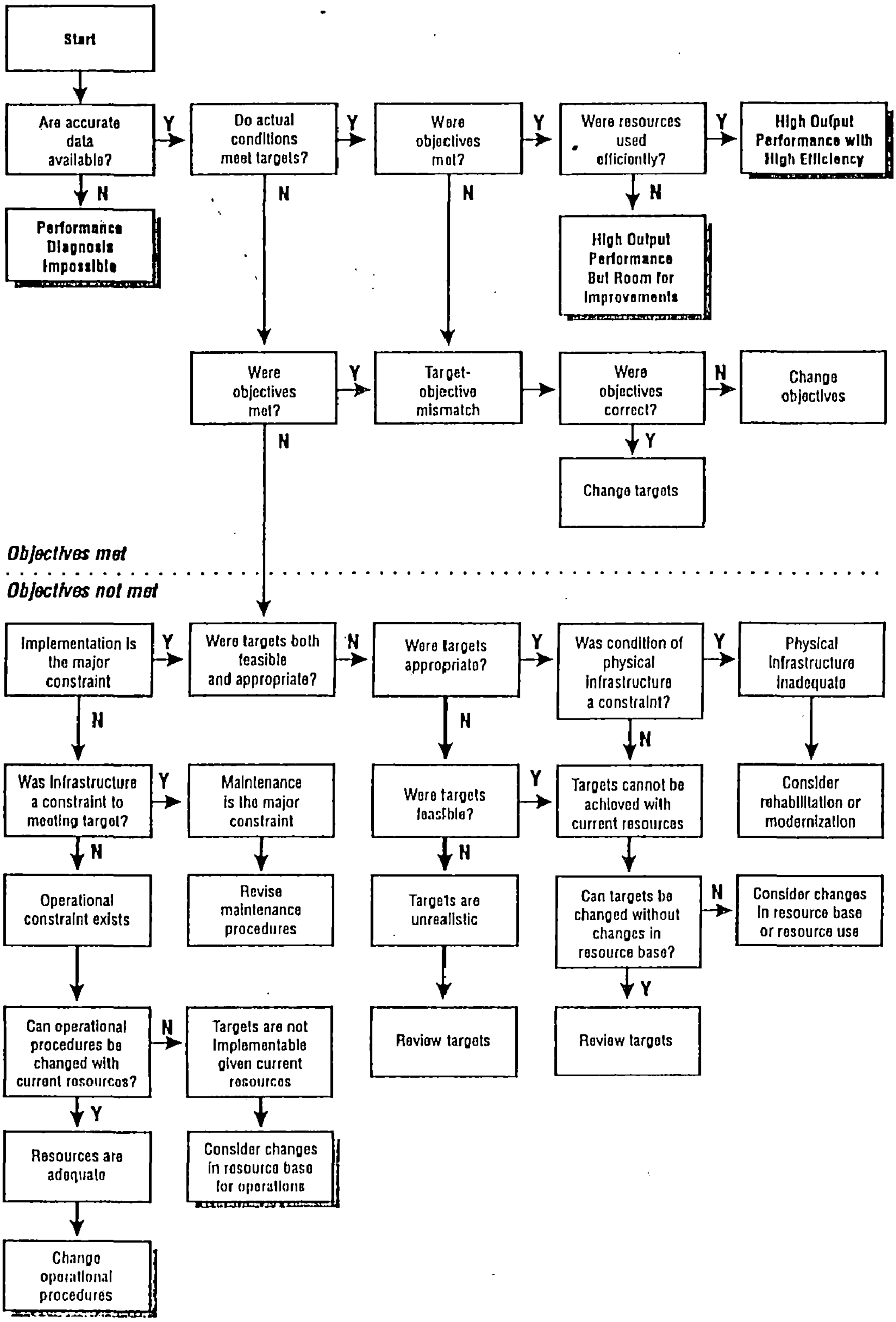


Figure 3: Flow chart to show process of performance assessment and diagnosis



STUDY AREA

4.1 GENERAL

The project area lies in the Terai region within Saptari district of Sagarmatha Zone in Nepal. Terai region extends almost throughout the length of the country and covers approximately 23% of Nepal's area. This is the region which yields bulk of the country's agriculture produce. The project area has large fertile alluvial sloping land. The land utilization statistic of Saptari district shows that there is very little scope for harnessing more land for cultivation. The food requirements are necessarily expected to grow continuously and required agriculture production has, therefore, necessarily to come from increasing intensity of cropping and irrigation and using modern practice for intensive agriculture for increased productivity. The country is heavily dependent on agriculture, in which almost 94% of the economically active population is engaged in producing 60% of the GNP. Table 4.1 shows the estimate of land use.

Chandra Canal Irrigation System (CCIS) is the oldest public irrigation system in Nepal. This system was constructed between 1923-27 A.D. during the rule of Rana Chandra Shamsher. It was designed to irrigate about 9900 hactares of land during monsoon season.

The system draws water from Trijuga river which is a tributary of Saptakoshi. Trijuga river originates from Mahabharat region and its watershed area is about 750 square kilometer.

This system comprises of a headwork with one undersluice, one main canal of a about 29 km long with designed capacity 11.80 m^3/sec at the head reach, twelve distributary canals, twenty-five minors and 237 tertiary or water course. These tertiary canals were constructed during the time of Chandra Canal Rehabilitaion under Koshi Agreement. Most of the tertiary canals constructed during CCIS extension have been demolished by the farmers.

4.2 LOCATION

The project area is located in the western section of the Koshi river basin between latitude $26^{0}25'$ N and 26^{0} 45' N and between longitude $86^{0}44'$ E and $86^{0}57'$ 30" E, and forms a part of the eastern Tarai lands of Nepal. The location and project are shown in Figures 1 and 2, Annex. B.

4.3 CLIMATE

The project area has a humid sub-tropical monsoon climate. Temperature in the project area remains high (40^{0}C) during the dry month of April, May and June. 80% of annual rainfall occurs in the months of June, July, and Aug, due to southeasterly monsoons. Table 4.2 presents the temperature and relative humidity records of the project area.

Data of annual rainfall for period 1972-80 for Rajbiraj, located in the project commend and Lahan and Siraha, just adjacent to project area are given in Table 4.3.

4.4 TOPOGRAPHY

The command area has east and southward average slope of 1 in 800. The ground elevation ranges from 100m north to 90m along the Western Koshi Canal on the southern limit of the command.

4.5 GEOLOGY

The Chandra Canal is a Contour Canal, which irrigates on its east and south side only (i.e. left side only). Sub-surface geological studies carried out reveal that the lithological units, which are mainly composed of sand and gravel of varying thickness in 11.50 Km reach of the main canal and represent channel deposits and sand and days in down command area which is due to flood plain deposits.

4.6 HODROLOGY

Koshi is the principal river in the east of the project area. Trijuga river (source of water for the project) is a perennial river with varying discharge. Other rivers in the command area are flasy river only. Koshi is also known for its sudden spate of floods. A rise of over 10 m is 24 hrs in the Koshi gorge about 10 km upstream of project headworks is no surprise. Swollen by metting show and have rainfall, Koshi is known to overflow in banks and inundates vast area. Since the constriction of Koshi embankment, the inundation has however, been controlled to a great extent.

4.7 GEOHYDROLOGY

Ground water is available at shallow depths in the upper reach. Depth of ground water varies from season to season. During rains, it rises within 2m and 5m below ground surface in upper and lower command area respectively. Similarly in summer (April - May) it lies at 5m and 10m deep.

In view of the abundance of ground water in upper reach of main canal and relatively low incidence of rain during winters, it would be advantageous to exploit the ground water resources for conjunctive use with surface irrigation during Rabi season.

4.8 SALIENT FEATURES OF THE PROJECT

The salient features of the Chandra Canal Irrigation System, Nepal are given on the next page.

SALIENT FEATURES

Name of the Project	-	**CCIS, Nepal**
Construction period	-	AD 1923-1927
Location:		
Latitude	-	26^0 25' N - 26^0 45' N
Longitude	-	86^0 44' E - 86^0 57' 30" E
District	-	Saptari
Temperature:		
Max. Temperature (Annual Mean)	-	33.0^0C
Min. Temperature (Annual Mean)	-	19.3^0C
Mean Annual Rainfall	-	**1360 mm**
Name of the River	-	**Trijuga**
Catchment Area (C.A)	-	750 Sq. Km
Head Works:		
Type of H/W	-	Weir (Solid)
Total Length of Weir	-	290 m
Design Discharge of Weir	-	3539 m^3/sec
Maximum Flood Discharge	-	4147 m^3/sec (Aug. 20, 1996)
Command Area:		
G.C.A	-	13,500 ha
C.C.A (Original)	-	9900 ha
C.C.A at present (after extension of M/C)	-	10,088 ha

Main Canal:

Design Capacity	-	11.80 m^3/sec
Total Length of M/C (Original)	-	24 km
Total Length of M/C (after extension)	-	28 km

Distributary Canals:

Total Nos. of Distributaries	-	12
Total Length of Distributaries	-	46.865 km
Total Command Area Served by Distributaries	-	8138 ha

Minors / Subminors:

Total Nos. of Minors and Subminors	-	25
Total Length of Minors/ Subminors	-	25.186 km

Tertiary / WC:

Total Nos. of Tertiaries / WCs	-	237
Total Length	-	226.5 km

Direct Outlets from M/C - 34 Nos.

Canal Reach:

Head Reach	-	upto 12 + 831 km
Middle Reach	-	12 + 831 km to 22 + 245 km
Tail Reach	-	22 + 245 to 27.871 km

Table 4.1: Area under cultivation in Saptari District

Land use area under	Total cultivated land		% land use of total cultivated land	
	Low land in ha	Up land in ha	Low land	Up land
Seasonal crops	74472	8646	97.37	77.81
Current fallow	358	564	0.47	5.08
Fruits	313	558	0.40	5.02
Permanent pasture	164	296	0.21	2.67
Private forest, grass	162	174	0.22	1.56
Miscellaneous	1015	874	1.33	7.86
Total	**76484**	**11112**	**100.00**	**100.00**

The present land use pattern of the project area is reported as below:

		Percent
1.	Cultivated land, including ridges	80
2.	Grass land, including dikes of ponds and slopes of streams	7
3.	Forests, including bamboo thickets	4
4.	Villages	4
5.	Ponds, rivers	3
6.	Roads and miscellaneous	2
	Total	**100**

Table 4.2: Temperature And Relative Humidity Records (Year 1994)

Station :Phattepur **Latitude: 26^0 44' N**
District : Saptari **Elevation : 100 m** **Longitude: 86^0 51' E**

Month		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean ^{0}C	Max	28.4	26.5	31.4	35.5	37.0	35.7	36.4	35.5	35.5	33.5	31.8	28.4
	Min	10.1	10.8	15.7	19.5	23.4	25.2	25.4	25.3	24.5	20.4	18.9	12.5
Relative Humidity % average 8:45 & 17: 45		88.5	88.0	87.5	79.5	62.5	69.5	76.0	76.5	80.0	80.0	79.5	

Table 4.3: Data of Annual Rainfall of Project Area (mm)

Year		1972	1973	1974	1975	1976	1977	1978	1979	1980
Stations	Rajbiraj	1323	-	1610	1146	1244	958	1066	1541	1342
	Siraha	1110	1310	1724	1905	1443	1251	1409	1213	1634
	Lahan	1137	1471	2106	2158	1594	1628	1152	1289	1107

WATER REQUIREMENTS

5.1 GENERAL

This chapter is divided into two main sections:

- Crop water requirements
- Irrigation water requirements

The method used are based on FAO Irrigation and Drainage Paper Nr. 24 (and 33)
The steps required to calculate water requirements are summarized in Figure 5.1.

5.2 CROP WATER REQUIREMENT

The crop water requirement is defined as the quantity of water utilized by the plant during its lifetime; this water may be supplied either entirely by rainfall, entirely by irrigation or by a combination of both. The water requirement of a chosen cropping pattern is compared with the available water resource to determine the maximum cropping intensity and extent of irrigable area.

The consecutive steps involved in calculating net crop water requirement and the irrigation supply to supplement rainfall are shown in Fig. 5.1 and discussed below:

5.2.1 Cropping Pattern

This section is limited to a discussion of cropping pattern in relation to water availability and assumes that farmers will continue to plant rice in preference to other crops with lower water requirements.

In general terms the annual cropping pattern can be divided into three seasons:

(i)	Monsoon rice	July - November
(ii)	Pre-monsoon rice	March - June
(iii)	Winter season crop	December - February / March.

The main rainy season is from July to September and farmers expect to crop 100% of their land with monsoon rice. The peak irrigation requirement for monsoon rice is normally in late September and October. When rainfall is much reduced, although in some circumstances the peak may be in June or July.

Table 1 (Annex. C) gives some typical cropping patterns. In practice planting dates in even a small area are spread over several weeks but, for simplicity, only indicative dates are given in Table 1 (Annex. C), where it is assumed that the whole crop is planted during a 15 - day period. The present cropping pattern of CCIS, Nepal is shown in Figure 1 (Annex. C).

5.2.2 Reference Crop Evapotranspiration (ETo)

Reference crop evapotranspiration (ETo) represents the rate of evapotranspiration of an extended surface of an 8 to 15 cm tall green grass cover, actively growing, completely shading the ground and not short of water.

There are several methods of calculating ETo, the best review of these is provided by FAO Irrigation and drainage paper Nr. 24 "Crop Water Requirments". The four methods presented, the Blaney - Criddle, Radiation, Penman and Pan Evaporation method, are modified to calculate ETo, using the main daily climatic data for 30 or 10 - day periods. ETo, is expressed in mm/day and represents the mean value over that period. Primarily the choice of method must be based on the type of climatic data available and on the accuracy required in determining water needs.

Climatic data needed for the different methods are:

Method	Temperature	Humidity	Wind	Sunshine	Radiation	Evaporation	Environ
Blaney-criddle	*	0	0	0			0
Radiation	*	0	0	*	(*)		0
Penman	*	*	*	*	(*)		0
Pan evaporation		0	0			*	*

* Measured data; 0 estimated data; (*) if available, but not essential.

Concerning accuracy, only approximate possible errors can be given since no base - line type of climate exists. The modified Penman method would offer the best results with minimum possible error of plus or minus 10 percent in summer, and upto 20 percent under low evaporative conditions. The Pan method can be graded next with possible error of 15 percent, depending on the location of the pan. The radiation method, in extreme conditions, involves a possible error of upto 20 percent in summer. The Blanney - Criddle method should only be applied for periods of one month or longer; in humid, windy, mid-latitude winter condition an over and under prediction of upto 25 percent has been noted. The Penman method is recommended for crop water requirements in Nepal. The form of the modified Penman method is

$$ETo = [\, W.R_n + (1-W)\,.\, f(u)\,.\,(e_a - e_d)]$$

A step by step procedure for calculating ETo by modified Penman method is given in Appendix - C.

5.2.3 Crop Coefficient (Kc)

To account for the effect of the crop characteristics on crop water requirements, crop coefficients (Kc) are presented to relate ETo to crop evapotranspiration (ET crop). The Kc value relates to evapotranspiration of a disease - free crop grown in large fields under optimum soil water and fertility conditions and achieving full production potential under the given growing environment. ET crop can be found by

$$ET_C = Kc.\ ETo$$

Crop coefficients are given in Table 2 and 3 (Annex. C) for a range of crop lengths and planting dates for suitable varieties of the most commonly irrigated crops in Nepal. The crop coefficients are based on those provided in FAO Irrigation and Drainage Paper Nr. 24 adjusted for length of season where necessary.

5.2.4 Land Preparation Requirement

The estimates of water requirements for land preparation can be critical as they generally cause a peak in irrigation demand, principally for the pre-monsoon rice crop.

The water is applied to make tillage easier and to saturate the soil prior to planting. For paddy rice crops water is also required to flood the fields.

The land preparation process for pre-monsoon rice is to add about 50 mm of water to the field prior to ploughing. After 1 to 2 weeks a further 100 mm is added for puddling of the fields and to provide about 20 mm depth of water during transplanting. For crop calendars starting with monsoon rice, this requirement can be met in part by rainfall and a total of only 110 mm is needed over the month up to transplanting. Where monsoon rice is grown following pre-monsoon rice, the requirement is further reduced as the soil is easier to prepare and it is possible for farmers to have the fields ready for transplanting in two weeks; the requirement is taken to be 55 mm. The water applied until transplanting is subject to evaporation losses (EO), thereafter the losses are included in the evapotranspiration calculation. Deep percolation losses are included in the land preparation requirement. Monthly open water evaporation estimates (E0) in mm / day for the nearest station (Tarahara) of the CCIS (Nepal) is given in Table 4 (Annex. C).

For non-paddy crops the much lower land preparation requirements are assumed to be met from soil moisture storage, except in the case of wheat for which 60 mm is applied to improve germination.

In summary, land preparation requirements in millimeters over 15 day periods are:

Period (15-days)

Paddy Rice	1st	2nd	3rd	4th	5th
Pre-monsoon	75	75	50	50	-
Follow paddy	55	50	50	-	-
Monson (first crop)	55	55	50	50	-
Dryfoot crops Wheat	60	-	-	-	-
All other	-	-	-	-	-

5.2.5 Deep Percolation Losses

Deep percolation losses are only explicitly considered in the calculation of requirements for paddy rice. In the case of dry-foot crops deep percolation is indirectly allowed for in the field efficiency factor.

The estimate of deep percolation losses for rice can have a major impact on the overall calculation of irrigation requirements, and field measurement are desirable whenever possible.

Table 5.1 gives estimates of deep percolation losses for different soil categories which can be used in the absence of field measurements.

Table 5.1 : Estimated Deep Percolation Losses (mm/day)

Soil Texture	Newly Irrigated	Long Term Irrigated
Sand, loamy sand	>20	>20
Sandy loam	20	10
Very fine sandy loam, loam silty loam, sandy clay loam	10	5
Silty clay loam, clay loam, silty clay, clay	5	2

Figure 2 (Annex. C) is used for deep percolation losses for Terai schemes.

5.2.6 Effective Rainfall

Precipitation falling during the growing period of a crop that is available to meet the evapotranspiration needs of the crop is called effective rainfall. It does not include precipitation lost through deep percolation below the root zone or the water lost as surface runoff. Since there are no records of effective rainfall available, it is necessary to estimates the portion of total rainfall that can be effective. An approximate procedure for arriving at effective rainfall is given as follows:

P_e = Effective rainfall (mm)

$P_e = 0.8P - 25$ if $P \geq 75$ mm/month

$P_e = 0.6P - 10$ if $P \leq 75$ mm/month.

For the crop, other than rice USDA method is used.

Table 5 (Annex. C), presents the main precipitation over the 14 years records of the project area. Table 6 (Annex. C), represents average monthly effective rainfall as related to average monthly ET crop and mean monthly rainfall (USDA) (SCS), 1969).

5.2.7 Net Irrigation Requirement

In summary, the elements in the calculation of the net irrigation requirement are:

Paddy Rice :

Crop evapotranspiratoin

+ land preparation,

+ evaporation

+ deep percolation

- effective rainfall.

Dry-foot Crops

Crop evapotranspiration

(+ land preparation for wheat)

- effective rainfall.

Table 5.2 and 5.3 presents the net irrigation requirement of monsoon rice and wheat in the project area.

5.3 IRRIGATION REQUIREMNETS AT THE HEADWORKS

Assumptions on field and conveyance efficiencies are critical to the calculation of irrigation requirements. There has been considerable variation in estimates for these key parameters in past studies in Nepal with overall efficiencies ranging from 15 to 68%.

5.3.1 Field Irrigation Requirement

Basin irrigation for dry-foot crops can be reasonably efficient given good management. However, it is still difficult to apply the desired amount of irrigation to the furthest corner of the field without considerable over supply to the crop closest to the supply point. This over supply is regarded as a loss from the system and is expressed as a field irrigation efficiency.

This efficiency depends on several factors including basin size, soil type, size of irrigation stream, the skill of the farmers and so on.

Generally, application efficiency ranging 50 - 70% i.e. water stored in root zone / water applied to field is taken for the calculation of field irrigation requirement (FIR).

$$FIR = \frac{NIR}{\text{Field Irrigation Efficiency } (0.75)}$$

5.3.2 Gross Irrigation Requirement

Conveyance efficiency relates to the main and secondary canals and is dependent on seepage losses, management efficiency and losses due to rotation.

Gross irrigation requirement at the head works or at the point of diversion which include all field losses, conveyance and operational losses are worked out assuming the conveyance efficiency ranging between 70 - 80% (i.e. water received at field gate / water released at project head).

$$GIR = \frac{FIR}{0.80}$$

Table 5.4 presents the Gross Irrigation Requirement of monsoon rice and wheat of CCIS, Nepal. Figure 5.2 shows the Net Irrigation / Gross Irrigation

Table 5.2: Crop Water Requirement - Monsoon Rice

Project - CCIS, Nepal | **Crop Periods -120 days**

Month	June	July	Aug	Sept	Oct	Nov	Notes
Periods	16-30	1-31	1-31	1-30	1-31	1-15	
ETo (mm/day)	5.56	5.33	5.07	4.41	4.06	3.42	From Penmen estimate Table C-5
Crop coefficient Kc	-	1.10	1.10	1.10	1.05	0.95	From Table - 2 (Annex. C)
ET crop (mm/day)	-	5.86	5.58	4.85	4.26	3.25	ET crop = ETo x Kc
ET crop (mm/month)	-	93.76*	172.98	145.50	132.06	48.75	ET crop x periods * For July 16 day considered
Land preparation (mm)	55	105	50				Monsoon rice first crop
Deep percolation (mm)	30.00	37.50	30.00	75.00	82.50	**	Figure 2 (Annex. C) **Field drying out no percolation loss included in calculation
Evaporation during land preparation (mm/month)	103.05	90.90	-	-	-	-	Eo x month, data from Table -4 (Annex. C)
Total crop water requirements (mm/ month)	188.05	327.16	252.98	220.50	214.56	48.75	Total = 1252 mm
Rainfall (mm)	243.00	395.00	215.00	264.00	64.00	10.00	From Table -5 (Annex. C)
Effective rainfall Pe ,(mm)	169.40	291.00	147.00	186.20	28.40	0	Pe = 0.8P- 25 if P ≥75 mm/ month Pe = 0.6P -10 if P≤ 75mm/ month
Net crop - (mm/month) Irrigation requirement	18.65	36.16	105.98	34.30	186.16	48.75	Total = 430 mm
NIR - (l/s/ha)	0.14	0.14	0.40	0.13	0.70	0.38	8.64 mm / day = 1l/s/ha

Table -5.3: Crop Water Requirement - Wheat

Project - CCIS, Nepal **Crop Periods -120 days**

Month	Nov	Dec	Jan	Feb	Mar	Notes
Periods	16-30	1-31	1-31	1-28	1-15	
ETo (mm/day)	3.42	2.68	2.50	2.98	4.30	From Penmen estimate Table C-5
Crop coefficient Kc	0.43	0.85	1.15	1.02	0.40	From Table -3 (Annex. C)
ET crop (mm/day)	1.47	2.28	2.88	3.04	1.72	ET crop = ETo x Kc
ET crop (mm/month)	22.05	70.68	89.28	85.12	25.80	Etcrop x periods
Land preparation (mm)	60.00					For germination
Total crop water requirements (mm/ month)	82.05	70.68	89.28	85.12	25.80	Total = 352.93 mm
Rainfall (mm)	10	12	5	13	10	From Table -5 (Annex. C)
Effective rainfall Pe ,(mm)	0	0	0	8	0	USDA Method Table- 34 (FAO Nr. 24)
Net crop - (mm/month) irrigation requirement	82.05	70.68	89.28	77.12	25.80	Total = 344.93 mm
NIR - (l/s/ha)	0.63	0.26	0.33	0.32	0.20	8.64 mm / day = 1l/s/ha

Project: CCIS, Nepal

Table 5.4: Gross Irrigation Requirement (Monsoon Rice/ Wheat)

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Notes
Crop - Rice (monsson) Area - 9700 ha													
Net irrigation requirement in l/s/ha Cumec						0.14 1.40	0.14 1.40	0.40 3.90	0.13 1.30	0.70 6.80	0.38 3.70		From Table5.2
Field irrigation requirement in cumec						1.87	1.87	5.20	1.73	9.07	4.93		FIR = NIR/AE AE = 75%
Gross irrigation requirement in cumec						2.34	2.34	6.50	2.16	11.34	6.16		GIR = FIR / C.A. CA = 80%
Crop - Wheat Area - 4700 ha													
Net irrigation requirement in l/s/ ha Cumec	0.33 1.55	0.32 1.50	0.20 0.94								0.63 2.96	0.26 1.22	From Table 5.3
Field irrigation requirement in cumec	2.07	2.00	1.25								3.95	1.63	FIR = NIR / 0.75
Gross irrigation requirement in cumec	2.59	2.50	1.56								4.94	2.04	GIR = FIR / 0.80
Total GIR in cumec	2.59	2.50	1.56	-	-	2.34	2.34	6.50	2.16	11.34	11.10	2.04	Total = 44.47 cumec

Figure 5.1: Crop Water Requirements

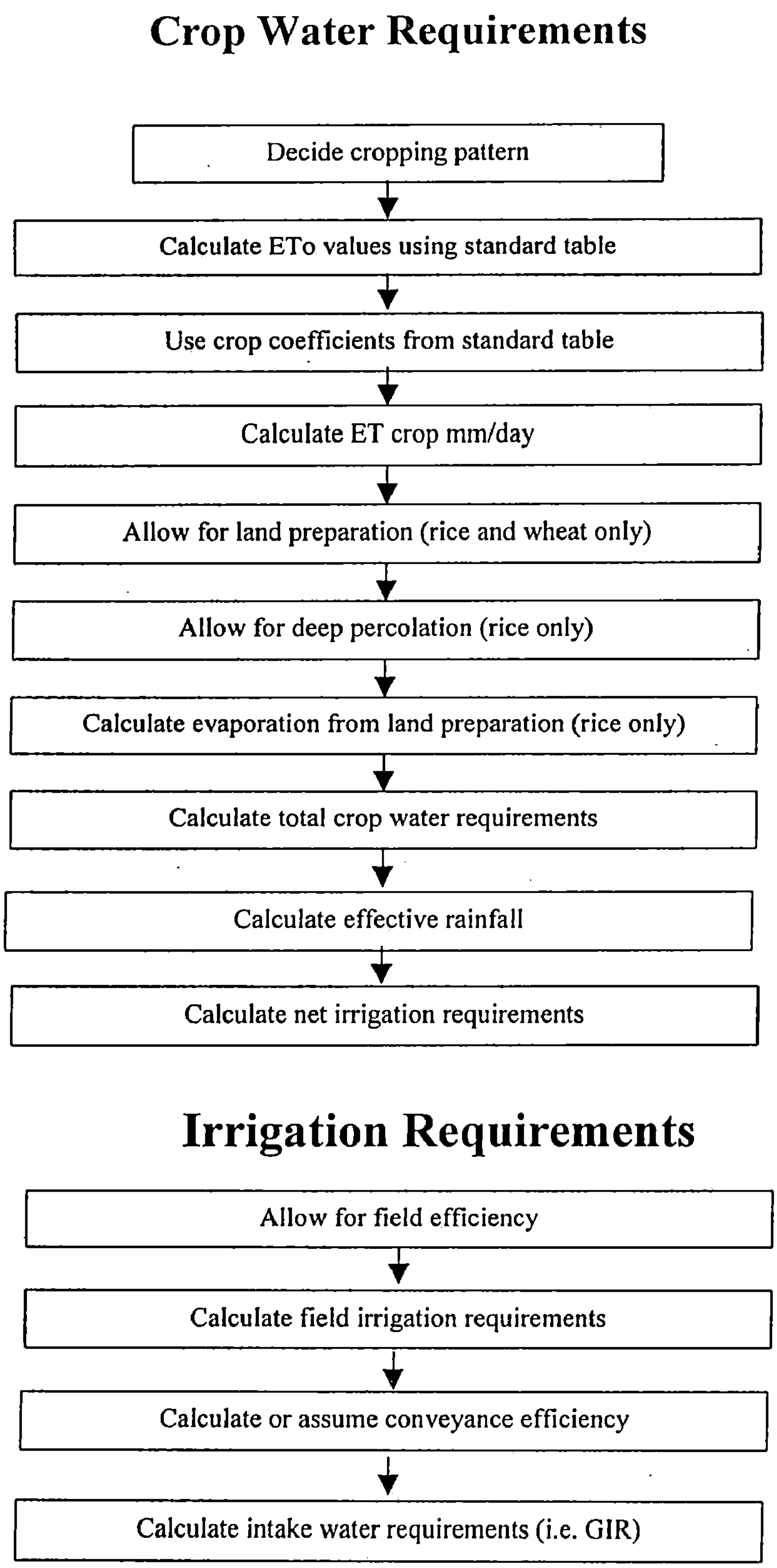
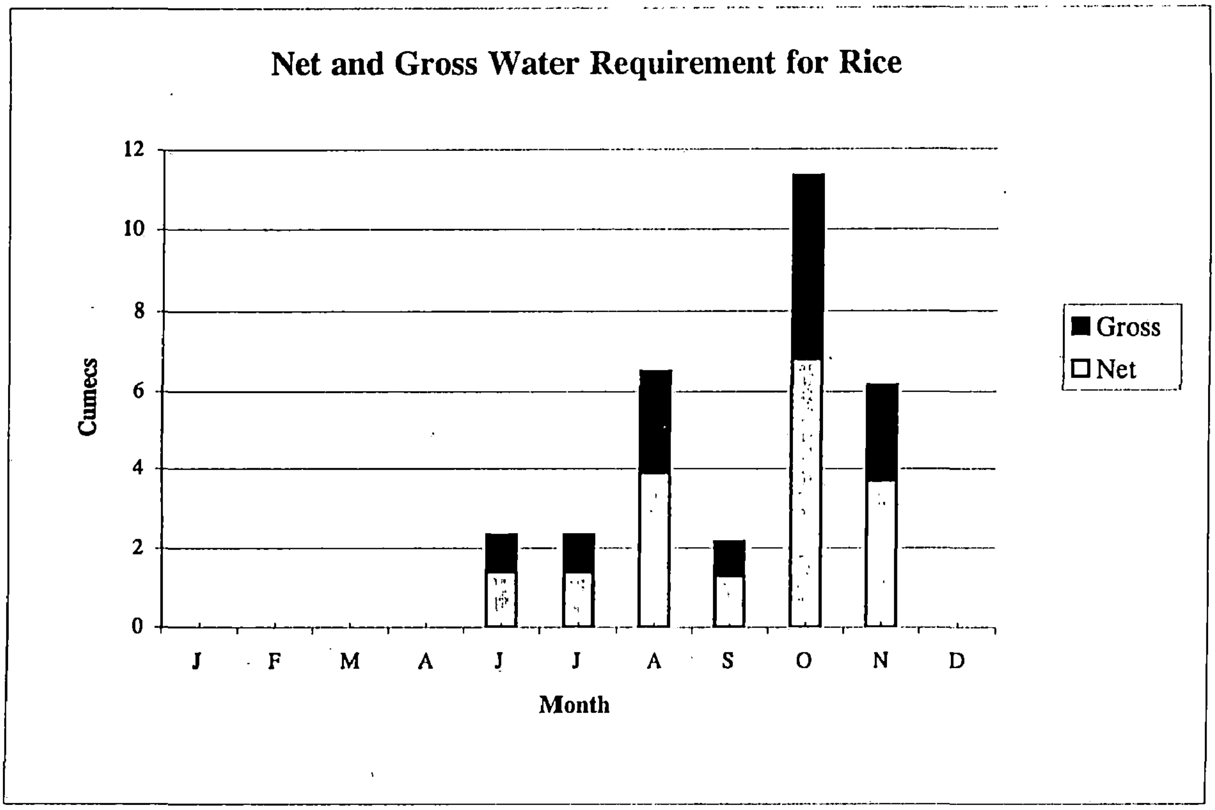
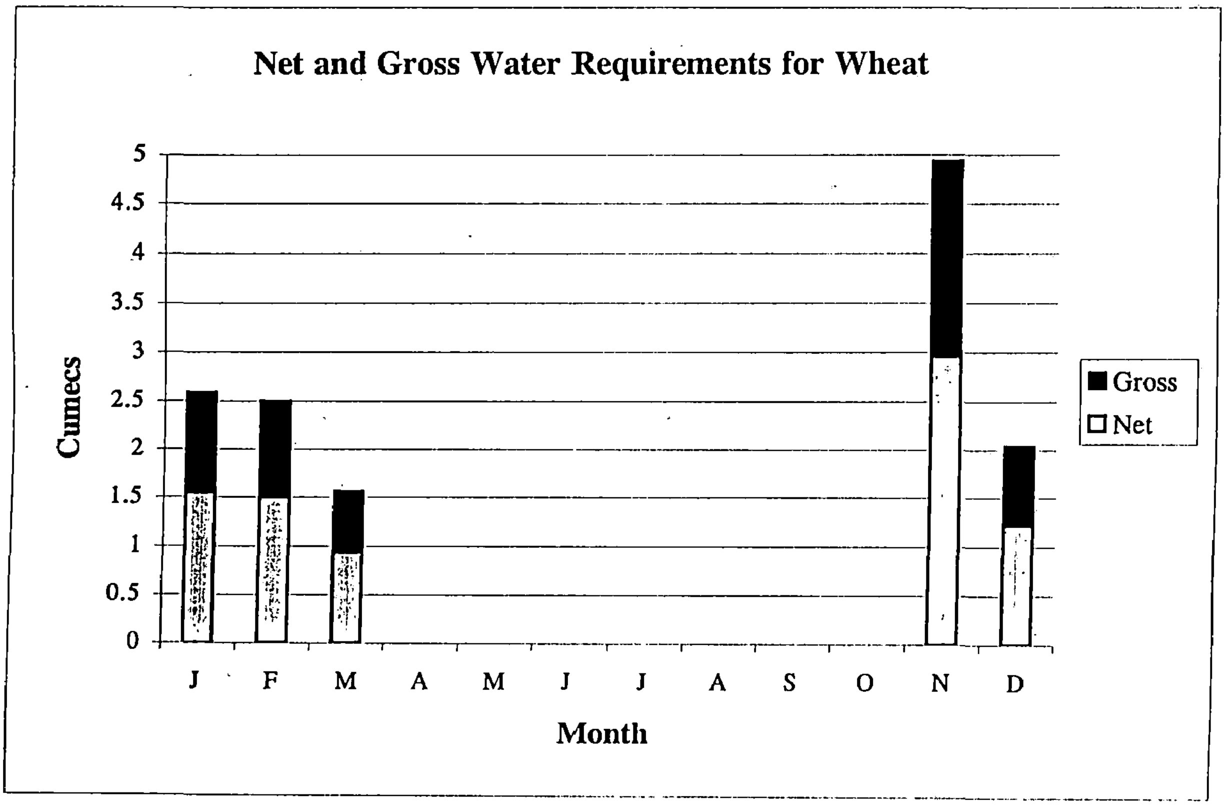


Figure 5.2:



Net and Gross Water Requirement for Rice
12
10
8
6
4
2
0
Cumecs
J
F
M
A
J
J
A
S
O
N
D
Month
Gross
Net



Net and Gross Water Requirements for Wheat
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Cumecs
J
F
M
A
M
J
J
A
S
O
N
D
Month
Gross
Net

PERFORMANCE EVALUATION AND PRESENTATION OF RESULTS

6.1 GENERAL

The performance indicators used in this chapter are

- Water delivery system,
- Environmental sustainability and drainage,
- Agriculture system,
- Maintenance,
- Social.

The results are presented in tabular form

6.2 WATER DELIVERY SYSTEM

6.2.1 Scheme Water Balance

The scheme water balance is essentially a comparison of the available river flows with the diversion requirement of a number of potential cropping patterns. Table 6.1 presents the available river flows for the 1 in 5 year.

Table 6.1: Available river flows (1 in 5 years)

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec
80% reliable flow at diversion point in cumecs	2.20	1.80	1.60	2.40	3.40	9.30	30.50	36.10	27.30	12.10	5.0	3.20

Table 6.2 presents the diversion requirement for a rice (monsoon)- wheat crop sequence and table 6.3 shows the calculation of water deficit for rice / wheat crop sequence, which is equal to 7.15 cumecs over the year and assumed to be meet by ground water (GW) supply by the farmers.

Table 6.2: Water Balance-Monsoon Rice / Wheat

Project: Chandra Canal Irrigation Project Nepal

River: Trijuga

Net command area (ha) - 10,088

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Notes
Period	1-31	1-28	1-31	1-30	1-31	1-30	1-31	1-31	1-30	1-30	1-30	1-31	
Intake water requirement for Rice: (l/sec/ha)						0.14	0.14	0.40	0.13	0.70	0.38		From Table 5.2
Wheat:(l/sec/ha)	0.33	0.32	0.20								0.63	0.26	From Table 5.3
Total intake water requirement in l/s/ha	**0.33**	**0.32**	**0.20**	-	-	**0.14**	**0.14**	**0.40**	**0.13**	**0.70**	**1.01**	**0.26**	
80% reliable river flow at intake l/sec	2200	1800	1600	2400	3400	9800	30500	36100	27300	12100	500	260	From Table 6.1
Reliable irrigated area (ha)	6666.67	5625	8000	NA	NA	70000	217857	90250	210000	17285.70	495.05	1000	80% reliable river flow ÷total intake water requirement
% command area	66	56	79	NA	NA	100	100	100	100	100	5.0	10	

Table 6.3: Water Deficit- Monsoon Rice / Wheat

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Notes
Total GIR over the year in cumec	2.59	2.50	1.56	-	-	2.34	2.34	6.50	2.16	11.34	11.10	2.04	
Water available at diversion point in cumec	2.20	1.80	1.60	2.40	3.40	9.80	30.50	36.10	27.30	12.10	5.0	3.20	Total deficit = 7.19 cumecs
Water deficit in cumec	0.39	0.70	-	-	-	-	-	-	-	-	6.10	-	

6.2.2 Calculation of Irrigation Efficiencies

The movement of water through an irrigation system can be regarded as three separate operations: conveyance, distribution and field application.

6.2.2.1 Conveyance Efficiency

The conveyance efficiency of the canal system can be expressed as

$$e_c = \frac{v_d + v_2}{v_c + v_1}$$

where

v_c = volume diverted from the river (m^3)

v_d = volume delivered to the distribution system (m^3)

v_1 = inflow from other sources (m^3)

v_2 = non-irrigation deliveries from conveyance system (m^3)

If v_1 , v_2 = 0, then

$$e_c = \frac{v_d}{v_c}$$

The full calculation of conveyance efficiency is presented in Annex. E, Table1 From Table 1 (Annex. E)

e_c = 80%

6.2.2.2 Distribution Efficiency

The distribution efficiency is affected by possible seepage losses from the distributaries, by the method of water distribution, and by the size of the farms which are served by the distribution system.

To obtain a reasonable efficiency the distribution network should be well designed and be operated by skilled farmers or a common irrigator representing a group of small farmers.

The distribution efficiency has been defined as:

$$e_d = \frac{v_f + v_3}{v_d}$$

where

v_d = volume delivered to the distribution system (m^3)

v_f = volume of water furnished to the fields (m^3)

v_3 = non-irrigation deliveries from the distributary system (m^3)

The full calculation of distribution efficiency is presented in Annex. E, Table 2.

From Table 2 (Annex. E)

e_d = 92%

6.2.2.3 Field Application Efficiency

After the water is conveyed through a canal system to the (tertiary) off take where the farmer (or farmers) distributes the flow to the field inlet, the ultimate goal is to apply it as uniformly as possible over the field, at an application depth which matches the water depletion of the rootzone. The field application efficiency e_a, is defined as

$$e_a = \frac{v_m}{v_f}$$

where,

v_f = volume of water furnished to the fields (m^3)

v_m = volume of water needed to maintain the soil moisture above a minimum level required to the crop (m^3)

The full calculation of field application efficiency is presented in Annex. E, Table 3.

From Table 3 (Annex E)

e_a = 40%

6.2.2.4 Tertiary Unit Efficiency

A farmer or a group of small farmers, receiving a volume of irrigation water from the conveyance system, has to distribute this water over the farm (s) and fields, where it is applied to the crops. The tertiary unit efficiency, e_u is defined as:

$$e_u = \frac{v_m + v_3}{v_d}$$

where,

v_m = volume of water needed to maintain the soil moisture above a minimum level required for the crop (m^3)

v_d = volume delivered to the distribution system (m^3)

v_3 = non-irrigation deliveries from the distributary system (m^3)

If the non-irrigation deliveries are negligible compared with v_m, which is usually true, we may write

$$e_u = e_d \,.\, e_a$$

The tertiary unit efficiency thus expresses the efficiency of water use downstream of the point where the control of the water is turned over from the water supply organization to the farmers.

Thus, $e_u = 0.92 \times 0.40 = 0.37$

e_u = 37 %

6.2.2.5 Irrigation System Efficiency

The ultimate goal of any irrigation project is to convey and distribute a quantity of water over the project area and to the fields within it, so that the water can be applied to the crops.

This combined efficiency of water conveyance and distribution is expressed by

$$e_s = \frac{v_f + v_2 + v_3}{v_c + v_1}$$

If the non-irrigation deliveries from the conveyance system (v_2) and from the distribution efficiency (v_3) are small compared with the volume of water delivered to the fields (v_f), which is usually true, we may write:

$e_s = e_c \,.\, e_d = 0.80 \times 0.92 = 0.74$

e_s = 74%

6.2.2.6 Overall or Project Efficiency

The overall or project efficiency, e_p, is expressed as

$$e_p = \frac{v_m + v_2 + v_3}{v_c + v_1}$$

If the non-irrigation deliveries from the conveyance system (v_2) and from the distribution system (v_3) are small compared with the volume of water needed to maintain the soil moisture at the required level for the crop (v_m), which is usually true, we may write

$$e_p = e_c \,.\, e_d \,.\, e_a = e_c \,.\, e_u = e_s \,.\, e_a$$

$$= 0.80 \times 0.92 \times 0.40 = 0.29$$

$$\mathbf{e_p = 29\%}$$

6.2.3 Water Delivery Performance

The primary task of the managers of the 'irrigation system', and of the managers of the subsystems (the WUA) is so deliver water in accordance with a plan as intended. The simplest and yet probably the most important, hydraulic performance indicator is

$$\text{Water Delivery Performance} = \frac{\text{Actually Delivered Vol.of Water}}{\text{Intended Vol. of Delivered Water}}$$

Table 6.4 below shows the monthly water delivery performance ratio.

Table 6.4: Monthly Water Delivery Performance

Month	Actual delivered volume of water (m^3)	Intended vol. of delivered water (m^3)	Delivery Performance Ratio	Remarks
Jan.	5892480	6937056	0.85	Average water delivery performance ratio = 2.2
February	4354560	6048000	0.72	
March	2073600	2021760	1.03	
April	-	-	-	
May	-	-	-	
June	12700800	3032640	4.19	
July	31605120	6267456	5.04	
August	31605120	17409600	1.82	
September	30585600	5598720	5.46	
October	31605120	30373056	1.04	
November	12960000	28771200	0.45	
December	8570880	5463936	1.57	

6.2.4 Equity and Dependability

The primary indicator proposed for use in measuring dependability of water deliveries are concerned with the duration of water delivery compared to the plan, and the time between deliveries compared to the plan. This has been defined as:

$$\text{Dependability of Duration} = \frac{\text{Actual Duration of Water Delivery}}{\text{Intended Duraiton of Water Delivery}}$$

$$= \frac{288 \ \ days}{273 \ \ days}$$

$$= \mathbf{1.05}$$

6.3 ENVIRONMENTAL SUSTAINABILITY AND DRAINAGE

6.3.1 Sustainability of Irrigation

The simplest measure of sustainability is given as:

$$\text{Sustainability of Irrigable Area} = \frac{\text{Current Irrigable Area}}{\text{Initial Total Irrigable Area}}$$

The initial area refers to the total irrigable area in the design of the system or in the latest rehabilitation. Where it is appropriate, this ratio can be modified to specifically refer to water logged or saline areas as a percentage of the total irrigable area. Due to the above mention reason the new area can not be extended hence the latest rehabilitation area and current irrigable area is 10,088 ha only. Therefore,

$$\text{Sustainability of Irrigable Area} = \frac{10{,}088}{10{,}088} = 1$$

Hence irrigation is sustainable.

6.3.2 Depth to groundwater

Many of the adverse environmental impacts of irrigation are related to ineffective drainage.

The sustainability of irrigation is determined by the ratio

$$\text{Relative Groundwater Depth} = \frac{\text{Actual Groundwater Depth}}{\text{Critical Groundwater Depth}}$$

The critical groundwater depth mostly depends on the effective rooting depth of crop.

Considering the very deep rooted crop such as sugarcane, its effective root zone depth is equal to 1.80 m and lowest groundwater depth in some part of the command area as reported is equal to 3.0 m. Hence,

$$\text{Relative Groundwater Depth} = \frac{3.0}{1.80} = 1.67 \quad (> 1)$$

The result is satisfactory.

6.3.3 Drainage

The command area of CCIS has the advantage of sloping from north west to south east. There exists many natural drains such as Mahuli, Sundari, Khando, inside the command area. The excess water in the command area flows to these natural drains and finally join the Kosi River. Similarly irrigation water from the irrigated fields join the Kosi River through natural drains. It has been found that there is no any problem of water logging in the command area of CCIS. Therefore, it has no any adverse impact on crop yield.

6.4 AGRICULTURAL PERFORMANCE

Agriculture is the main occupation and major source of livelihood of the sample population in the project area. Summer paddy is the main crop, followed by wheat.

6.4.1 Ethnicity

The command area is inhabited by diverse ethnic groups with a significant majority of native population of Terai origin. Chaudhary account for highest share followed by the other casts such as Brahman, Chhetry, Yadav, Teli, Kurmi, Koiree, Musahar, etc. Immigrant population of hill origin also constitute in large proportion who moved down at various times over last several decades. The immigrant people are mixed up with the local people and culture.

6.4.2 Household size and composition

The average family size of the households is estimated as 8.3. The family size is invariably high in all reaches of the canal system. Males account for 56% of the total population. As high as 30% males and 24% females belong to 14 to 59 years of age group.

Males slightly outnumber the females with a ratio of 113 males for every 100 females. There are some variations in male female's ratio across the distributaries and reaches of the canal system (Annex. E, Table 4).

6.4.3 Occupation and Literacy

About 93% of resident's population is engaged in agriculture as their main occupation. About 44% resident's are just literate without formal education whereas the 22% reported to have attained some form of formal education. Table 5 of Annex. E represents the literacy and occupational status of the sample resident's population.

6.4.4 Land Holding Size

Table 6.5 represents the average land holding size and distribution of land by tenurial status.

Table 6.5: Average Land Holding Size and Distribution of Land by Tenurial Status

Canal segments	Avg. land holding(ha)	Owner cultivated (%)	Rented in (%)	Rented out (%)	Total
1. Head	1.4	91.4	4.4	4.1	100
2. Middle	1.8	77.5	10.7	11.7	100
3. Tail	1.3	97.2	1.7	1.1	100
4. Total / Avg.	1.5	88.7	5.6	5.7	100

6.4.5 Tenancy Structure

Majority of the sample households in the project area are owner-cultivator (75%) followed by owner-cum tenants and owner-cum-rented-out. Table 6.6 below: Presents the land tenancy figure by canal reach.

Table 6.6: Land Tenancy by Canal Reach

Canal segment	Owner only (%)	Owner cum tenants (%)	Tenants only (%)	Owner cum rented out (%)	Rented out only (%)	Total
1. Head	75.0	14.3	0.0	7.1	3.6	100
2. Middle	73.5	6.1	2.0	18.4	0.0	100
3. Tail	77.8	11.1	0.0	0.0	11.1	100
4. Total / Avg.	**75.4**	**10.5**	**0.7**	**8.5**	**4.9**	**100**

6.4.6 Cropping Intensity

The total cropped area in a given period of time (season / year) when expressed in terms of percentage to culturable / cultivable area is termed as cropping intensity for that period (season / year).

The cropped area in Kharif (paddy) and Rabi (wheat) are 9700 ha and 4700 ha respectively and the cultivable area is 10,088 ha. From the given data the cropping intensity is calculated as follows:

(a) Cropping intensity for Kharif season = $\frac{9700}{10{,}088} x100 = 96\%$

(b) Cropping intensity for Rabi season = $\frac{4700}{10{,}088} x100 = 47\%$

Hence, cropping intensity for the year = (96 + 47) % = 143%

Cropping intensity calculated on the basis of cropped area and average land holding size is given in Table 6.7 below.

Table 6.7: Cropping intensities at different reaches of canal system

Canal segments	Average land holding (ha)	Cropped area (ha)	Cropping intensities (%)
1. Head	1.39	1.99	143
2. Middle	1.84	2.53	138
3. Tail	1.34	2.11	158
4. Total / Avg.	**1.52**	**2.21**	**146**

6.4.7 Crop Yields

The yield of major crops such as paddy and wheat is given in Table 6.8 below. The average crop yields are comparatively lower than national average.

Table 6.8: Average yield of crops (MT/ ha)

Canal segments	Paddy	Wheat
1. Head	2.31	1.35
2. Middle	2.00	1.31
3. Tail	2.18	1.03
4. Total / Avg.	**2.16**	**1.23**
5. Nat Avg.	**2.39**	**1.55**

Source: Statistical Information on Nepalese Agriculture, DOA

6.4.8 Inputs Use

The main inputs used in the project area are seeds, chemical fertilizers, and pesticides and insecticides for plant protection. Chemical fertilizers such as Di-Ammonium Phosphates (DAP), Urea and Muriate of Potash (MoP) are used by farmers. The amount of fertilizers used and the percent of households cropping fertilizers are presented in Table 6.9 below.

Table 6.9: Average use of chemical fertilizer in different crops

Canal segments	Paddy (kg / ha)						Wheat (kg/ha)					
	DAP	HH (%)	Urea	HH (%)	Potash	HH (%)	DAP	HH (%)	Urea	HH (%)	Potash	HH (%)
1. Head	55.9	35.9	81.6	45.3	19.1	19.8	54.3	47.4	65.5	44.3	16.4	33.3
2. Middle	40.8	38.7	35.7	41.5	24.0	20.0	74.7	61.9	79.8	68.6	13.3	28.3
3. Tail	64.3	50.0	49.2	50.0	15.0	8.3	39.5	50.0	53.0	58.3	0.0	0.0
4. Tot. / Avg.	**53.6**	**41.6**	**55.5**	**45.6**	**19.4**	**16.0**	**56.1**	**53.1**	**66.1**	**57.1**	**9.9**	**20.5**
5. Nat. Avg.	**65.0**		**192.0**		**50.0**		**109.0**		**174.7**		**41.7**	

Source: Agriculture Information Division, Department of Agriculture

6.4.9 Agricultural Support Systems

Notable success of agricultural performance cannot be expected without proper and reliable supports of line agencies. Coordination and mutual understanding among these agencies are equally vital in agricultural development. Agricultural Development Office, inputs and credit supplying agencies and District Irrigation Office should always work jointly in order to fulfill each others objectives and targets.

(a) Extension and Training

Agricultural extension is on of the vital aspects in overall agricultural development. It works as conduit transferring the research findings in farmers' fields. It plays crucial role in disseminating modern and latest technologies of agriculture of farmers. The responsibility of agricultural extension falls on Agricultural Development Office (ADO) located in the district headquarter Rajbiraj; and its sub-centers scattered in different areas of the district. There are five agricultural sub-centres (Fatehpur, Kanchanpur, Portaha, Mahuli and Bathnaha) meant to provide technical services. The main duty of these sub-centres is to impart technical know-how to the farmers and carryout outreach programs through mini-kit distribution in the area.

(b) Credit

Agricultural credit is another important input for the agricultural development. Credit is required to purchase agriculture inputs, seeds, fertilizers and different agricultural tools and equipment etc. There are a number of financing institutions in the command area. They are listed below:

- Agricultural Development Bank (ADB/N), Kanchanpur and Rajbiraj
- Small Farmers Development Programs (SFDP), Odraha
- Gramin Vikash Bank, Kanchanpur
- Nepal Bank Limited, Kanchanpur

In the project area, credit delivery in agriculture crop production is mainly carried out by Agriculture Development Banks located in Kanchanput and Rajbiraj.

(c) Cooperatives (Sajhas)

The role of cooperatives in supplying inputs is quite praise worthy but it has not yet served farmers to the required extent. The cooperative society Ltd. Located in Kanchanpur is successfully serving the farmers. Most of inputs, fertilizers, improved and hybrid seeds, pesticides and insecticides and small tools and equipment required for crop cultivation are available in the society. Different categories of chemicals used for plant protection are also available in the society.

(d) Marketing

The project area is well connected by road networks. Fatehpur, Hanuman Nagar and Rajbiraj are the major permanent market centres of the area where farmers sell their agricultural produces. All these markets are in close proximity with different transport means for transporting the food grains. Beside, the temporary markets known as "Haat Bazzars" take place in and around the command area which provide opportunities for the sale of any kind of farm product.

6.4.10 Economics of Agriculture

The main crops grown in the project area are paddy and wheat. The crop budget calculated for paddy and wheat are presented in Table 6.10 below whereas the detailed breakdowns of the cost and returns for the year 1998 presented in Annex. E, Table 6 and 7 respectively.

Table 6.10: Gross Returns from Different Crops under Irrigated and Rainfed Condition

Particulars	Paddy		Wheat	
	1	2	1	2
1. Total Cost	11077	9897	10270	9017
2. Total Income	18863	14221	12634	10688
3. Gross Returns	7786	4324	2364	1671

Source: 1= Irrigation condition and 2 = Rainfed condition

Source: Diagnostic Study of CCIS, Nepal (1998).

6.5 OPERATIONAL AND MAINTENANCE PERFORMANCE

6.5.1 Operation

Management requirements for operation of the system are summarized in Table 6.11. This table states the obvious, whenever a design includes an adjustable structure, there is an operational input required.

Table 6.11: System management inputs required for each design

Type of structures	Operations			Maintenance	
	Discharge at head of canal	Offtake gates	Regulator gates	Canal cross section	Control gates
Ungated overflow	*	-	-	(*)	-
Submerged orifice	*	-	-	**	-
Gates, little cross-regulation	*	*	-	*	*
Gated, fixed weir cross-regulation	*	*	-	(*)	*
Gated, adjustable cross-regulation	*	*	*	(*)	*
Downstream control	-	-	-	(*)	**

Key to symbols: ** critical * important (*) to avoid losses - no input

Fixed division system:

Fixed division systems can only be operated at the control locations provided at the head of each major canal section. Although this means that there is a relatively limited number of locations at which managerial inputs can be required, the design requires very close attention to inputs at these locations because there are no further opportunities downstream to compensate for poor upstream management.

(a) **Ungated over flow Systems** will respond to water level or discharge variations equally throughout the entire system. Equity is unaffected, unreliability is felt equally at all points, as is the short fall in adequacy.

(b) **Submerged orifice systems** respond in an entirely different manner to upstream fluctuations, although the extent of the response is highly dependent on design. The Adjustable Proportional Modules (APM) widely used in rehabilitation works in the project show smaller variations in discharges as upstream water conditions fluctuate compared to simple pipe outlets. Orifices near the head of the system will have smaller fluctuations in discharge and smaller percent reductions in discharge than orifices near the tail of the canal. For these systems to function at designed levels of performance, it is essential that discharges into the ungated sections are kept as close as possible to designed discharge and discharge fluctuations kept to a minimum.

Gated division systems:

Gated division systems require greater operational inputs. Operational inputs are required at every offtake structure, and increase further as the number of moveable cross-regulators increases.

Because such systems have the potential to meet a number of different demand conditions they also require a clear monitoring process:

- checking of actual discharges or water levels and comparison with the targets laid down in operational plans, and
- monitoring of field-level conditions that determine whether the targets themselves were appropriate or require modification for the next set of operational plans.

System of this design also require much greater attention to communication both among agency staff and between agency staff and farmers.

6.5.2 Maintenance

Maintenance requires a completely different pattern of management inputs from operations. This has been illustrated in Table 6.11.

Maintenance is required for three different purposes:

- minimizing conveyance losses,
- prevention of failure of control structures, and
- sustaining the hydraulic conditions required by the design for effective water distribution.

Conveyance losses: All systems, irrespective of design, require maintenance to control conveyance losses as this directly affects objectives of adequacy and equity. Variations in the intensity of maintenance inputs relate to the physical environment (notably soil type, climate and rates of weed growth) and the total length of canals. These inputs are more or less constant for each system, and can only be changed through lining, compaction, or other structural change. Determination of the actual rate of loss, and its change over time, requires monitoring.

Prevention of failure of control structures: Maintenance intensities for prevention of failure of control structures are also easy to quantify, and are constant for each system. The intensities increases as the number of control structures increases. Maintenance is critical: for automatic systems and instantaneous demand systems if gates are not maintained properly and thus do not respond to changes in water levels, then the system objectives cannot be met.

Sustaining the hydraulic integrity of the conveyance system : Maintenance requirements to sustain hydraulic integrity of the conveyance system are highly dependent on the system design. If the system relies on open channel hydraulic relationships to achieve the water distribution objectives then maintenance will be the critical management input. Failure to maintain the canal cross section at or close to design specifications in submerged orifice systems or gated systems with little or no cross-regulation means that head-discharge relationships at offtakes will be different from those intended, and the result will be a lower than expected performance of water distribution.

6.5.3 Operation and Maintenance Practice in the Project

The system carries a long history of operation and maintenance under various arrangements ever since its construction. In the earlier period the O&M was taken care by then Badahakim of Sapatari. After Rana regime, the O & M responsibility shifted to then Irrigation Department which was called Nahar Bibhag. At that time, the system enjoyed the privilege of receiving adequate attention and resources. At present the O&M responsibility of the system lies with the District Irrigation Office (DIO) Sapatari.

In the past the canal operation schedules were normally prepared by the Project officials with little or no consultation of user farmers. However, after the formation of Water users Association (WUA), the agency and WUA are coming n close contacts to decide and prepare the water supply schedules.

Usually, canal is opened on the first week of June for monsoon paddy. After the opening of canal it takes about one to two weeks to reach the water at tail end of the command area. The main canal is normally closed on first week of October. However WUA is demanding to release irrigation water two weeks earlier than the regular opening date in order to start paddy transplantation earlier. Similarly, for Rabi crops canal is opened on second week of December and closed on last week of February. No regular irrigation service is provided by the agency for spring crops.

O&M practices have been changing over the years with the changes in management responsibility. O&M rules were strict in the past. Violation of rules and any illegal operations such as cutting canal banks, opening gates by unauthorized persons, using service road by farmers, grazing livestock along canal banks would lead to punishments of varied extent depending upon the seriousness of damage to the canal system. As a result of this, the system was in good condition and provided satisfactory services. The overall operation and maintenance practices have eroded considerably over the years for various reasons. Illegal operations such as removing gates, canal bank cuttings, demolishing Water Courses have been observed at various places of the canal system. Due to constantly deteriorating situation of O&M practice the system has largely failed to proved desired level of services.

Regular maintenance of the canal is performed during the closing time especially between February and July. Required maintenance is prioritized based on available budget.

Emergency maintenance of the system is done whenever needs arise. The process of such maintenance involves hiring contractors and making instant payments upon submission of bills. Other way of emergency maintenance is to get the work done by deploying labors by agency. The field channels and tertiaries are maintained by farmers themselves. Sometimes heavy equipment is used for desilting canal without disrupting water supplies in the canal system.

6.5.4 O & M Staffing

This system was constructed during Rana regime. The construction was done by then Rana Government based on technical and financial viability. No social institutional aspects were considered. Although, large voluntary contributions were sought during construction and farmers were hardly involved in regular operation and maintenance of the system in the past.

The followings are the staff at DIO Sapatari

1.	Senior Divisional Engineer	1 no.
2.	Civil Engineer	2 nos.
3.	Agriculture Engineer	1 no.
4.	Overseer	10 nos.
5.	Draft Man	1
6.	Nayab Subba (Head Clerk)	1
7.	Accountant (Lekhapal)	1
8.	Kharidar	1
9.	Junior Accountant	1
10.	Pump Operator	1
11.	Mechanical Gate Operator	6
12.	Amin (Survey Technician)	2
13.	Typist	1
14.	Line man	1
15.	Dhalpa (Canal Watch Man)	3
16.	Bahidar (Junior Clerk)	1
17.	Driver	2
18.	Assistant Supervisor	4
19.	Peon	26
20.	Sociologist	1

6.5.5 Effectivity of Infrastructure

To quantify the maintenance performance, and to asses the extent to which (control) structures can be operated as intended, the following ratio is used.

$$\text{Effectivity of Infrastructure} = \frac{\text{No. of Functioning Structures}}{\text{Total No. of Structures}}$$

There are altogether 398 structures in the canal networks and out of which only 317 structures are functional. Hence,

$$\text{Effectivitivity of infrastructure} = \frac{317}{398} = 0.80$$

Since, this ratio is less than unity, this means that effectivity of infrastructure is out of satisfactory.

6.5.6 O + M Fraction

To quantify the effectiveness of the irrigation agency with respect to the actual delivery of water (operation) and the maintenance of the canals and related structures, the O + M fraction is used which is defined as:

$$\text{O + M fraction} = \frac{\text{Cost of Operation + Maintenance}}{\text{Total Agency Budget}}$$

O & M budget of the project for the year 1997-98 was NRs 25, 72,000 and the cost of the operation and maintenance was also the same. Therefore,

$$\text{O \& M Fraction} = \frac{25{,}72{,}000}{25{,}72{,}000} = 1$$

Since, the fraction is equal to unity that means the result is upto satisfaction.

6.5.7 Fee Collection Performance:

This indicator has been defined as:

$$\text{Fee Collection Performance} = \frac{\text{Irrigation Fees Collected}}{\text{Irrigation Fees Due}}$$

Irrigation service fee (ISF) is the major resource which the agency can collect from user farmers against the irrigation service rendered. This collection is forwarded to the government treasury. At present ISF collection is very poor whereas the O&M cost of the system is rising every year. The rate of ISF is NRs 60/ha/crop which is quite low in comparison to the O&M cost. The ISF collections of this system are presented in Table 6.12 below:

Table 6.12: Irrigation service fee collection records

S.NO.	Fiscal Year	To be collected	Collected	Balance to be collected
1.	1975/76			14997.90
2.	1976/77	441911.00	370997.42	70914.26
3.	1977/78	501990.07	412891.40	89098.67
4.	1978/79	515328.00	311591.42	203737.00
5.	1979/80	536199.00	145351.96	390848.00
6.	1980/81	428786.80	68408.35	360378.45
7.	1981/82	479421.34	64583.17	414838.17
8.	1982/83	434489.14	32161.00	402327.85
9.	1983/84	490989.87	64003.00	396986.58
10.	1984/85	536157.60	71207.44	464950.16
11.	1985/86	567808.29	19115.29	548693.38
12.	1986/87	505197.26	4065.25	501132.01
13.	1987/88	493052.79	1458.20	491594.56
14.	1988/89	517231.00	130494.48	386736.52
15.	1989/90	502388.05	12581.25	489806.76
16.	1990/91	494849.45	68704.30	426145.15
17.	1991/92	517301.40	3567.93	513733.47
18.	1992/93	505480.00	49702.62	455777.78
19.	1993/94			444232.70
20.	1994/95	487095	25401.75	461684.25

From the above table, it is clear that the trend of paying ISF is very discouraging. About 7.5 million has remained as over dues upto F.Y 1996-97.

For the year 1996-97,

$$\text{Fee Collection Performance} = \frac{25402}{461684} = 0.06$$

6.6 SOCIAL CAPACITY

This indicator refers to the social capacity of people and organizations for managing and sustaining, the irrigated agriculture system.

6.6.1 Technical Knowledge Staff:

$$\text{Technical Knowledge Staff} = \frac{\text{Knowledge Needed for Job}}{\text{Actual Technical Knowledge of Staff}}$$

Actual technical knowledge and staff is ascertained through tests, while required knowledge is inherent in the job description. Since, the staff is selected through standard tests, interviews or and through public service commission. Hence, technical knowledge of the staff is considered satisfactory.

6.6.2 The Water Users Associations

(i) Water Users Associations

The details of WUA committees at each level of canal system are presented in Table 6.13 below:

Table 6.13: WUA Formation in Different Levels of Canal System

S. NO.	B. Canals/ Distributaries	S. Branch/ Minors	VCs/WCs	WUA Formation	WUA Formation		Total Committees
					1996/97	1997/98	
1.	Odhara	1	-	18	18	1	19
2.	Maleth	1	-	6	7	-	7
3.	Baluwa	1	-	5	6	-	6
4.	Kanchanpur	1	-	9	-	10	10
5.	Baramajhiya	1	3	27	-	31	31
6.	New Hanumannagar	1	3	53	-	57	57
7.	Goithe	1	-	18	-	19	19
8.	Dimon		-	16	-	17	17
9.	Banauli Bhagbatipur	1	2	29	-	32	32
10.	Banauli Pakari (ext.)	1	2	31	-	34	34
11.	Main Canal (D.A.S. branch)	-	10	38	7	41	48
12.	Main Canal Minor	-	4	7	3	8	11
	Total	**10**	**24**	**257**	**41**	**250**	**291**

Source: CCIS, Project Office, 1998

(ii) Organizational Structure of the WUA

It has been found that there are different committees at different tiers of the canal system. Main committee is at the highest hierarchy followed by branch committees, sub-branch or minor committees and tertiary / VC/ WC level committees respectively. The general assembly (GA) is above all these committees. The structure of various level committees accordingly to different levels of canal system is given in Figure 6.1.

The general assembly is the apex body which is responsible to guide and advise the WUA main committee and other committee as and when needed. The members of the general assembly elect executive bodies viz. Chairperson, vice-chairperson, secretary and treasury of the main committee at main canal. The members of general assembly represent water users of each village channel and other levels of the canal system.

In CCIS Nepal, WUA committee members are selected on the basis of land area. Size of the committee varies according to land size of a particular location. The size of a committee varies form as low as 5 members to 13 members. Normally, four different size of committees have been formed based on following land size category.

	Land Size	Size of the Committee
1.	25 ha	5 member committee
2.	25-50 ha	7 member committee
3.	50-70 ha	9 member committee
4.	> 70 ha	11 -13 member committee

The main committee constitutes a total of 33 officials comprising of representative members of different tiers of canal system. The position and number of main committee officials is presented in Table 6.14 below:

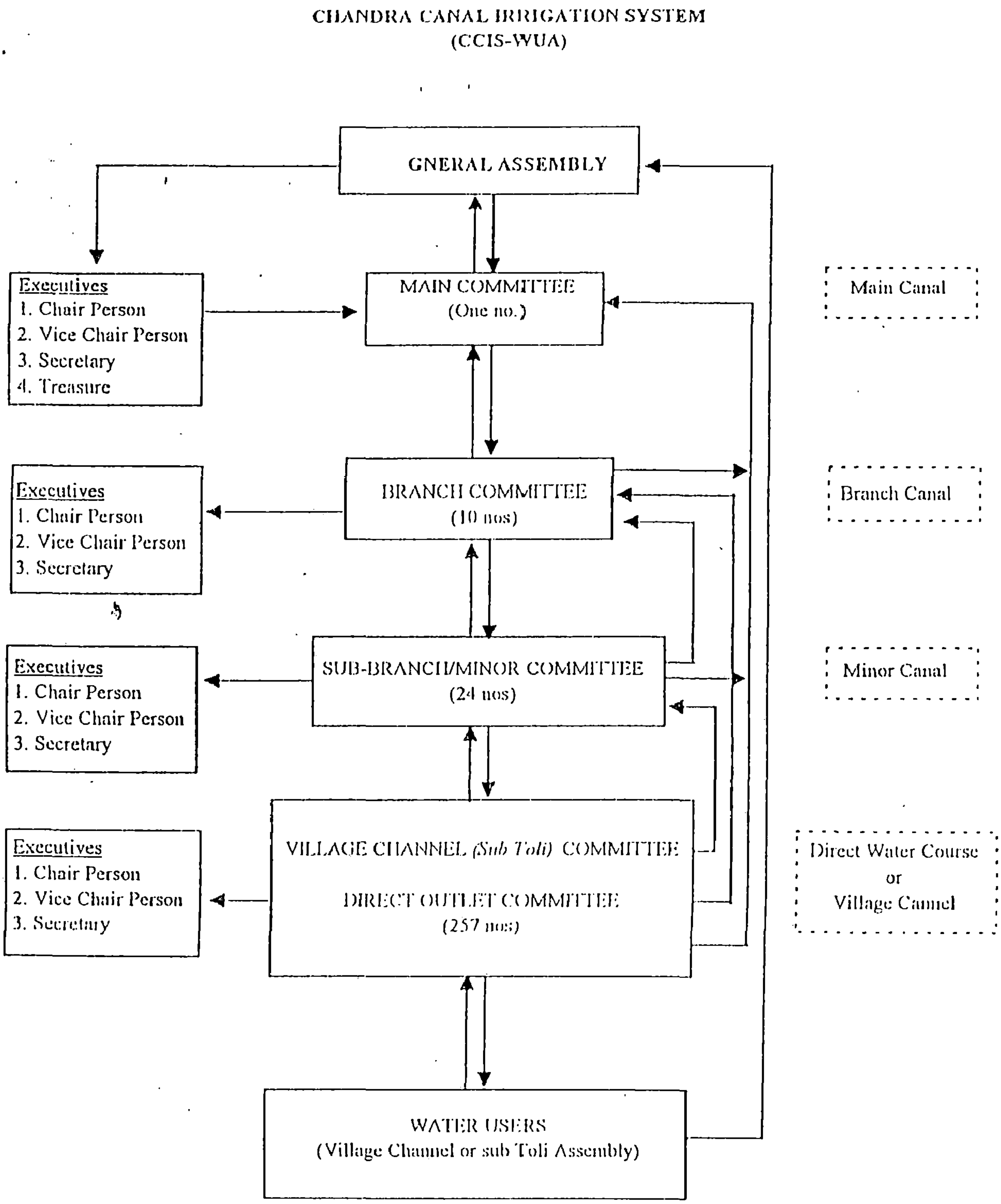
Table 6.14: Main Committee Officials in CCIS (1998)

S. No.	Position	Total No.
1	Chairman	1
2	Vice Chairman	1
3	Secretary	1
4	Treasurer	1
5	Members	29
6	**Total**	**33**

6.7 RESULTS

Indicators	Result
1. Irrigation Water Delivery System	
(i) Irrigation efficiencies	
(a) Conveyance efficiency	80%
(b) Distribution efficiency	92%
(c) Field application efficiency	40%
(d) Tertiary unit efficiency	37%
(e) Irrigation system efficiency	74%
(f) Overall or project efficiency	29%
(Ii) Water Delivery Performance	
Average (yearly)	2.2
(iii) Equity and dependability	1.05
2. Environmental Sustainability and Drainage	
(i) Sustainability of irrigable area	1
(ii) Relative ground water depth	1.67
(iii) Drainage	no water logging
3. Agricultural System	
(i) Average land holding size	1.5
(ii) Cropping intensity	143%
(iii) Crop yields:	
- Paddy	2.16 MT/ha
- Wheat	1.23 MT/ha
4. Operation and Maintenance	
(i) Effectivity of infrastructure	80%
(ii) O + M fraction	1
(iii) Fee collection performance	6%
5. Social	
(i) Technical knowledge staff	O.K.
(ii) Water users association activities	O.K.

Figure 6.1 : Organizational Structure of the CCIS' WUA Committee



CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS:

The concept of performance is fundamental to the successful management of any enterprise. Managers must know what their enterprise is trying to achieve, and to what extent these aims are currently being achieved. When there is evidence of significant under-achievement, then managers must identify and apply performance-enhancing strategies. These performance-enhancing strategies have usually had to be found by some combination of experience, analysis, and analogy with events observed at other enterprise.

Management, in many organizations, has been focused upon the provision of facilities and inputs, while measurement, recording and publicizing of outputs have not been emphasized. Monitoring itself has tended to be understood as meaning some process of checking up that an operational plan or set of operating rules is being followed, rather than verification that objectives are being attained.

Performance monitoring in irrigation should not be regarded just as a technological activity, but as a central determinant of institutional attitudes and financial efficiency. The irrigation system specially the larger surface irrigation systems are normally quiet complex and need an appropriate process of evaluating the performance so that the attainment of benefits and the sustainability of the system be examined and ensured.

The main points drawn from the results and study of the Chandra Canal Irrigation System, Nepal are given as follows:

- It has been observed from the study that the physical system except tertiaries / watercourses are in good conditions.
- In the lean periods of flow e.g. in the months of November to February, monthly water delivery performance ratio is less than unity. This means that there is inadequate supply of water for the requirement of crop needs. It has

been observed that farmers are utilizing ground water to fulfill the crop water requirements in addition to surface water resources. Conjunctive use of surface and ground water is one of the practical techniques to mitigate the shortage in canal supply subjected to constraint of steep variation in the river supply during the year. The underlying objective of conjunctive use of surface and ground water is generally to strengthen the supplement of canal irrigation system. The needs and scope of conjunctive use, for optimally utilizing ground water to fulfill the crop water requirements in addition to surface water resources has been discussed in detail in Chapter 3.

- Conveyance efficiency has been found out 80% (World Average is 90%)
- Distribution efficiency of the system as calculated is 92% (World Average is 80%). Higher efficiency is due to lack of accurate data from the field.
- Field application efficiency is 40% (World Average is 40%)
- Tertiary unit efficiency of the system is 37% (range is 27% - 41%, Bos and Nugteren).
- Overall or Project efficiency has been found out 29% (world average is 28%).
- Relative ground water depth is 1.67 (>1) which shows that there is no adverse environmental impacts of irrigation in the command area.
- At present cropping intensity over the year is 143% which is less than the National Average, (Nepal) 175 % in irrigated areas.
- The yield of crops such as paddy and wheat has been recorded as 2.16 and 1.23 MT/ha respectively (National Average, Nepal: paddy = 2.39 MT/ha and wheat 1.55 MT/ha).
- Fertilizers used for the crops are not to the standard (standard ratio for paddy and wheat is N:P:K = 120:60:60). However, actual input of fertilizers to field crops should be based on the measurement of soil nutrients available after the field test.
- Gross returns from paddy and wheat are less.
- Agricultural support systems e.g. banks, cooperatives and markets are well established in the command area and it has been observed that farmers are getting reliable services from the above agencies.

- Effectivity of infrastructure is 0.80<1. It shows that there is need of improvement of operation and maintenance of the system.
- Fee collection performance is very poor, 6% only. The urgent attention is needed to get all the dues clear from the farmers, as this money can be utilized for the maintenance and operation of the system, in turn this will help farmers to be benefited from the increased production of crops.

7.2 RECOMMENDATIONS

- Provision of flow measurements at important regular points of the canal system on monthly / seasonal / yearly basis.
- A conjunctive use study shows that augmentation of canal water supply can be carried out during lean water supply through canal constructing a well field near the middle reach of the canal. The economical well field, so that cost of construction and energy consumption is minimum, can be designed.
- Modernization of the project-for better prosperous life of the farmers through increased crop production, reduction in labor required for operation., improved water use efficiency, environmental conservation etc.
- In the lean period of river flow, operation of irrigation supply can be practiced taking into account "yield response to water, FAO No. 33" as discussed in Chapter 3.
- To strengthen and increase the capability of water Users Association of CCIS as it is in the process of Turnover Scheme.
- To raise the water charges from NRs 60/ha to some realistic limits.
- Effective cooperation between different line agencies for higher yield is needed.

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APPENDICES

APPENDIX A

FIGRUES OF CASE STUDIES

CONTENTS

LIST OF FIGURES

Figure 1: Weekly relative water supply (RWS) in three Terai systems in Nepal

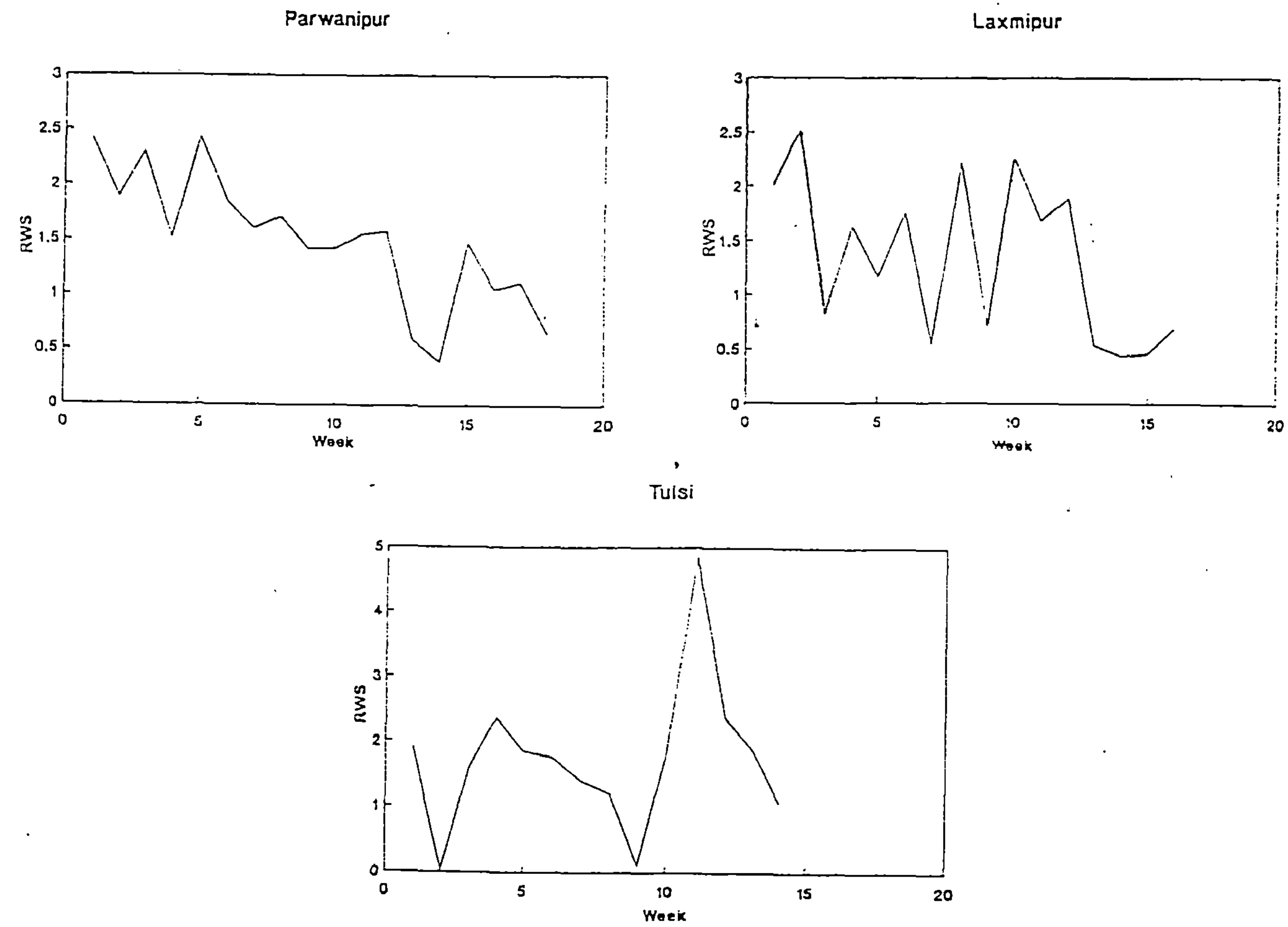


Figure 2: Weekly relative water supply (RWS) in three Hill systems in Nepal

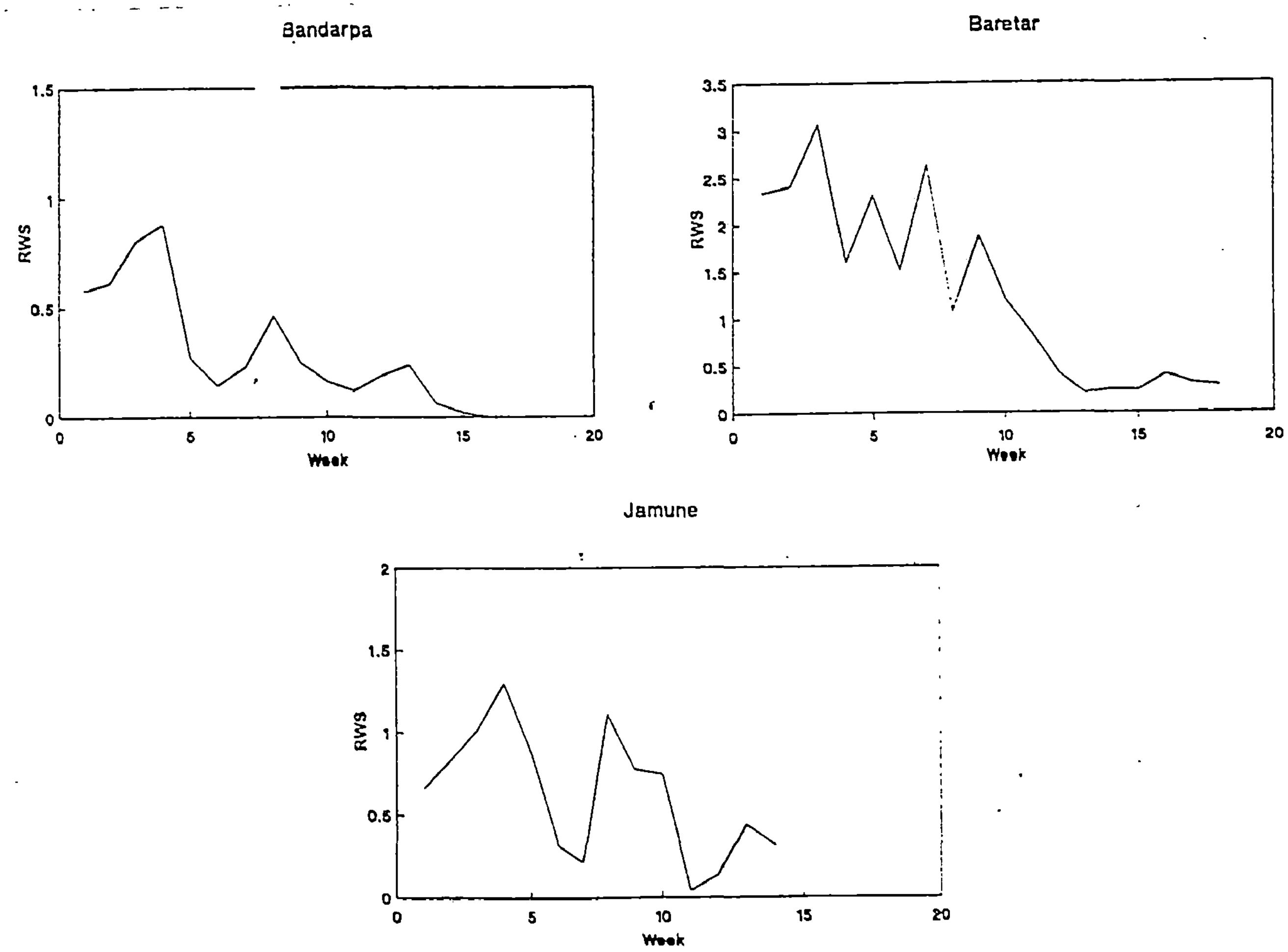


Figure 3: Water availability index and yield in three Terai systems in Nepal

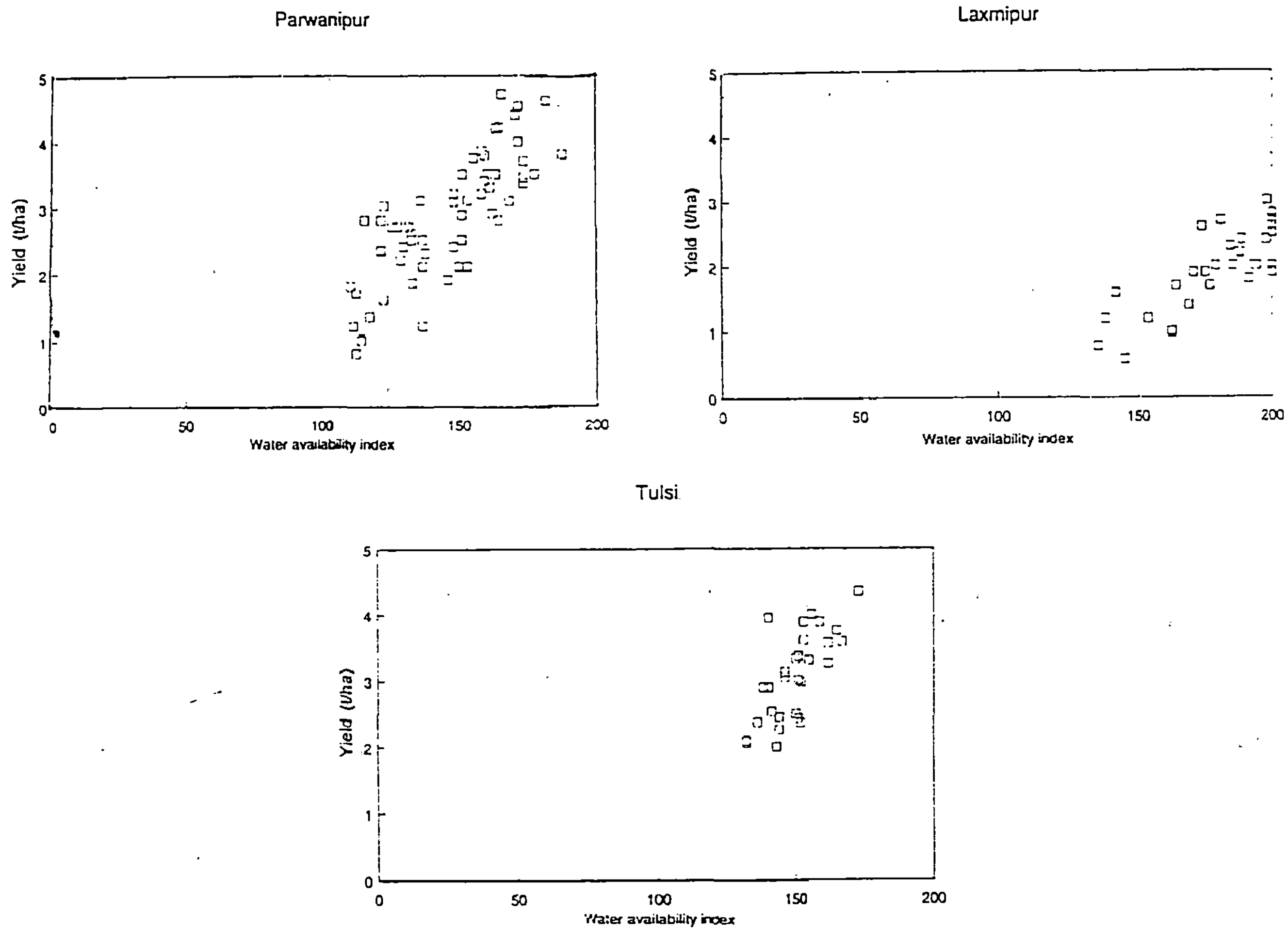


Figure 4: Water availability index and yield in three Hill systems in Nepal

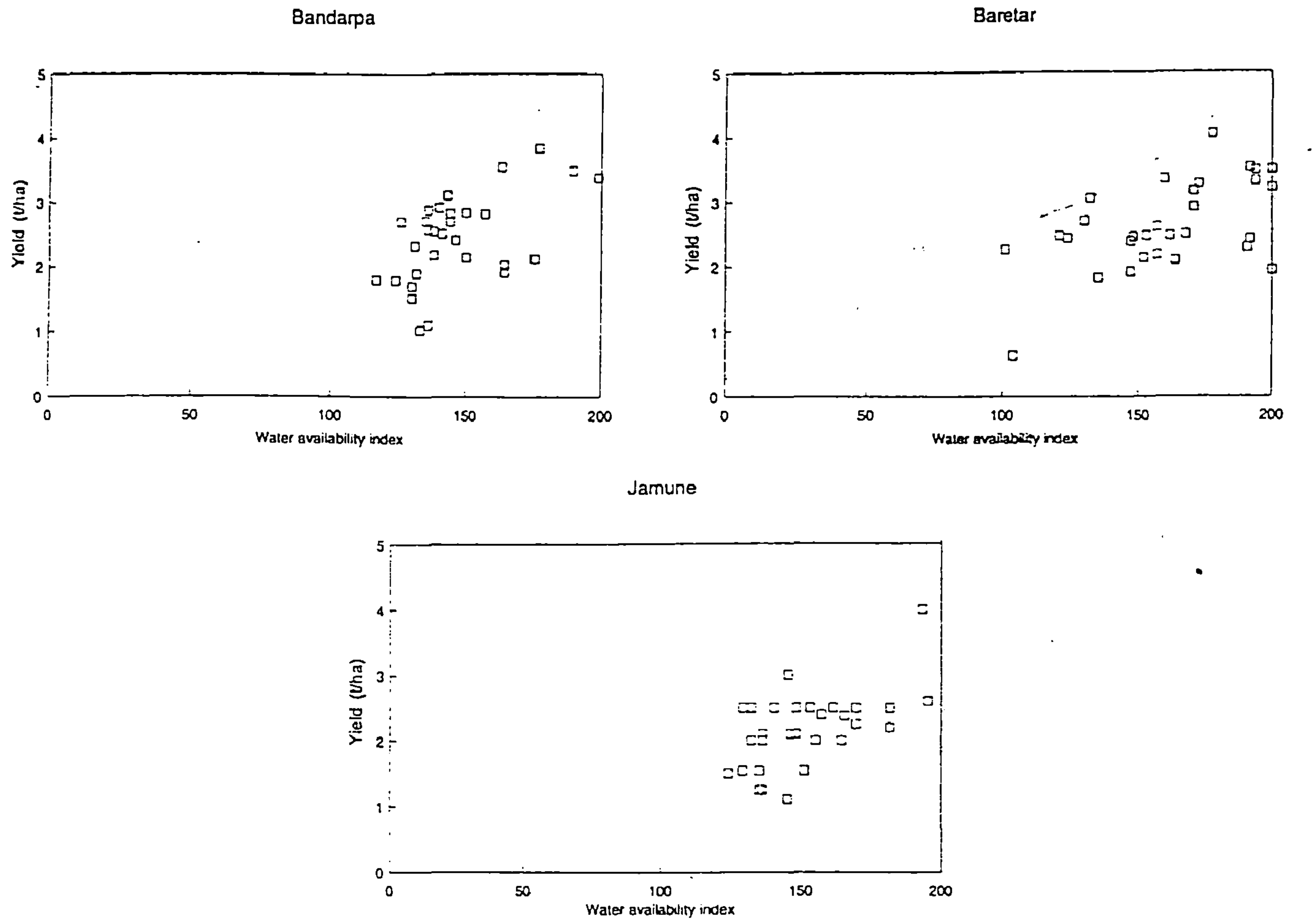
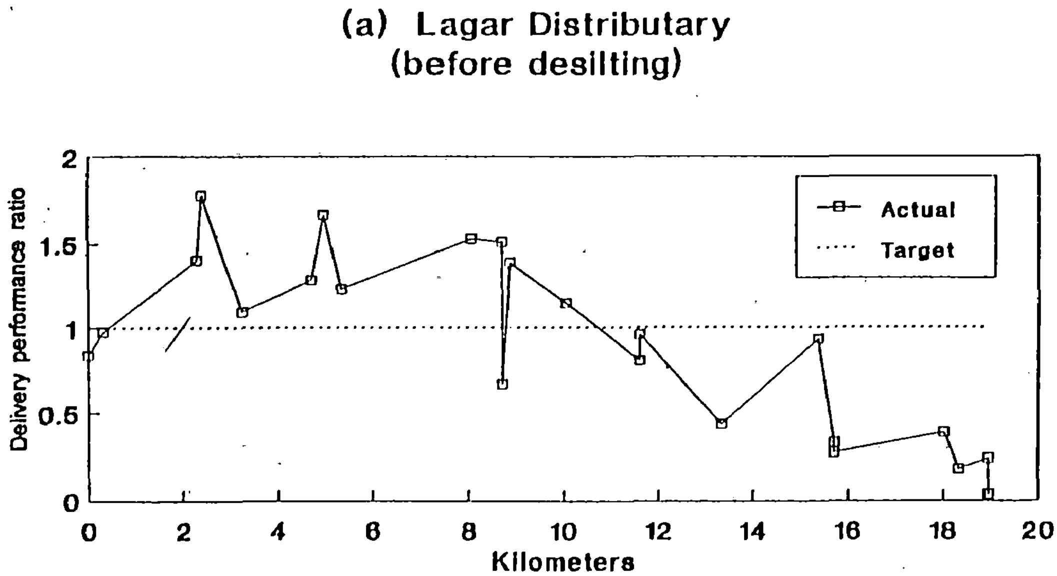


Figure 5: Water distribution equity, Lower Chenab Canal, Pakistan



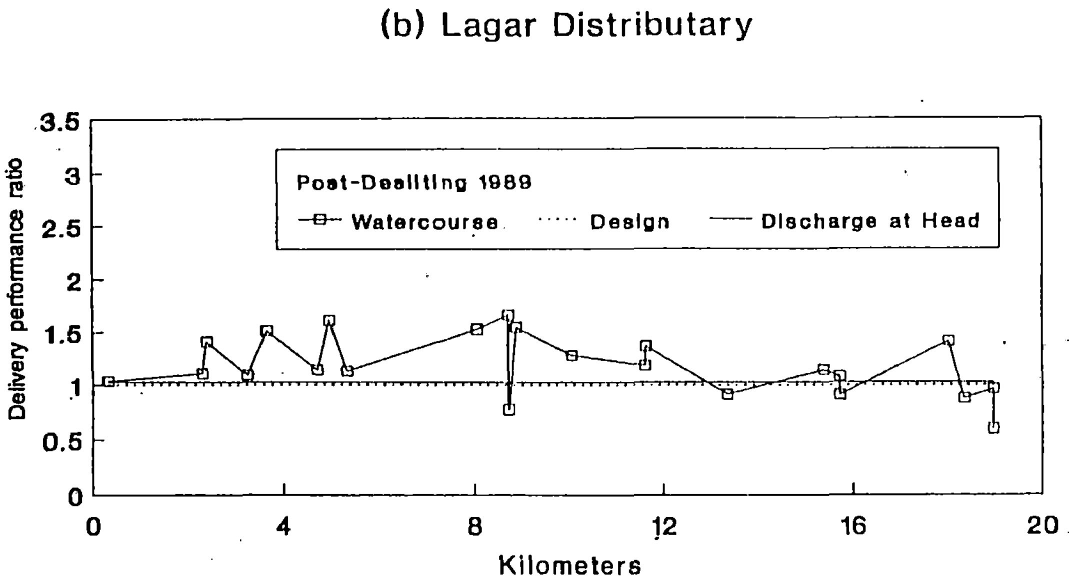
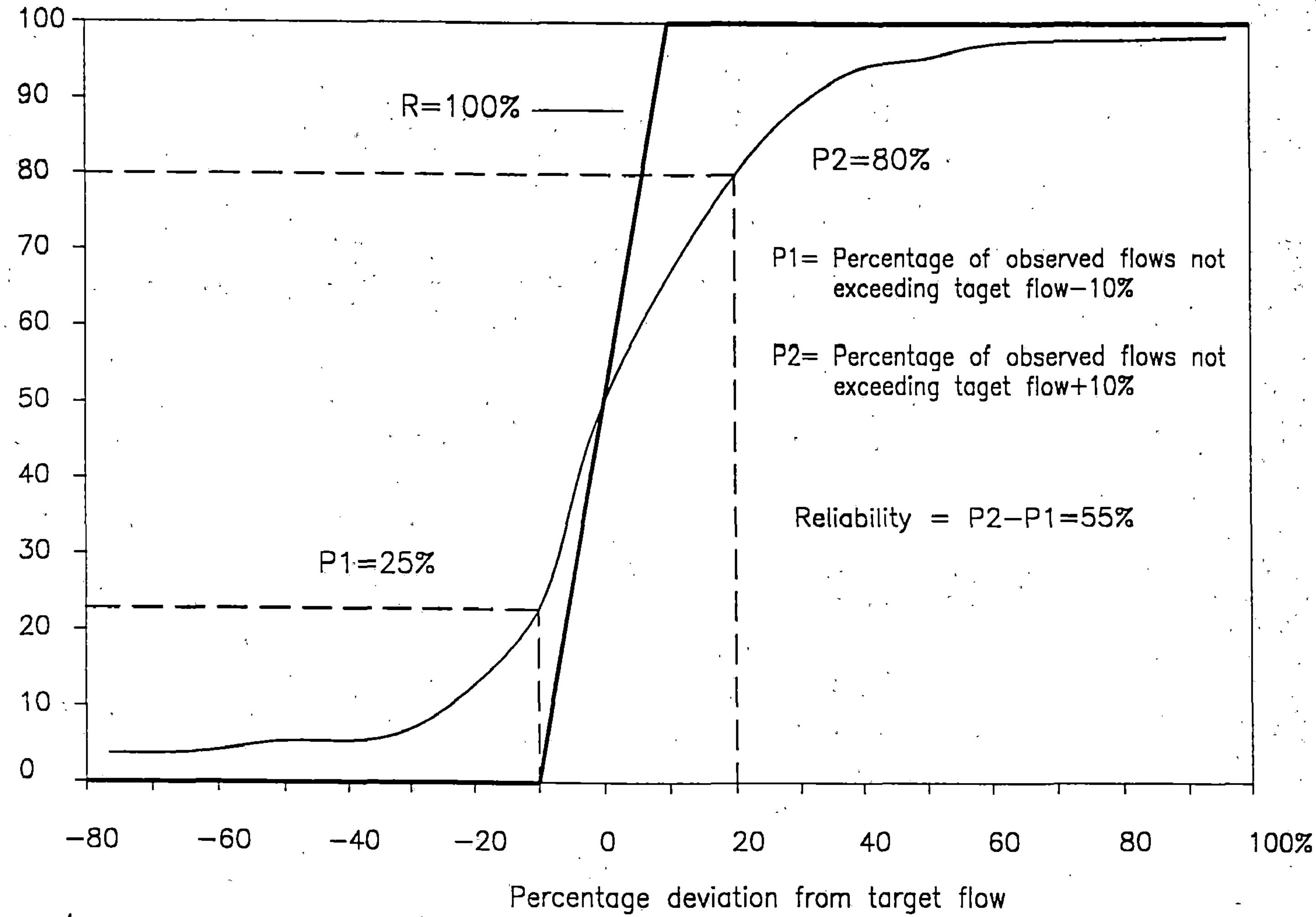


Figure 6.0 – Typical analysis of reliability from Kraseio (Head IR Canal)



(Source: Makin et al, 1991)

APPENDIX B

LOCATION AND INDEX MAP OF THE PROJECT

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Figure 1 : Location Map

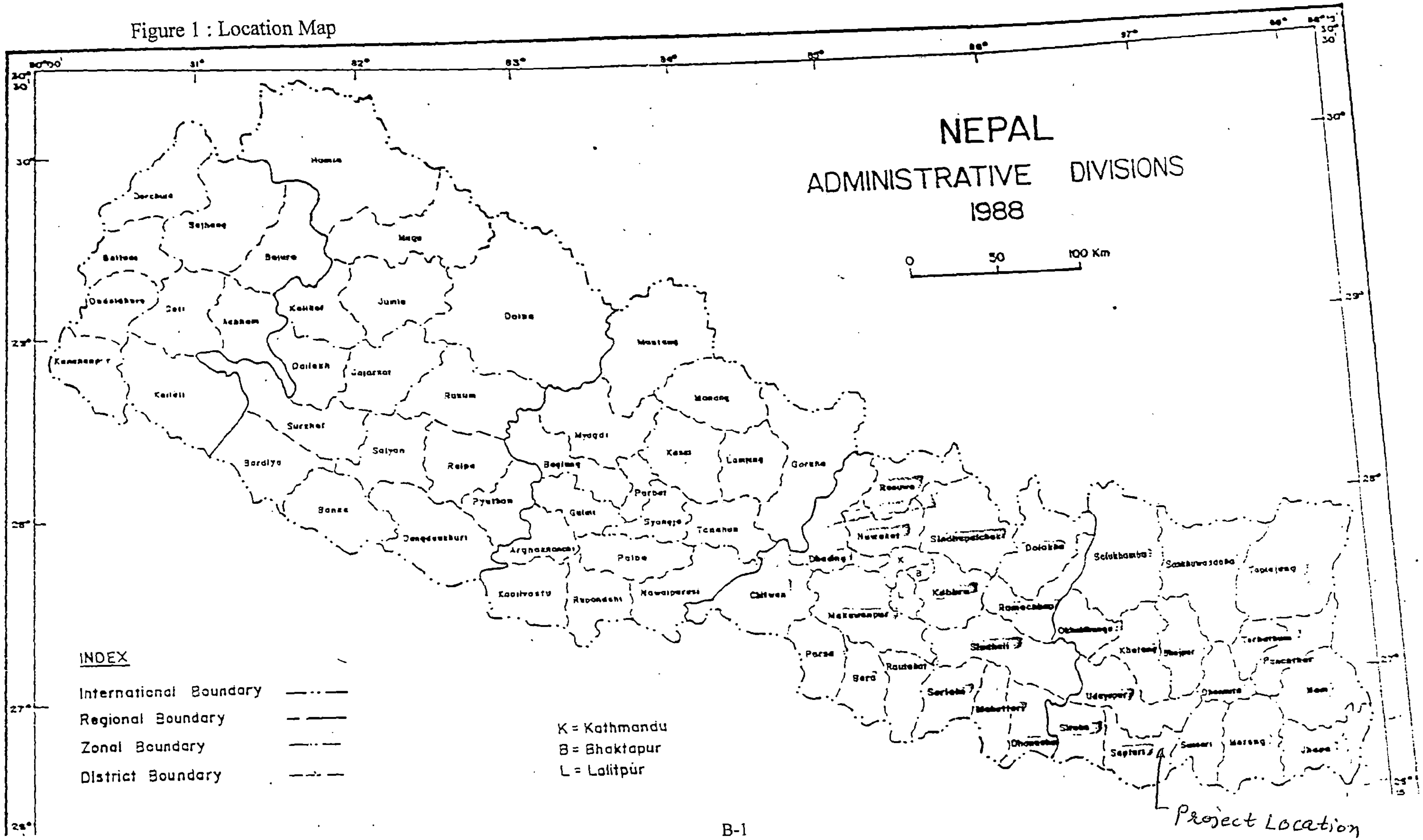
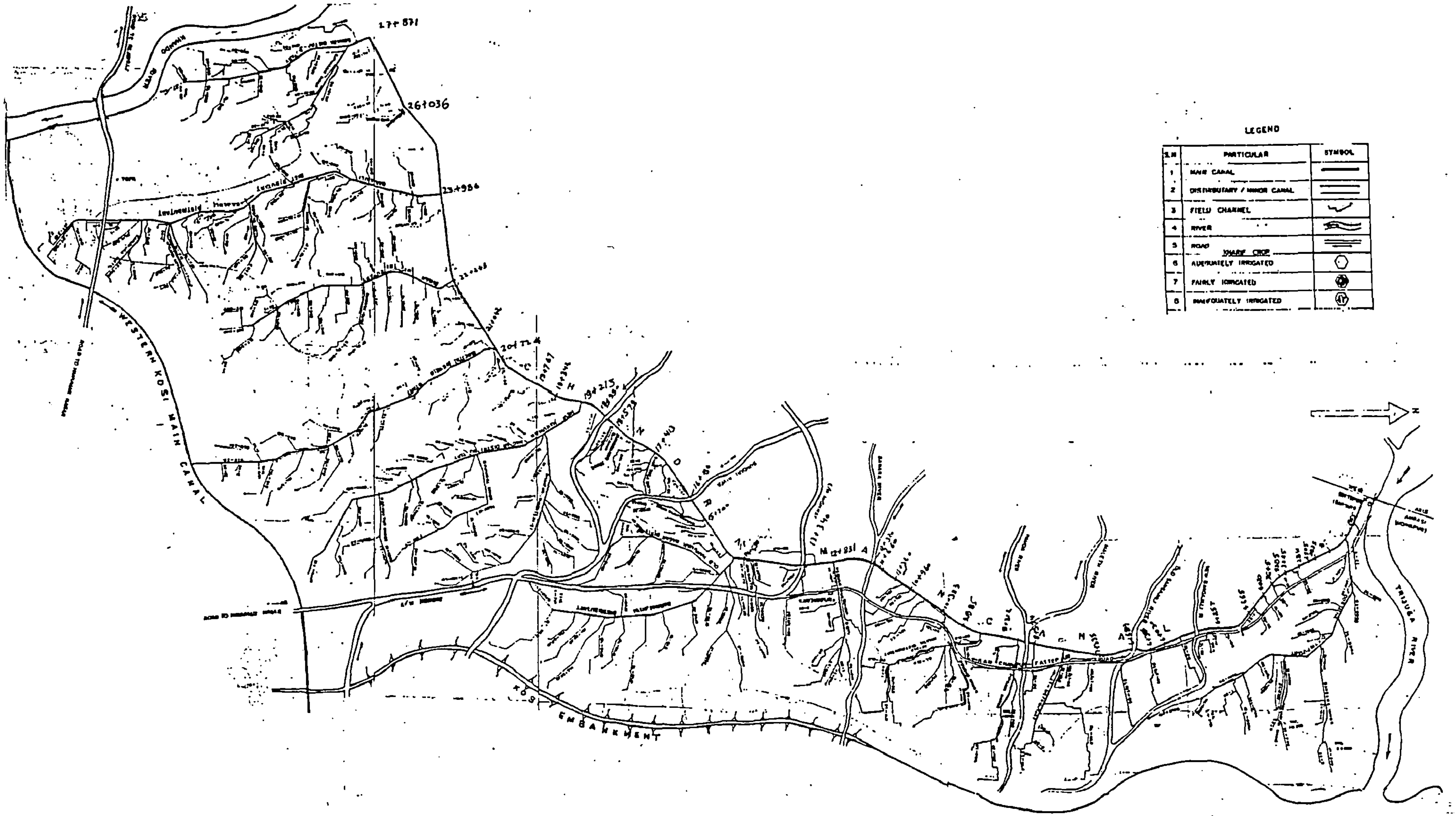


Figure 2 : Index Map of Chandra Canal System



APPENDIX C

(Annex. C)

PENMAN ETo CALCULATION

CONCERNING FIGURES AND TABLES ON WATER REQUIREMENTS

APPENDIX C

PENMAN ETo CALCULATION

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CONCERNING TABLES AND FIGURES OF WATER REQUIREMENTS

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CALCULATION OF ETo BY MODIFIED PENMAN METHOD

(Ref. FAO Nr. 33)

C.1 Reference Crop Evapotranspiration (ETo)

The form of the equation is

$ETo = C\,[W\,Rn + (1-W)\,.\,f(u).\,(e_a - e_d)]$

Where,

e_a = saturation vapour pressure at mean temperature in m/bar (FAO Nr. 33, Table 9)

e_d = actual vapour pressure $e_a \times RH_{mean} / 100$ (m bar)

f(u) = wind function

$f(u) = 0.27\,(1+U/100)$ where, U is 24 hour wind run in km/day at 2 m height.

R_n = total net radiation in mm/day or

R_n = 0.75 Rs - Rnl where,

Rs = incoming short wave radiation in mm/day either measured or obtained from

Rs = (0.25 + 0.50 n/N) Ra

Ra = extra - terrestrial radiation in mm/day (Table 10).

n = mean actual sunshine duration in hour / day

N = maximum possible sunshine duration in hour/day (Table 11).

Rnl = net long wave radiation in mm/day and

$Rnl = f(T).\,f(n/N).\,f(e_d)$ where,

f(T) = function of temperature (Table 12)

$f(e_d)$ = function of actual vapour pressure (Table 13).

f(n/N) = function of the ratio of the sunshine duration (Table 14)

W = temperature and altitude dependent weighting (Table 15)

C = adjustment factor for ratio U day / U night, for RH_{max} and for Rs (Table 16)

The estimation is carried out in five steps:

(i) Calculation of saturation deficit (e_a - e_d)

(ii) Estimation of the wind function f(u)

(iii) Calculation of net radiation (Rn)

(iv) Estimation of the weighting factor

(v) Estimation of the adjustment factor.

C.2 Calculation of the Saturation Deficit (e_a - e_d)

Calculation of e_a

The mean daily maximum and minimum temperature for each month are calculated and averaged to give the mean monthly temperature (T_{mean}).

Using T_{mean} in Table 9 (FAO Nr. 33) gives e_a in millibars.

Calculation of e_d

In Nepal humidity data is recorded at 0840 hours and 1740 hours each day. For practical purposes the average of these two readings can be taken as the daily mean relative humidity and the average of the daily figures as the monthly mean (RH_{mean}). Then

$$e_d = \frac{RH_{mean}}{100} \times e_a$$

C.3 Estimation of the Wind Function f(u)

(a) Stations with Recorded Wind Speeds

Wind function f(u) is defined as

$$f(u) = 0.27\left(1 + \frac{U}{100}\right)$$

Where, U is 24-hour wind run in km/day at 2-m height.

Where wind data are not collected at 2 m height, the appropriate correction for wind measurements taken at different heights are given below:

Measurement height m	0.5	1.0	1.5	2.0	3.0	4.0	5.0	6.0
Correction factor	1.35	1.15	1.06	1.0	0.93	0.88	0.85	0.83

(b) **Stations where Wind Records are not Kept**

Due to the topography and limited data it has not been possible to derive a model for th country as a whole. Therefore a subjective estimate has to be made taking into account local experience, wind data from the nearest station and topography. Table C.1 gives values of f(u) for several wind strengths.

Table C.1 : Variation of f(u) with Wind Run

Wind	Range of wind run (Km/day)	Average (Km/day)	f(u)
Light	<175	85	0.50
Moderate	175-425	300	1.08
Strong	426-700	560	1.79
Very strong	>700	800	2.43

C.4 Calculation of Net Radiation (Rn)

Derive Total Radiation (Ra)

This figure, in millimeters per day equivalent evapotranspiration, is obtained from Table 10 (FAO Nr 33) and depends on the latitude of the station and the time of year.

Calculate Ratio of Actual Sunshine Hours to Maximum Possible Sunshine Hours (n/N)

(a) Where sunshine records are kept

From the records calculate the average daily sunshine hours per month. The figure for mean daily maximum possible sunshine hours is obtained from Table 11 (FAO Nr. 33). The ratio n/N can then be calculated.

(b) Where sunshine records are not available.

The following equation is used to derive n/N in these situations.

$$n/N = A + BP + CP^2$$

where, P = monthly precipitation in millimeters, and A, B and C are constants which depend on the geographical location and the elevation of the site being analyzed. The constants applicable to ten sunshine groups are tabulated in Table C.2.

Table C.2 : Constants of the Sunshine Model

Group Nr.	A	$B \times 10^2$	$C \times 10^5$
1	0.81	-0.14	0.11
2	0.85	-0.24	0.36
3	0.87	-0.25	0.40
4	0.90	-0.29	0.36
5	0.80	-0.11	0.08
6	0.79	-0.25	0.34
7	0.76	-.0.10	0.06
8	0.69	-0.15	0.12
9	0.76	-0.07	0.03
10	0.72	-0.26	0.34

The appropriate group number is identified by locating the project coordinate on Figure C.1.

Calculate Net Solar Radiation (Rs)

$$Rs = (0.25 + 0.50\, n/N)\, Ra$$

Calculate Available Net Short Wave Radiation (Rns)

$$Rns = (1 - \alpha)\, Rs$$

For most crops , $\alpha = 0.25$

$$\therefore\ Rns = 0.75\, Rs$$

Calculate Net Long Wave Radiation (Rnl)

$$Rnl = f(T)\,.\,f(e_d)\,.\,f\left(\frac{n}{N}\right)$$

Where,

f(T) = function of temperature (obtained from Table 12).

f(ed) = function of actual vapour pressure (Table 13).

f(n/N) = function of the ratio of the sunshine durations (Table 14).

Calculate Net Radiation (Rn)

$$Rn = Rns - Rnl$$

C.5 Weighting Factor (W)

The value of the weighting factor (W) is derived from the Table 15 (FAO Nr. 33) which relates to T_{mean} and elevation.

C.6 Adjustment Factor (C)

The adjustment factor can be taken as 1.0 for all regions of Nepal.

C.7 Calculation of ETo (mm/day)

The n/N calculated value based on the constants of the sunshine model are presented in Table C.3. A worked example for January is shown in Table C.4 and the monthly calculated ETo of the project area is presented in Table C.5. Reference tables of FAO Nr. 33 have been appended in Annex. D.

Table C.3 Estimation of Sunshine Hours

Project -CCIS, Nepal	Station - Phattepur, Latitude-26^0 44' N, Longitude - 86^0 51' E Elevation - 100m Group Nr.- 2		
Constants (from Table C.2) A = 0.85		B = -2.4×10^{-3}	C = 3.6×10^{-6}
Month	Mean Monthly Precipitation P(mm)	$A+BP+CP^2$	Estimated Sunshine Ratio (n/N)
Jan	5	$0.85 - 2.4 \times 10^{-3} x5+3.6 \times 10^{-6} x5^2$	0.838
Feb	13	$0.85-2.4x10^{-3}x\ 13+3.6x10^{-6}x13^2$	0.819
Mar	10	$0.85-2.4x10^{-3}x\ 10+3.6x10^{-6}x10^2$	0.826
Apr	34	$0.85-2.4x10^{-3}x\ 34+3.6x10^{-6}x34^2$	0.773
May	95	$0.85-2.4x10^{-3}x95+3.6x10^{-6}x95^2$	0.654
June	243	$0.85-2.4x10^{-3}x243+3.6x10^{-6}x243^2$	0.479
July	395	$0.85-2.4x10^{-3}x\ 395+3.6x10^{-6}x395^2$	0.464
Aug	215	$0.85-2.4x10^{-3}x215+3.6x10^{-6}x215^2$	0.500
Sept	264	$0.85-2.4x10^{-3}x264+3.6x10^{-6}x12^{264}$	0.467
Oct	64	$0.85-2.4x10^{-3}x64+3.6x10^{-6}x64^2$	0.711
Nov	10	$0.85-2.4x10^{-3}x10+3.6x10^{-6}x10^2$	0.826
Dec	12	$0.85-2.4x10^{-3}x12+3.6x10^{-6}x12^2$	0.822

Table - C.4

Worked Example of Monthly ETo Calculation

Sl. No.	Peman Reference Crop ETo = C [W.Rn+ (1-W). f (u) . (e_a-e_d)]		
	Data **Month Jan**	**Project -CCIS Nepal, Station- Phattepur, Latitude 26^{0}44' N** **Elevation- 91 m Longitude 86^0 51' E**	
		Calculation	**Reference and Method**
1	Tmean 19.25^{0}C RH mean 88.50%	e_a = 22.35 mbar e_d =19.78 mbar	Table 9. (FAO Nr.33) $e_d = \frac{RH_{mean}}{100} x e_a$
		e_a - e_d = 2.57 mbar	
2	Wind run 85 (km/day)	f(u) = 0.50	F (u) = [0.27 $(1 + \frac{U}{100})$]
3	Month Jan Latitude 26.73 N	R_a mm/day = 9.62 Sunshine group = 2 n/N = 0.838 Rs = 6.43 Rns = 4.82 f (T) = 14.45 f (e_d) = 0.14 f (n/N) = 0.85 Rnl = 1.72 Rn = 3.10	Table 10 (FAO Nr. 33) Figure C.1 Table C.3 Rs = (0.25 +0.50 n/N) Ra Rns =0.75 Rs Table 12 (FAO Nr. 33) Table 13 (FAO Nr. 33) Table 14(FAO Nr. 33) Rnl = f(T) .f (e_d). f (n/N) Rn = Rns -Rnl
4	Tmean 19.25 ^{0} C Altitude 100m	W = 0.67	Table 15 (FAO Nr. 33)
5	C 1.0	C = 1.0 ETo = 2.50 mm/day	ETo = [C (WRn + (1-W) . f(u) . (e_a -e_d)]

Table C.5: Monthly Reference Evapo-transpiration ETo (mm/day)

Project- CCIS, Nepal

Elevation - 100 m

Latitude 26^0 44' N
Longitude 86^0 51' E

Month	Tmean^{0}C	Rhmean %	e_a	e_d	e_a-e_d	R_q	R_s	R_{ns}	f(T)	f(e_d)	f(n/N)	R_{nl}	R_n	f(u)	W	(1-w). f(u). (e_a -e_d)	C	ETo
Jan.	19.25	88.50	22.35	19.78	2.57	9.62	6.43	4.82	14.45	0.14	0.85	1.72	3.10	0.50	0.67	0.42	1	2.50
Feb.	18.65	88.00	21.51	18.93	2.58	11.35	7.49	5.62	14.33	0.15	0.84	1.81	3.81	0.50	0.67	0.43	1	2.98
Mar.	23.55	87.50	29.03	25.40	3.63	13.59	9.01	6.76	15.31	0.12	0.84	1.54	5.22	0.50	0.73	0.49	1	4.30
Apr.	27.50	79.50	36.75	29.22	7.53	15.30	9.74	7.30	16.20	0.10	0.80	1.30	6.00	0.50	0.77	0.87	1	5.49
May	30.20	62.50	42.90	26.81	16.09	16.44	9.49	7.12	16.75	0.11	0.69	1.27	5.85	0.50	0.78	1.77	1	6.33
June	30.45	69.50	43.52	30.25	13.27	16.74	8.20	6.15	16.81	0.10	0.53	0.89	5.26	0.50	0.78	1.46	1	5.56
July	30.90	76.00	44.65	33.93	10.72	16.64	8.02	6.02	16.92	0.08	0.52	0.70	5.32	0.50	0.79	1.13	1	5.33
Aug.	30.40	76.50	43.40	33.20	10.20	15.70	7.85	5.89	16.80	0.09	0.55	0.83	5.06	0.50	0.78	1.12	1	5.07
Sept.	30.00	80.00	42.40	33.92	8.48	14.23	6.88	5.16	16.70	0.08	0.52	0.70	4.46	0.50	0.78	0.93	1	4.41
Oct.	26.95	80.00	35.60	28.48	7.12	12.19	7.38	5.53	16.09	0.11	0.74	1.31	4.22	0.50	0.76	0.85	1	4.06
Nov.	25.35	79.50	32.36	25.73	6.63	10.15	6.73	5.05	15.74	0.12	0.84	1.59	3.46	0.50	0.74	0.86	1	3.42
Dec.	20.45	77.50	24.07	18.65	5.42	9.12	6.02	4.52	14.69	0.15	0.84	1.85	2.67	0.50	0.69	0.84	1	2.68

Note:

$ETo = c\ [W.\ R_n + (1-w).f(u).(e_a - e_d)]$

$R_s = (0.25 + 0.5n/N)R_a$

$R_n = 0.75\ R_s - R_{nl}$

$R_{nl} = f(T)\ .\ f(e_d).\ f(n/N)$

Figure C.1

Sunshine Groups

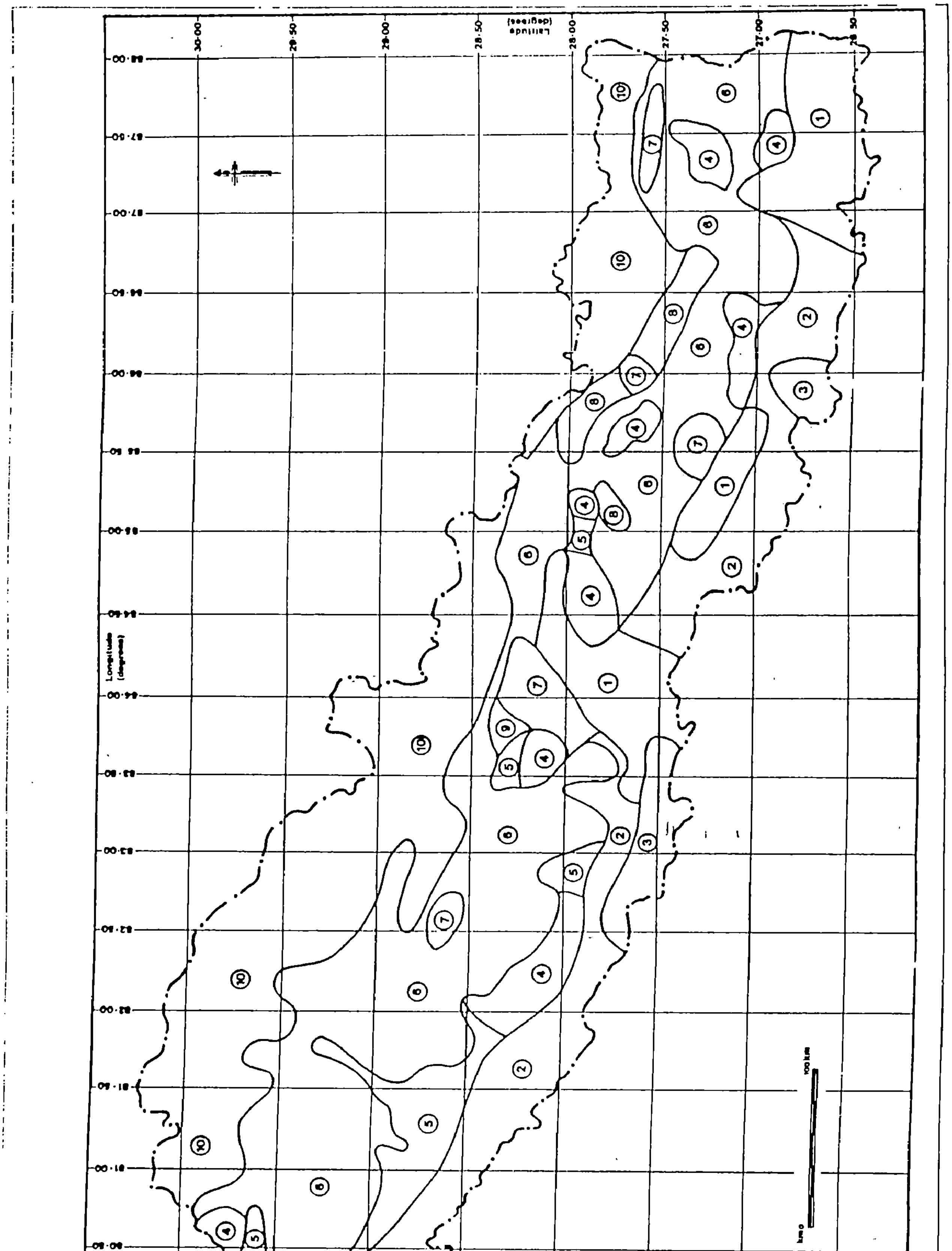

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Table 1: Possible Cropping Patterns (Terai)

S. No.	Patterns	Seedbed	Dates: Transplant / Plant	Harvest
1	Rice Spring Rice Monsoon Wheat	Apr. 1 July 1 -	May 1 Aug. 1 Dec. 1	Aug. 1 Nov. 2 Apr. 2
2	Rice Wheat	June 1 -	July 1 Nov. 2	Nov. 1 Mar. 2
3	Rice Wheat Mungbean	June 1 - -	July 1 Nov. 2 Apr. 1	Nov. 1 Mar. 1 June 1
4	Rice Potato	June 1 -	July 1 Nov. 2	Nov. 1 Apr. 1
5	Rice Maize	May 1 -	June 1 Oct. 1	Sept. 2 Nov. 2
6	Jute Rice	- July 1	Mar. 1 Aug.1	July 2 Nov.2
7	Rice Pulses /Oilseed	Apr. 2 -	May. 2 Oct. 2	Sept. 2 Mar. 1
8	Sugarcane	-	Feb.1	Dec. 2
9	Vegetables (winter) (summer)	- -	Nov. 2 July 1	Mar. 1 Oct. 2

Table 2 : Crop Coefficients (Kc) for Rice

Crop Coefficients (kc) for Rice

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Approx. Duration (days)
Crop	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
Monsoon													1.10	1.10	1.19	1.10	0.95	0.95							90
Early							1.10	1.10	1.10	1.10	1.00	1.00													90
Late															1.10	1.10	1.10	1.10	0.95	0.95					90
Monsoon														1.10	1.10	1.10	1.10	1.05	0.95	0.95					105
Early						1.10	1.10	1.10	1.10	1.25	1.00	1.00													105
Late															1.10	1.10	1.10	1.10	1.05	0.95	0.95				105
Monsoon														1.10	1.10	1.10	1.10	1.05	1.05	0.95	0.95				120
Monsoon														1.10	1.10	1.10	1.10	1.05	1.05	1.05	0.95	0.95			135
Monsoon														1.10	1.10	1.10	1.10	1.05	1.05	1.05	1.05	0.95	0.95		150

Source: Derived from FAO Irrigation and Drainage Paper No. 24.

Table 3 : Crop Coefficients (Kc) for Selected Crops

Crop Coefficients (kc) for Selected Crops

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Approx. Duration (days)
Crop	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
Maize 1					0.45	0.60	0.80	1.05	1.05	1.05	0.80														105
Maize 2							0.45	0.60	0.80	1.05	1.05	1.05	0.80												105
Pulses	0.50	0.75	0.95	1.05	1.05	0.96																		0.40	105
Oilseeds	0.46	0.82	1.00	1.00	0.72																			0.40	90
Wheat 1	1.15	1.15	1.15	0.90	0.40																	0.43	0.65	1.05	120
Wheat 2	1.05	1.15	1.15	1.15	0.90	0.40																	0.43	0.65	120
Vegetable (summer)													0.34	0.54	0.93	1.05	1.05	1.04	0.91						-
Vegetable (winter)	0.86	0.95	0.95	0.89																		0.28	0.34	0.54	-
Potatoes	1.01	1.13	1.13	1.08	0.94	0.77																0.42	0.55	0.79	130
Potatoes	0.79	1.01	1.13	1.13	1.08	0.94	0.77																0.42	0.55	130

Source: Derived from FAO Irrigation and Drainage Paper No. 24.

Table 4 : Monthly Open Water Evaporation Estimates (EO)(mm/day)

Station	Index Nr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
MAHENDRA NAGAR	105	2.27	3.39	4.79	6.92	8.00	6.99	5.25	5.17	5.06	4.42	3.42	2.54	4.85
PUSMA CAMP	401	2.64	3.80	5.88	8.64	8.52	6.05	4.83	4.53	4.16	4.15	3.36	2.53	4.92
KHAJURA	409	2.61	3.80	5.69	8.13	9.27	8.27	6.09	5.88	5.41	4.88	3.54	2.49	5.50
BHAIRHAWA	707	2.67	3.68	5.62	8.09	8.78	7.61	6.25	6.05	5.29	4.88	3.81	2.72	5.45
LUMLE	814	2.23	3.24	4.83	5.90	5.42	4.47	3.65	3.75	3.63	3.72	2.80	2.73	3.87
KHAIRINTAR	815	2.43	3.42	4.84	6.20	6.64	6.28	5.34	5.45	4.98	4.18	3.01	2.18	4.58
RAMPUR	902	2.49	3.65	5.62	7.70	7.75	6.53	5.17	5.59	5.04	4.67	3.42	2.47	5.01
KATHMANDU AIRPT	1030	2.39	3.35	4.95	5.91	6.46	5.77	5.27	4.98	4.64	4.13	2.97	2.25	4.42
OKHALDHUNGA	1206	2.71	3.73	7.03	7.71	5.94	4.71	4.04	4.04	3.86	3.93	2.94	2.62	4.44
HARDINATH	1114	3.15	4.35	6.30	8.79	9.04	7.28	6.78	6.54	5.56	5.21	3.83	3.06	5.82
DHANKUTA	1307	2.86	3.94	5.92	6.58	5.96	5.20	4.20	4.39	4.11	4.27	3.31	2.92	4.47
TARAHARA	1320	3.05	4.23	6.38	8.05	7.95	6.87	6.06	6.11	5.52	4.90	3.79	2.97	5.49

Table 5: Precipitation Records (in mm)
Station 1223 Rajbiraj **District (175) Saptari** **Zone Sagarmatha**
Elevation 91 **Mean Annual Rainfall 1360**

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
No. of Years	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**
Mean	5	13	10	34	95	243	395	215	264	64	10	12
Standard deviation	6	16	14	20	50	144	178	86	138	71	15	16
1 in 5 Non-homogeneous	0.0	0.0	0.0	17.2	56.4	140.5	233.2	121.7	136.0	4.8	0.0	0.0
Homogeneous	0.0	4.1	19.9	24.0	69.0	224.0	295.0	263.0	124.0	34.0	7.0	2.0

Table 6 Average Monthly Effective Rainfall as Related to Average Monthly ETcrop and Mean Monthly Rainfall

(USDA (SCS), 1969)

Monthly mean rainfall mm	12.5	25	37.5	50	62.5	75	87.5	100	112.5	125	137.5	150	162.5	175	187.5	200
Average monthly ETcrop mm	Average monthly effective rainfall in mm*															
25	8	16	24													
50	8	17	25	32	39	46										
75	9	18	27	34	41	48	56	62	69							
100	9	19	28	35	43	52	59	66	73	80	87	94	100			
125	10	20	30	37	46	54	62	70	76	85	92	98	107	116	120	
150	10	21	31	39	49	57	66	74*	81	89	97	104	112	119	127	133
175	11	23	32	42	52	61	69	78	86	95	103	111	118	126	134	141
200	11	24	33	44	54	64	73	82	91	100	109	117	125	134	142	150
225	12	25	35	47	57	68	78	87	96	106	115	124	132	141	150	159
250	13	25	38	50	61	72	84	92	102	112	121	132	140	150	158	167

* Where net depth of water that can be stored in the soil at time of irrigation is greater or smaller than 75 mm, the correction factor to be used is:

Effective storage	20	25	37.5	50	62.5	75	100	125	150	175	200
Storage factor	.73	.77	.86	.93	.97	1.00	1.02	1.04	1.06	1.07*	1.08

EXAMPLE:

Given:

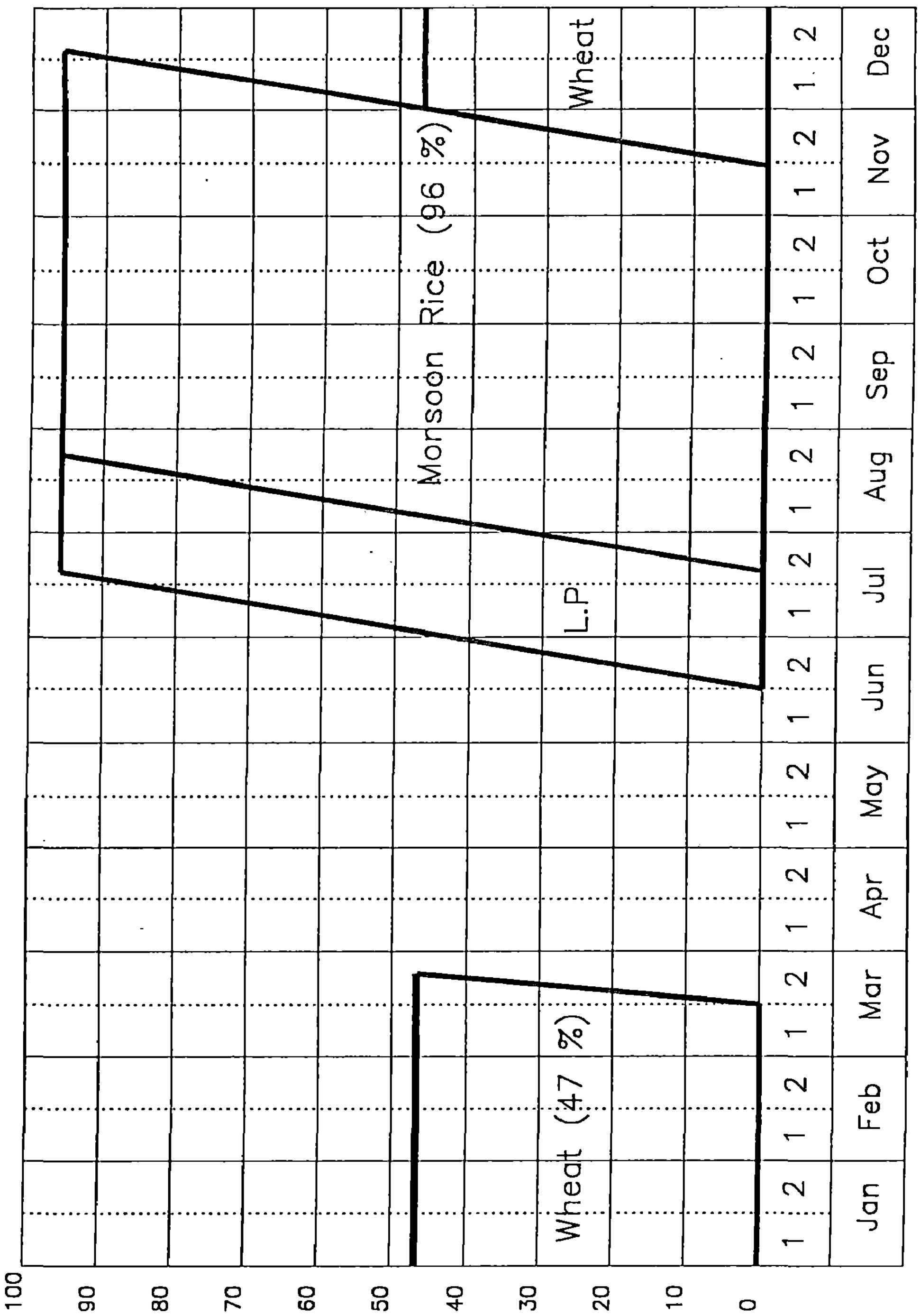
Monthly mean rainfall = 100 mm; ETcrop = 150 mm; effective storage = 175 mm

Calculation:

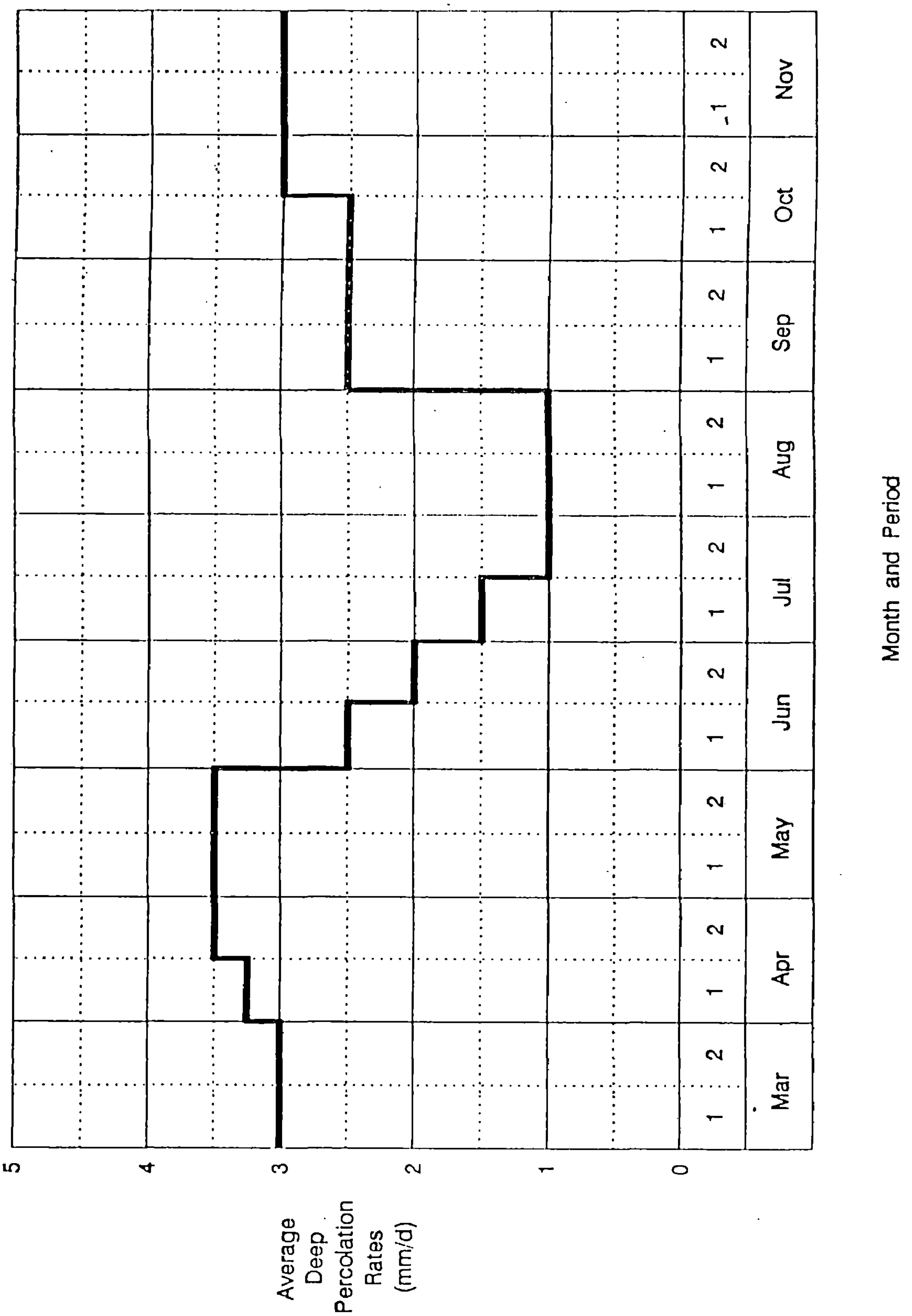
Correction factor for effective storage = 1.07

Effective rainfall 1.07 x 74 = 79 mm

Figure 1 – Present Cropping Pattern in Command Area



Representative Deep Percolation Rates for Terai Paddy Fields



APPENDIX D

REFERENCE TABLES (FAO NO. 33) FOR ETO CALCULATOIN

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Table 9 Saturation Vapour Pressure (ea) in mbar as Function of Mean Air Temperature (T) in °C 1/

Temperature °C	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
ea mbar	6.1	6.6	7.1	7.6	8.1	8.7	9.3	10.0	10.7	11.5	12.3	13.1	14.0	15.0	16.1	17.0	18.2	19.4	20.6	22.0
Temperature °C	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
ea mbar	23.4	24.9	26.4	28.1	29.8	31.7	33.6	35.7*	37.8*	40.1*	42.4	44.9	47.6	50.3	53.2	56.2	59.4	62.8	66.3	69.9

1/ Also actual vapour pressure (ed) can be obtained from this table using available Tdewpoint data. (Example: Tdewpoint is 18°C; ed is 20.6 mbar)

Table 10 Extra-terrestrial Radiation (Ra) expressed in equivalent evaporation in mm/day

Northern Hemisphere													Southern Hemisphere											
Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Lat	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
6.4	8.6	11.4	14.3	16.4	17.3	16.7	15.2	12.5	9.6	7.0	5.7	40°	17.9	15.7	12.5	9.2	6.6	5.3	5.9	7.9	11.0	14.2	16.9	18.3
6.9	9.0	11.8	14.5	16.4	17.2	16.7	15.3	12.8	10.0	7.5	6.1	38	17.9	15.8	12.8	9.6	7.1	5.8	6.3	8.3	11.4	14.4	17.0	18.3
7.4	9.4	12.1	14.7	16.4	17.2	16.7	15.4	13.1	10.6	8.0	6.6	36	17.9	16.0	13.2	10.1	7.5	6.3	6.8	8.8	11.7	14.6	17.0	18.2
7.9	9.8	12.4	14.8	16.5	17.1	16.8	15.5	13.4	10.8	8.5	7.2	34	17.8	16.1	13.5	10.5	8.0	6.8	7.2	9.2	12.0	14.9	17.1	18.2
8.3	10.2	12.8	15.0	16.5	17.0	16.8	15.6	13.6	11.2	9.0	7.8	32	17.8	16.2	13.8	10.9	8.5	7.3	7.7	9.6	12.4	15.1	17.2	18.1
8.8	10.7	13.1	15.2	16.5	17.0	16.8*	15.7	13.9	11.6	9.5	8.3	30	17.8	16.4	14.0	11.3	8.9	7.8	8.1	10.1	12.7	15.3	17.3	18.1
9.3	11.1	13.4	15.3	16.5	16.8	16.7	15.7	14.1	12.0	9.9	8.8	28	17.7	16.4	14.3	11.6	9.3	8.2	8.6	10.4	13.0	15.4	17.2	17.9
9.8	11.5	13.7	15.3	16.4	16.7	16.6	15.7	14.3	12.3	10.3	9.3	26	17.6	16.4	14.4	12.0	9.7	8.7	9.1	10.9	13.2	15.5	17.2	17.8
10.2	11.9	13.9	15.4	16.4	16.6	16.5	15.8	14.5	12.6	10.7	9.7	24	17.5	16.5	14.6	12.3	10.2	9.1	9.5	11.2	13.4	15.6	17.1	17.7
10.7	12.3	14.2	15.5	16.3	16.4	16.4	15.8	14.6	13.0	11.1	10.2	22	17.4	16.5	14.8	12.6	10.6	9.6	10.0	11.6	13.7	15.7	17.0	17.5
11.2	12.7	14.4	15.6	16.3	16.4	16.3	15.9	14.8	13.3	11.6	10.7	20	17.3	16.5	15.0	13.0	11.0	10.0	10.4	12.0	13.9	15.8	17.0	17.4
11.6	13.0	14.6	15.6	16.1	16.1	16.1	15.8	14.9	13.6	12.0	11.1	18	17.1	16.5	15.1	13.2	11.4	10.4	10.8	12.3	14.1	15.8	16.8	17.1
12.0	13.3	14.7	15.6	16.0	15.9	15.9	15.7	15.0	13.9	12.4	11.6	16	16.9	16.4	15.2	13.5	11.7	10.8	11.2	12.6	14.3	15.8	16.7	16.8
12.4	13.6	14.9	15.7	15.8	15.7	15.7	15.7	15.1	14.1	12.8	12.0	14	16.7	16.4	15.3	13.7	12.1	11.2	11.6	12.9	14.5	15.8	16.5	16.6
12.8	13.9	15.1	15.7	15.7	15.5	15.5	15.6	15.2	14.4	13.3	12.5	12	16.6	16.3	15.4	14.0	12.5	11.6	12.0	13.2	14.7	15.8	16.4	16.5
13.2	14.2	15.3	15.7	15.5	15.3	15.3	15.5	15.3	14.7	13.6	12.9	10	16.4	16.3	15.5	14.2	12.8	12.0	12.4	13.5	14.8	15.9	16.2	16.2
13.6	14.5	15.3	15.6	15.3	15.0	15.1	15.4	15.3	14.8	13.9	13.3	8	16.1	16.1	15.5	14.4	13.1	12.4	12.7	13.7	14.9	15.8	16.0	16.0
13.9	14.8	15.4	15.4	15.1	14.7	14.9	15.2	15.3	15.0	14.2	13.7	6	15.8	16.0	15.6	14.7	13.4	12.8	13.1	14.0	15.0	15.7	15.8	15.7
14.3	15.0	15.5	15.5	14.9	14.4	14.6	15.1	15.3	15.1	14.5	14.1	4	15.5	15.8	15.6	14.9	13.8	13.2	13.4	14.3	15.1	15.6	15.5	15.4
14.7	15.3	15.6	15.3	14.6	14.2	14.3	14.9	15.3	15.3	14.8	14.4	2	15.3	15.7	15.7	15.1	14.1	13.5	13.7	14.5	15.2	15.5	15.3	15.1
15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8	0	15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8

Table 11 — Mean Daily Duration of Maximum Possible Sunshine Hours (N) for Different Months and Latitudes

Northern Latitudes	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Southern Latitudes	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
40	9.6	10.7	11.9	13.3	14.4	15.0	14.7	13.7	12.5	11.2	10.0	9.3
35	10.1	11.0	11.9	13.1	14.0	14.5	14.3	13.5	12.4	11.3	10.3	9.8
30	10.4	11.1	12.0	12.9	13.6	14.0	13.9*	13.2	12.4	11.5	10.6	10.2
25	10.7	11.3	12.0	12.7	13.3	13.7	13.5	13.0	12.3	11.6	10.9	10.6
20	11.0	11.5	12.0	12.6	13.1	13.3	13.2	12.8	12.3	11.7	11.2	10.9
15	11.3	11.6	12.0	12.5	12.8	13.0	12.9	12.6	12.2	11.8	11.4	11.2
10	11.6	11.8	12.0	12.3	12.6	12.7	12.6	12.4	12.1	11.8	11.6	11.5
5	11.8	11.9	12.0	12.2	12.3	12.4	12.3	12.3	12.1	12.0	11.9	11.8
0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0

Table 12 — Effect of Temperature f(T) on Longwave Radiation (Rnl)

$T^{o}C$	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
$f(T) = \delta Tk^4$	11.0	11.4	11.7	12.0	12.4	12.7	13.1	13.5	13.8	14.2	14.6	15.0	15.4	15.9	16.3*	16.7	17.2	17.7	18.1

Table 13 — Effect of Vapour Pressure f(ed) on Longwave Radiation (Rnl)

ed mbar	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
$f(ed) = 0.34 - 0.044\sqrt{ed}$	0.23	.22	.20	.19	.18	.16	.15	.14	.13*	.12	.12	.11	.10	.09	.08	.08	.07	.06

Table 14 — Effect of the Ratio Actual and Maximum Bright Sunshine Hours f(n/N) on Longwave Radiation (Rnl)

n/N	0	.05	.1	.15	.2	.25	.3	.35	.4	.45	.5	.55	.6	.65	.7	.75	.8	.85	.9	.95	1.0
$f(n/N) = 0.1 + 0.9n/N$	0.10	.15	.19	.24	.28	.33	.37	.42	.46	.51	.55	.60	.64	.69	.73	.78	.82*	.87	.91	.96	1.0

Table 15 Values of Weighting Factor (W) for the Effect of Radiation on ETo at Different Temperatures and Altitudes

Temperature °C	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
W at altitude m																				
0	0.43	.46	.49	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77*	.78	.80	.82	.83	.84	.85
500	.45	.48	.51	.54	.57	.60	.62	.65	.67	.70	.72	.74	.76	.78	.79	.81	.82	.84	.85	.86
1000	.46	.49	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.80	.82	.83	.85	.86	.87
2000	.49	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.81	.82	.84	.85	.86	.87	.88
3000	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.81	.82	.84	.85	.86	.88	.88	.89

Table 16 Adjustment Factor (c) in Presented Penman Equation

	RHmax = 30%				RHmax = 60%				RHmax = 90%			
Rs mm/day	3	6	9	12	3	6	9	12	3	6	9	12
Uday m/sec	Uday/Unight = 4.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.79	.84	.92	.97	.92	1.00	1.11	1.19	.99	1.10	1.27	1.32
6	.68	.77	.87	.93	.85	.96	1.11	1.19	.94	1.10	1.26	1.33
9	.55	.65	.78	.90	.76	.88	1.02	1.14	.88	1.01	1.16	1.27
	Uday/Unight = 3.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.76	.81	.88	.94	.87	.96	1.06	1.12	.94	1.04	1.18	1.28
6	.61	.68	.81	.88	.77	.88	1.02	1.10	.86	1.01	1.15	1.22
9	.46	.56	.72	.82	.67	.79	.88	1.05	.78	.92	1.06	1.18
	Uday/Unight = 2.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.69	.76	.85	.92	.83	.91	.99*	1.05*	.89	.98	1.10*	1.14*
6	.53	.61	.74	.84	.70	.80	.94	1.02	.79	.92	1.05	1.12
9	.37	.48	.65	.76	.59	.70	.84	.95	.71	.81	.96	1.06
	Uday/Unight = 1.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.64	.71	.82	.89	.78	.86	.94*	.99*	.85	.92	1.01*	1.05*
6	.43	.53	.68	.79	.62	.70	.84	.93	.72	.82	.95	1.00
9	.27	.41	.59	.70	.50	.60	.75	.87	.62	.72	.87	.96

APPENDIX E

(Annex. E)

CALCULATION TABLES OF IRRIGATION EFFICIENCIES AND OTHER TABLES OF CHAPTER 6

APPENDIX E

CALCULATION TABLES OF IRRIGATION EFFICIENCIES AND OTHER TABLES OF CHAPTER 6

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Table 1: Calculation of the conveyance efficiency e_c

Row	Information required	Monthly data on flow in $m^3 \times 10^6$ (MCM)												Notes
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1	Flow diverted from river: v_c	5.89	4.35	4.28	-	-	25.40	31.61	31.61	30.59	31.61	12.96	8.57	
2	Inflow from other sources: v_I	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
3	Main canal waste	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
4	Flow delivered to distributaries directly from main	3.91	2.89	2.84	-	-	16.87	20.99	20.99	20.31	20.99	8.61	5.69	Loss 20% (assumed)
5	Flow delivered to direct outlets and minors offtaking from main canal	0.80	0.59	0.58	-	-	3.45	4.30	4.30	4.16	4.30	1.76	1.17	Loss 20% (assumed)
6	Non - irrigation deliveries from main	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
7	Main canal losses: $v_c + v_I$ - (3) - (4) - (5) - (6)	1.18	0.87	0.86	-	-	5.08	6.32	6.32	6.12	6.32	2.59	1.71	
8	Conveyance efficiency of main in % $e_c = \frac{(4)+(5)+(6)}{(1)+(2)}$	80	80	80	-	-	80	80	80	80	80	80	80	

Table 2: Calculation of the distribution efficiency e_d

Row	Information required	Monthly data on flow in $m^3 \times 10^6$ (MCM)												Notes
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1	Flow delivered into distributaries: v_d	4.71	3.48	3.42	-	-	20.32	25.29	25.29	24.47	25.29	10.37	6.86	
2	Flow delivered to fields : v_f	4.33	3.20	3.15	-	-	18.69	23.27	23.27	22.51	23.27	9.54	6.31	
3	Non-irrigation deliveries : v_3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
4	Distributary waste	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
5	Losses from distributary system $v_d - \{v_f + v_3 + (4)\}$	0.38	0.28	0.27	-	-	1.63	2.02	2.02	1.96	2.02	0.83	0.55	Loss 8% (assumed)
6	Distribution efficiency in (%) $e_d = (v_f + v_3) / v_l$	92	92	92	-	-	92	92	92	92	92	92	92	

Table 3: Calculation of the field application efficiency e_a

	Monthly Consumptive Use Per Crop (in mm)												Notes
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Crop: Rice	-	-	-	-	-	188.05	327.16	252.98	220.50	214.56	48.75	-	From Table - 5.2
Wheat	89.28	85.12	25.80	-	-	-	-	-	-	-	82.05	70.68	From Table - 5.3
Total: W	89.28	85.12	25.80	-	-	188.05	327.16	252.98	220.50	214.56	130.80	70.68	
Precipitation	5	13	10	34	95	243	395	215	264	64	10	12	From Table - 5 (Annex. C)
Effective precipitation, Pe	0	8	0	-	-	169.40	291.00	1497.0	186.20	284.00	0	0	
v_m = W-Pe	89.28	77.12	25.80	-	-	18.65	36.16	105.98	34.30	186.16	130.80	70.68	
	Monthly Field Application Per Crop (in mm)												
Crop: Rice	-	-	-	-	-	329.08	572.53	442.72	385.87	375.48	85.31	-	
Wheat	156.00	148.96	45.15	-	-	-	-	--	-	-	143.59	123.67	
V_f	156.00	148.96	45.15	-	-	329.08	572.53	442.72	385.87	375.48	228.90	123.69	
$e_a = \frac{v_m}{v_f}$	0.57	0.52	0.57	-	-	0.06	0.06	0.24	0.09	0.50	0.57	0.57	**Avg. e_a = 0.40**

Table 4: Average Family Size, Male / Female Ratio and Population Distribution by Age Groups and Canal Reach

Canal Reach	Sample Size	Family Member	Average Family Size	Male (%)				Female (%)				M/F Ratio	Total
				<14	14-59	>59	Total	<14	14-59	>59	Total		
HEAD													
1. Odraha Dy.	4	35	8.8	20.0	17.1	8.6	45.7	31.4	20.0	2.9	54.3	0.8	100
2. Maleth Dy	2	19	9.5	21.1	26.3	5.3	52.6	15.8	31.6	0.0	47.4	1.1	100
3. Baluwa Dy.	16	106	6.6	21.7	31.1	2.8	55.7	17.9	23.6	2.8	44.3	1.3	100
4. Kanchanpur Dy.	6	55	9.2	18.2	27.3	5.5	50.9	14.5	29.1	5.5	49.1	1.0	100
Sub-Total/Average	28	**215**	8.5	20.5	27.4	4.7	52.6	**19.1**	**25.1**	**3.3**	47.4	**1.1**	**100**
MIDDLE													
1. Old Hanumannagar Dy.	11	74	6.7	21.6	31.1	1.4	54.1	14.9	25.7	5.4	45.9	1.2	100
2. Barmajhiya Dy.	20	189	9.5	16.4	33.3	0.5	50.3	20.1	27.0	2.6	49.7	1.0	100
3. Subbatole Dy.	3	15	5.0	6.7	60.0	6.7	73.3	0.0	26.7	0.0	26.7	2.8	100
4. New Hanumannagar Dy.	5	43	8.6	14.0	39.5	2.3	55.8	14.0	25.6	4.7	44.2	1.3	100
5. Dhanpuri Minor	3	30	10 0	16.7	23.3	3.3	43.3	30.0	23.3	3.3	56.7	0.8	100
6. Maina 'Kaderi Minor	2	10	5.0	30.0	40.0	0.0	70.0	10.0	20.0	0.0	30.0	2.3	100
7. Goithi Dy.	5	50	10.0	20.0	26.0	8.0	54.0	14.0	24.0	8.0	46.0	1.2	100
Sub-Total/Average	49	**411**	**7.8**	**17.9**	**36.2**	**3.2**	**57.3**	**14.7**	**24.6**	**3.4**	**42.7**	**1.3**	**100**
TAIL													
1. Banauli Dy.	3	19	6.3	31.6	21.1	5.3	57.9	15.8	21.1	5.3	42.1	1.4	100
2. Diman Dy.	6	65	10.8	24.6	29.2	4.6	58.5	13.8	24.6	3.1	41.5	1.4	100
Sub-Total/Average	9	84	8.6	26.2	27.4	4.8	58.3	14.3	23.8	3.6	41.7	1.4	100
HEAD	28	215	8.5	20.5	27.4	4.7	52.6	19.1	25.1	3.3	47.4	1.1	100
MIDDLE	49	411	7.8	17.9	36.2	3.2	57.3	14.7	24.6	3.4	42.7	1.3	100
TAIL	9	84	8.6	26.2	27.4	4.8	58.3	14.3	23.8	3.6	41.7	1.4	100
TOTAL/AVERAGE	86	710	8.3	21.5	30.3	4.2	56.0	16.0	24.5	3.4	44.0	1.3	100

Table 5: Literacy and Occupational Status

Canal Reach	Sample Size	MAJOR OCCUPATION Agriculture (%)	Service (%)	Business (%)	Other (%)	EDUCATION Illiterate (%)	Literate (%)	Formal Schooling	Intermediate (%)	Bachelor (%)
HEAD										
1. Odraha Dy.	4	100.0					75.0	25.0		
2. Maleth Dy	2	100.0				50.0		50.0		
3. Baluwa Dy.	16	100.0				18.8	31.3	25.0	18.8	6.3
4. Kanchanpur Dy.	6	100.0					66.7	16.7	16.7	
Sub-Total/Average	**28**	**100.0**				**17.2**	**43.2**	**29.2**	**8.9**	**1.6**
MIDDLE										
1. Old Hanumannagar Dy.	11	100.0				18.2	45.5	36.4		
2. Barmajhiya Dy.	20	90.0	10.0			10.0	30.0	55.0	5.0	0.0
3. Subbatole Dy.	3	100.0					66.7	33.3		
4. New Hanumannagar Dy.	5	100.0					40.0	60.0		
5 Dhanpuri Minor	3	100.0	0.0	0.0	0.0	33.3	66.7	0.0	0.0	0.0
6. Maina 'Kaderi Minor	2	100.0	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0
7. Goithi Dy.	5	80.0	20.0				40.0	20.0	0.0	40.0
Sub-Total/Average	**49**	**95.7**	**4.3**	**0.0**	**0.0**	**15.9**	**48.4**	**29.2**	**0.7**	**5.7**
TAIL										
1. Banauli Dy.	3	66.7		33.3		33.3	33.3	0.0	33.3	0.0
2. Diman Dy.	6	100.0				16.7	50.0	16.7	16.7	0.0
Sub-Total/Average	**9**	**83.3**		**16.7**		**25.0**	**41.7**	**8.3**	**25.0**	**0.0**
HEAD	28	100.0	0.0	0.0	0.0	17.2	43.2	29.2	8.9	1.6
MIDDLE	49	95.7	4.3	0.0	0.0	15.9	48.4	29.2	0.7	5.7
TAIL	9	83.3	0.0	16.7	0.0	25.0	41.7	8.3	25.0	0.0
TOTAL/AVERAGE	86	93.02	1.43	5.56	0.00	19.37	44.43	22.25	11.52	2.43

Table 6: Crop Budget - Irrigated Condition - Improved

Particulars	Units	Paddy			Wheat		
		Rate / unit	Quantity	Amount (NRs)	Rate / unit	Quantity	Amount (NRs)
1. Seeds	Kg	14	50	700	15	120	1800
2. Chemical fertilizers							
- DAP	Kg	20	54	1072	20	56	1122
- Urea	Kg	8	56	444	8	66	528.8
- MoP	Kg	7	19	136	7	10	69.3
3. Manure	Carts	200	5	1000	200	4	800
4. Plant protection	Rs.			225			150
5. Labour	MD	50	120	6000	50	88	4400
6. Bullock	BD	70	20	1400	70	20	1400
7. Miscellaneous	Rs.			100			
Total cost				**11077**			**10270**
1. Main product	Kg.	7.5	2390	17925	8	1550	12400
2. By-product	Carts	100	9.4	937.25	50	5	234
Total income	**Rs.**			**18863**			**12634**
Gross return	**Rs.**			**7786**			**2364**

Source: Diagnostic Study of CCIS, Nepal (1998)