



Performance Assessment of Irrigation system of Pakistan

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Irrigation ??

Irrigation Systems

- Surface Irrigation
(Canal / Tubewell Irrigation)

- Sprinkler Irrigation
- Drip Irrigation

An Irrigation Project/System

“An Irrigation project is an endeavor to accomplish a specific objective through a unique set of interrelated tasks and the effective utilization of resources”.

Gido

Attributes of a an Irrigation Project

- Has a well-defined objective
- Composed of a series of interdependent tasks
- Utilizes various resources
- Has a specific time frame
- Is a unique or one-time endeavor
- Has a customer
- Involves a degree of uncertainty

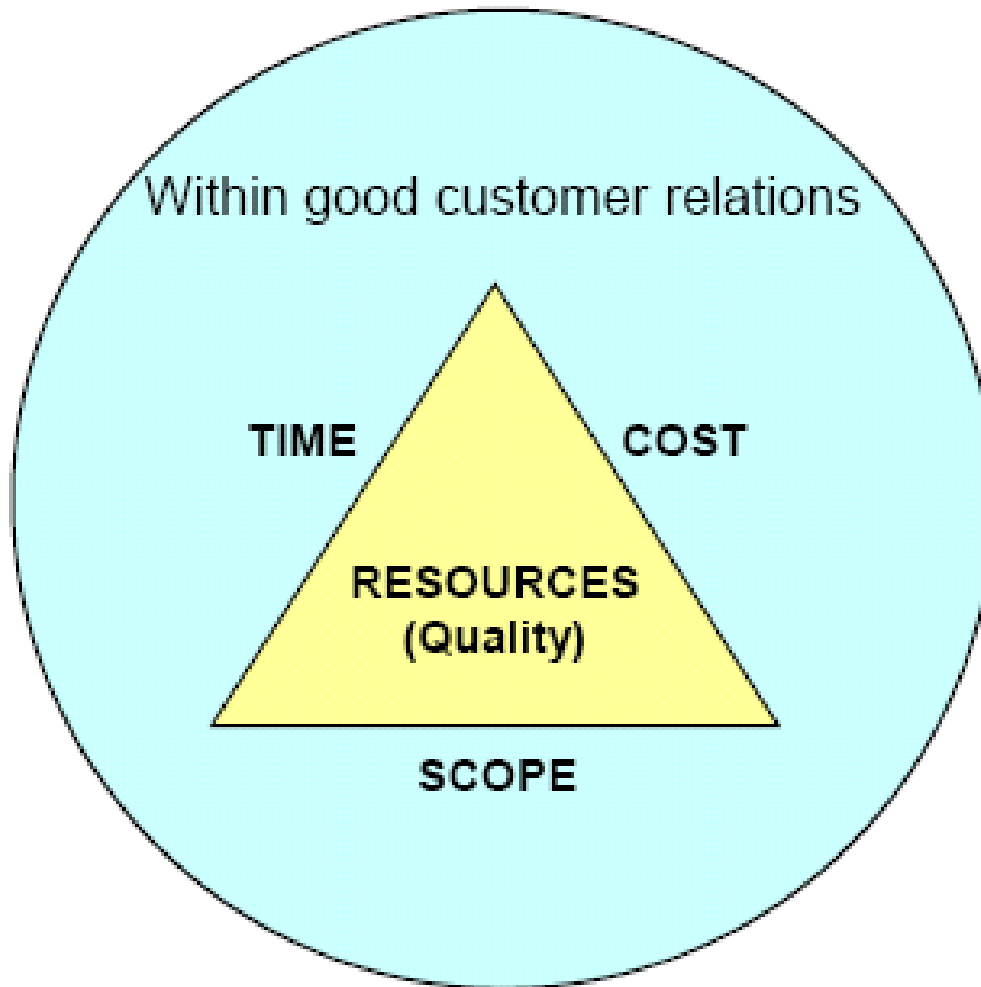
• ***Gido:***

Project Management knowledge Areas for Irrigation

- Project Scope Management
- What is the project trying to accomplish?
- Project Time Management
- Project Cost Management
- Project Integration Management
- Project Quality Management
- Project Human Resource Management
- Project Communications Management
- Project Risk Management
- Project Procurement Management

. ***Gido:***

Overview of Management of irrigation Projects



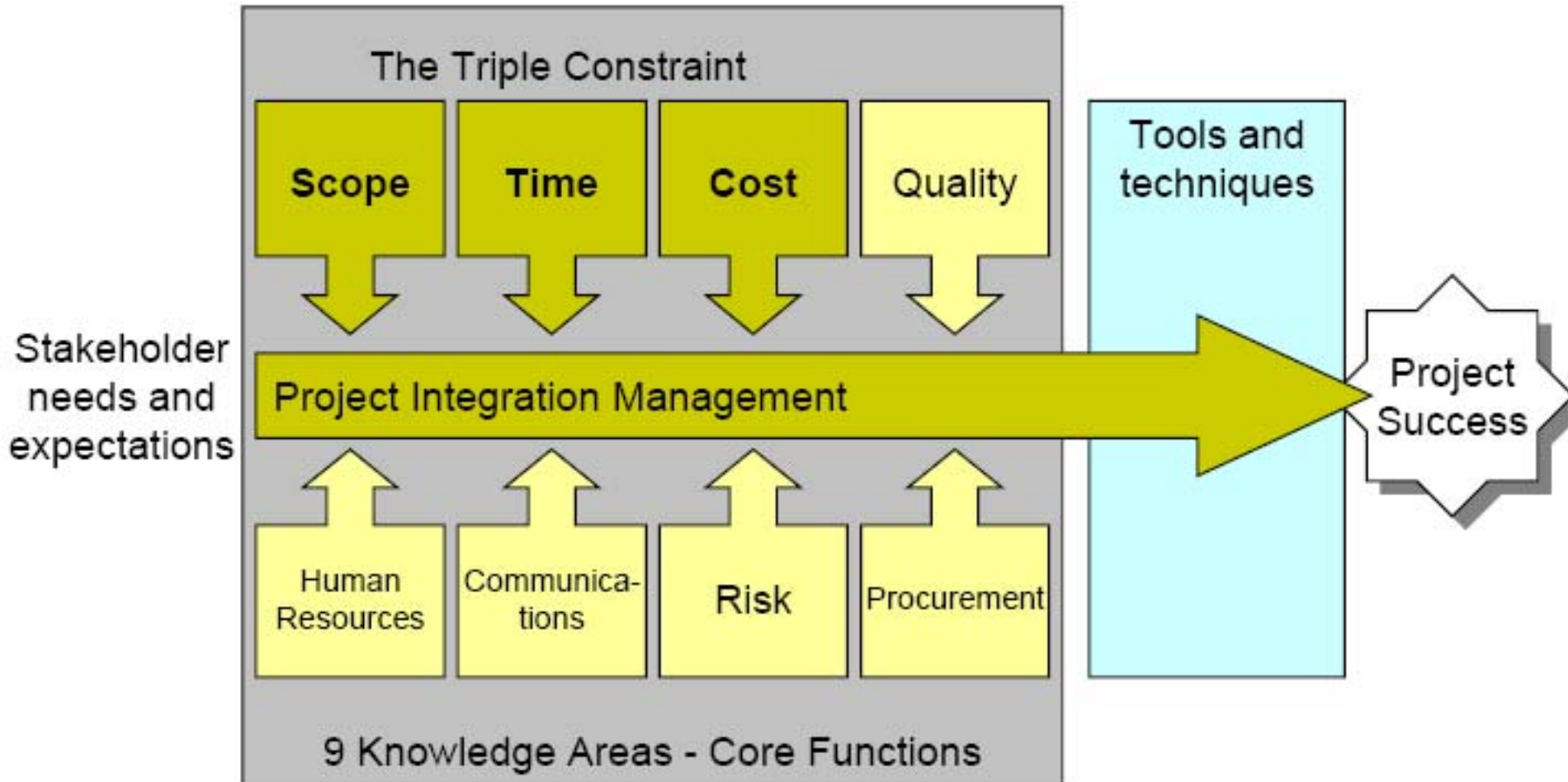
What resources are available to organizations?

- Money
- Personnel
- Equipment
- Facilities
- Materials
- Information/technology

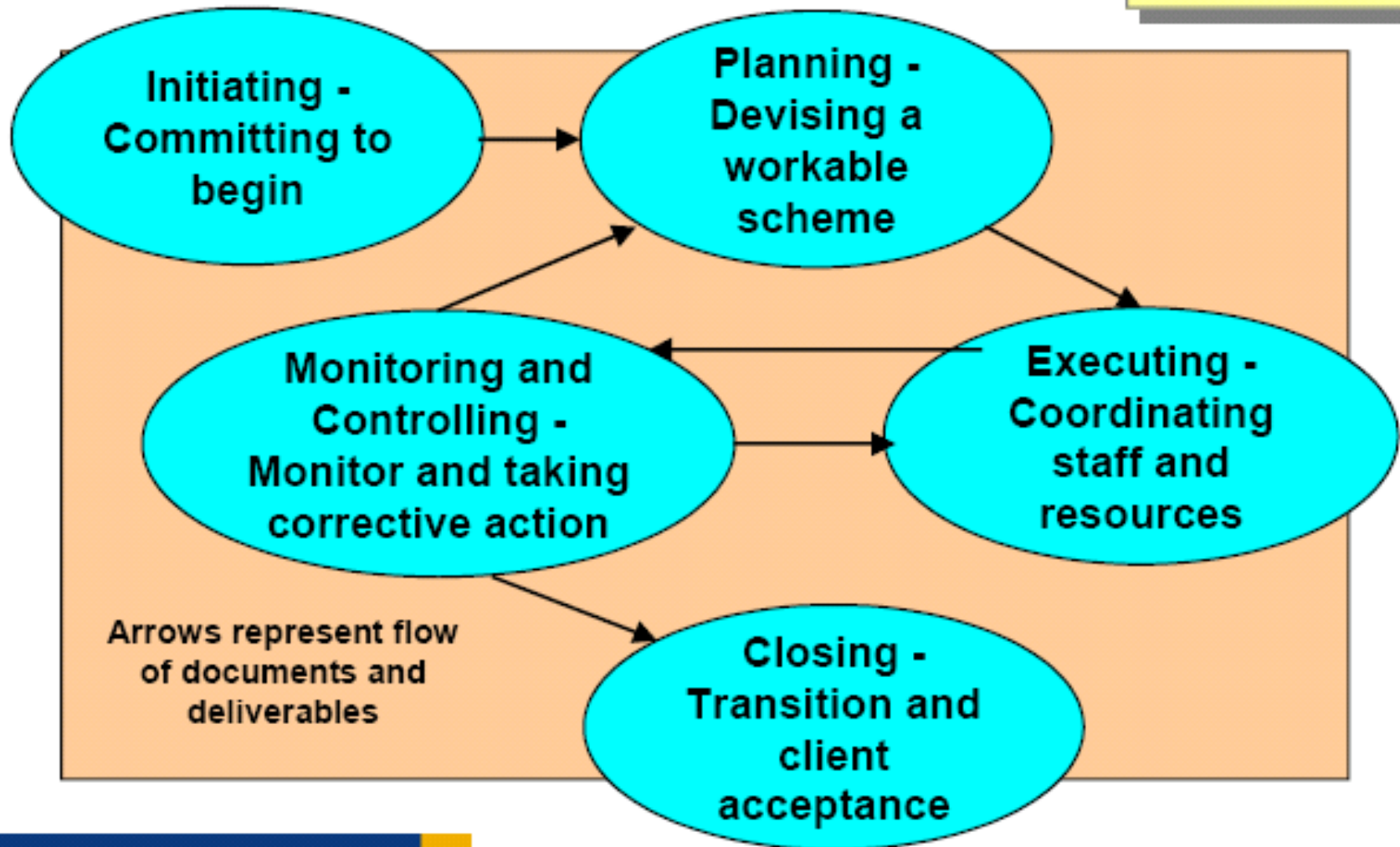
The Triple Constraint Concept

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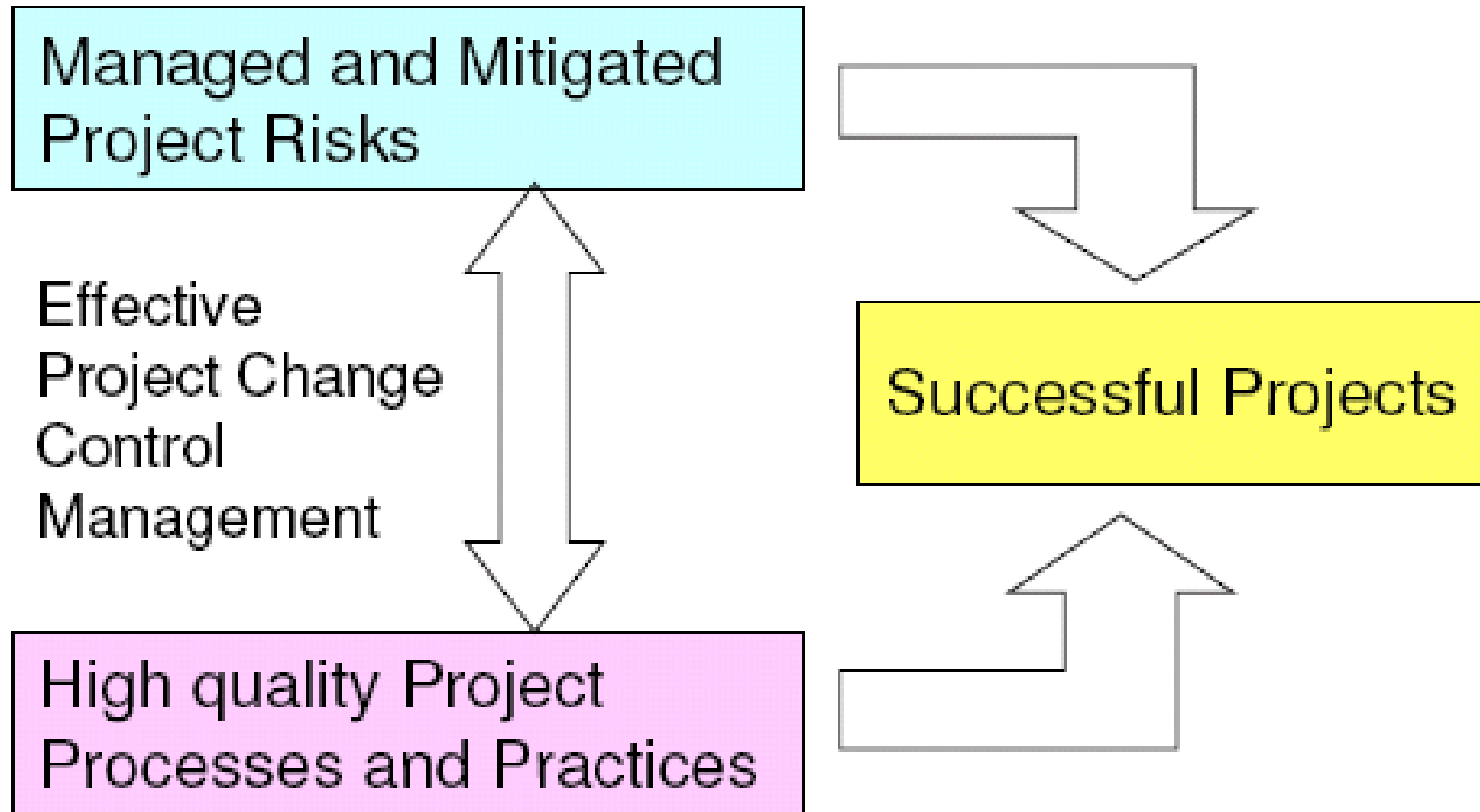
Management Framework of An Irrigation Project



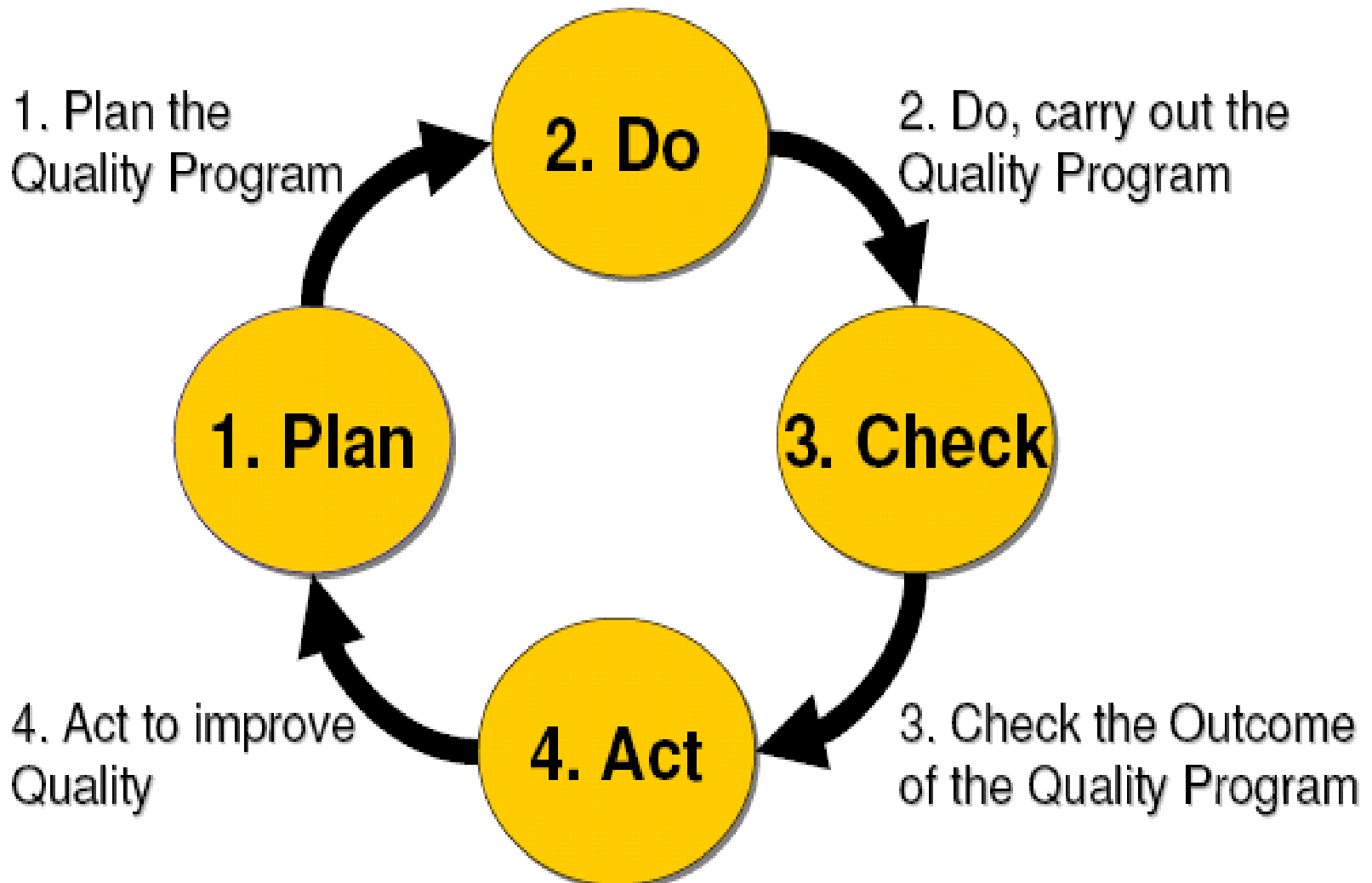
Processes of an Irrigation Project



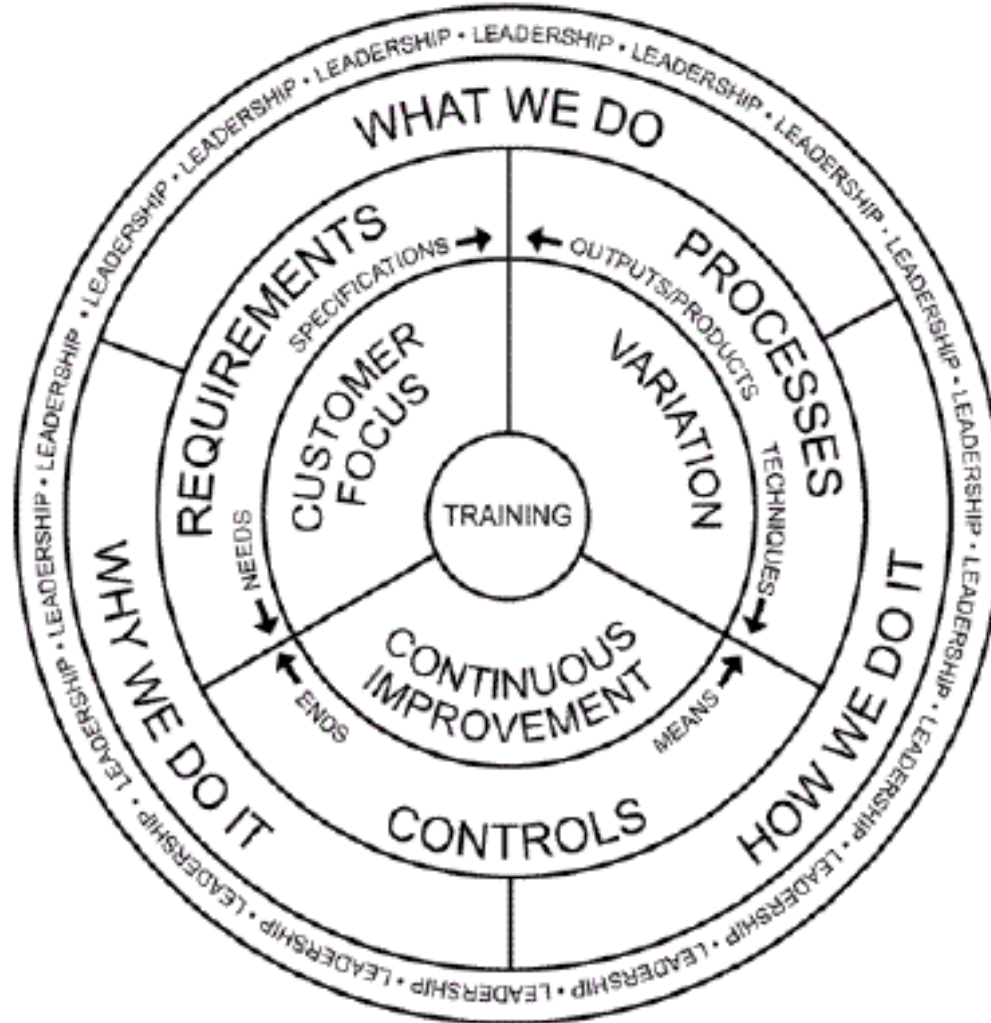
Link between Project Risk and Quality Management and Success



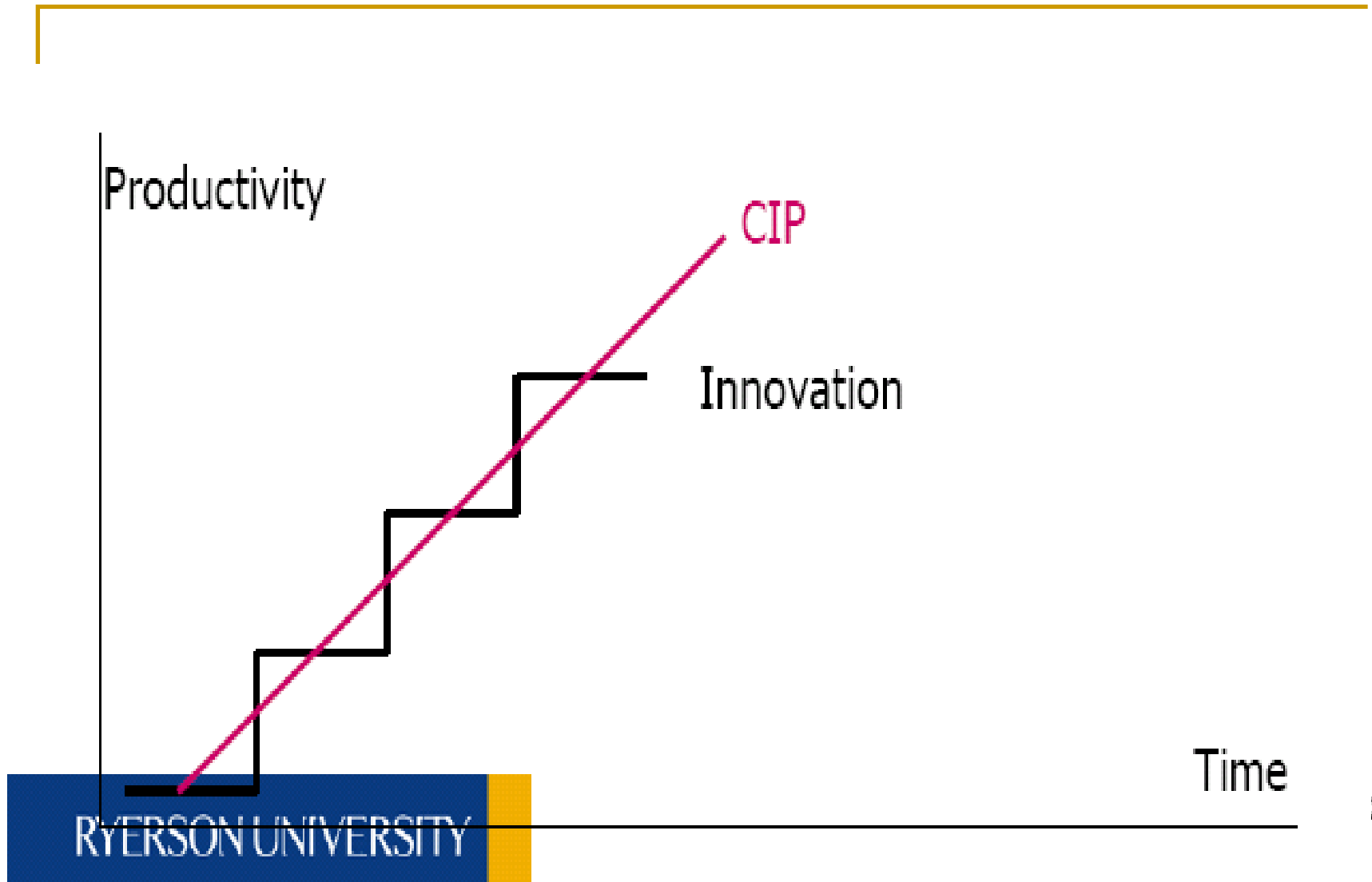
The Quality Cycle of Irrigation Projects



The Wheel of Quality Of Irrigation Projects



Continuous Improvement Process (CIP)



WATER SECTOR CHALLENGES

- ❑ Growing water shortages
- ❑ A high risk water environment
- ❑ Lack of transparency and inequities in distribution
- ❑ Large-scale degradation of the resource base
- ❑ Potential adverse implications of climate change
- ❑ Over-exploitation of groundwater
- ❑ Progressive deterioration of irrigation infrastructure

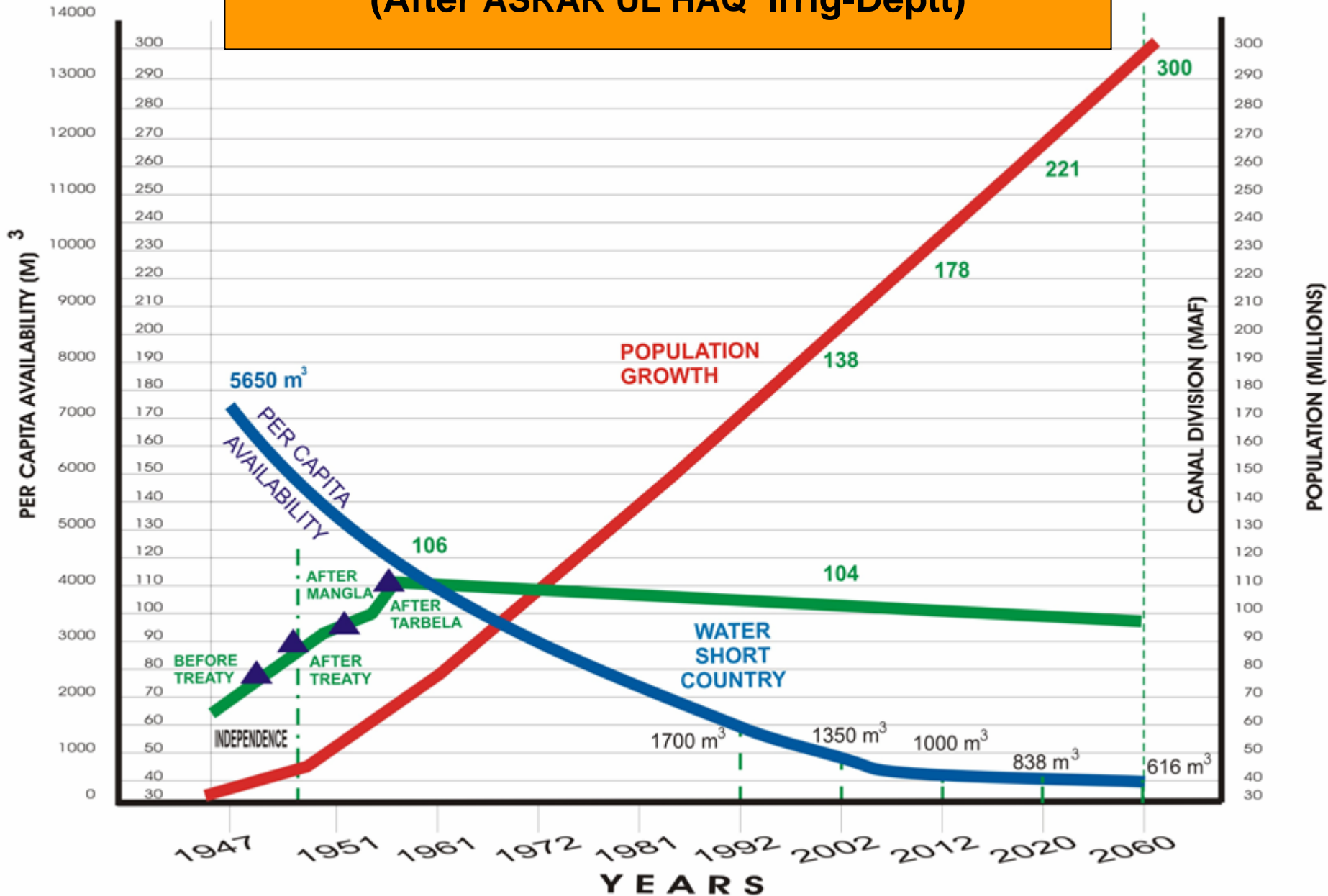
(After ASRAR UL HAQ Punjab-Irrig-Deptt)

WATER SECTOR CHALLENGES

- ❑ Lack of financial sustainability
- ❑ Gaps in governance and trust
- ❑ Low water productivity
- ❑ Increasing environmental hazards
- ❑ Inadequate knowledge base

(After ASRAR UL HAQ Irrig-Deptt)

DECLINING PER CAPITA WATER AVAILABILITY (After ASRAR UL HAQ Irrig-Deptt)



DECLINING PER CAPITA WATER AVAILABILITY

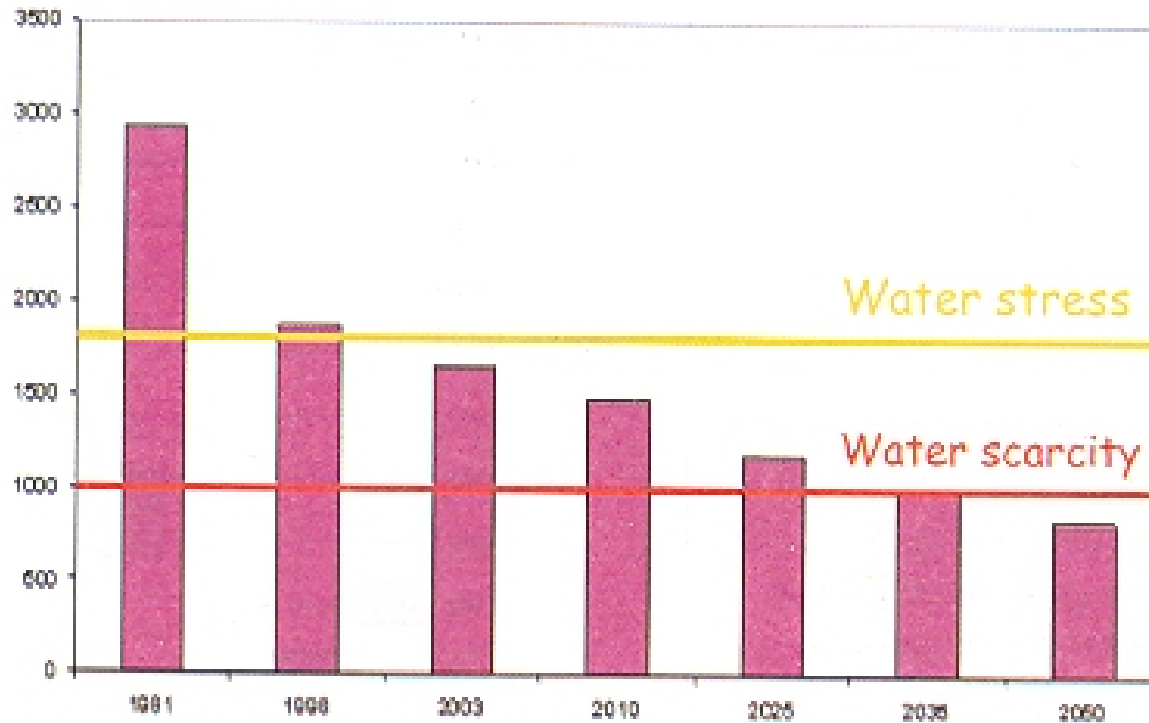


Figure S5: Declining per capita availability of water in Pakistan (cubic meters per capita per year)

Source: Amin 2005

Objectives and Concepts For Assessment Of Irrigation Systems

- **Objectives**
- Improve decision making by water management stakeholders
- Allow reliable comparison of different water management contexts in different countries.
- Address different aspects of the characterization of performance at different scales in different conditions of access to water.

Performance levels:

- The water-saving techniques and the technical and economic efficiency actually observed on the farm (at field level plus as an aggregate for the whole holding);
- The efficiency of the existing water allocation systems in the face of the liberalization of crop choices (at farm level).

Creating synthetic indicators:

- Formulation of global multi-criteria indicators that allow for interaction between the farming-system components. The following points need to be analysed at different scales:
- Hydraulic and agricultural features of farming systems, taking into account soil type variability and water availability;
- Farm costs and objectives (as objectives are not always strictly financial);
- The sensitivity of the system depending on the access to water (groundwater depth and quality, water service, restrictions on pumping, private storage) and the flexibility of the system itself;
- Possible future changes in existing systems and the advantages of sustaining them.

GRUSSE et al (2009)

Analysis of the effects of modernization and rehabilitation policies:

- Understanding why the performance targets of these policies are not always met and evaluating the profitability of the measures proposed at farm level (especially policies to subsidize water savings);
- Performing cost–benefit analysis of the measures planned at the farm scale (especially policies to subsidize water savings);
- Identifying the flexibility of the farming system and ways to change it by means of financial incentives or regulations. GRUSSE et al (2009)

Design of a framework to analyse performance:

- Hydraulic
- Agricultural
- Economic
- Environmental

Must be transferable from field level to farm level. The indicators should characterize the performance of the irrigation system in terms of both effectiveness and efficiency.

GRUSSE et al (2009)

Effectiveness:

- The ISO 9000 Norm states that effectiveness is the degree of accomplishment of planned activities and if the expected results are obtained (Froman and Gourdon, 2003).

- A raw value that characterizes performance or a ratio of characterization of the result obtained to the stated objective.

Absolute effectiveness (first case)

Relative effectiveness (second case).

GRUSSE et al (2009)

Efficiency:

- A ratio of output to input.
- The concept of efficiency in its broader sense is used to describe the use of resources. It can be stated that efficiency is a ratio concerning the performances of the production achieved and the maximum production allowed by a process that converts a set of inputs into output
(Boussemart, 1994).
- Technical efficiency
- Price (allocative) efficiency

(Farrell, 1957; Farrell and Fieldhouse, 1962).

Technical efficiency:

The maximum output (product) observed using a set amount of inputs (factors of production) given the range of technologies available to the farmer or, reciprocally, the minimum quantity of inputs (optimum and not excessive use) to produce a given output

(Azzam and Azzam, 1994). In this definition, it is assumed that the same technology is available to all the farmers and that only those who produce the maximum outputs are technically efficient.

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- **Technical inefficiency** corresponds to a lower rate of production than that technically possible with a given quantity of inputs (or, reciprocally, a larger quantity of inputs than that required for a given output).
 - **Technical efficiency** is measured by comparing the observed coefficients of the input points with the coefficients of inputs on the efficiency frontier for the same proportions of factors
(Timmer, 1971).
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- **Allocative efficiency**, or efficiency in relation to the price of production factors, evaluates the way in which farmers choose the proportions of the different inputs according to the prices on the market. It describes the way in which producers allocate their production resources to produce a given quantity of goods;
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■ Overall Efficiency

Technical efficiency + Allocative efficiency.

METHOD FOR PERFORMANCE CRITERIA CALCULATION

- Indicators, especially for hydraulic and agricultural performance, are defined at the plot level as a function of the irrigation system and the crop grown. Combining these to cover the farm as a whole is performed by assembling all the plots forming an irrigated field. Below, we examine the two scales in turn.
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Hydraulic performance indicators

- Water is the only factor involved in hydraulic performance. It should be recalled that the aim is to maintain a soil moisture content that is favourable for plant growth. Watering quality criteria depend on the amount of water stored in the root zone, that percolating beneath this zone, loss by surface runoff (in the case of gravity irrigation), and also on uniform application and on the percentage of under-irrigated area after watering. Many indicators are used, but the most frequent are
 - **AE, application efficiency,**
 - **CU, the coefficient of uniformity.**
 - Although a preliminary evaluation can be made from the total quantity of water applied throughout the farming season, the volume of water used for each irrigation application must be considered.
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■ Application efficiency :

Ratio of the volume V_{rz} actually stored in the root zone (rz) and the total volume applied V_T . The latter is made up of V_{rz} plus the percolated volume V_p beneath the root zone and the runoff volume V_{ro} in the case of open-ended furrow or border strip irrigation.

$$AE = 100 (V_{rz}/V_T)$$

Burt et al. (1997)

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- For **Sprinkling**, as in gravity irrigation, the application often consists of the amount required to use up the easily usable water reserve to avoid having to return to the plot too often.
 - The volume stored in the root zone can be estimated by measurement (sample-taking using an auger, neutron probe, time-domain reflectometry (TDR) probe, with measurements taken in several test areas before and after watering). However, this method is long and laborious and consequently modelling is used whenever possible.
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- Sprinkler irrigation requires a model capable of evaluating water distribution in basic test areas (Molle et al., 1999; Montero et al., 2001; Ruelle et al., 2003). There are many models for gravity irrigation. They are easy to use and are calibrated on the advance trajectory (Renault and Wallender, 1992; Mailhol and Gonzalez, 1993) using intake flow and cut-off time. Given the spatial variability of the advance-infiltration process, estimating these criteria at plot level requires calculating a typical furrow with average advance-infiltration features.
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- In **Drip irrigation**, infiltration is either axisymmetrical, for an isolated source, or bidirectional for a line of drippers, and field measurement of hydraulic performance is thus fairly delicate. However, when measuring the initial moisture content at the beginning of the season, the characteristics of the installation and the duration of irrigation application make it possible to estimate, by subtracting possible percolation beneath the root zone, if the crop is managed at maximum evapotranspiration (MET), as is often the case for vegetables. Application efficiency can be calculated using Equation (1). Models such as HYDRUS-2D (Simunek et al., 1999) may be necessary for more complex cases.

■ Coefficient of Uniformity

vary with the irrigation system. For example, in furrow irrigation the CU is the ratio between the average amount of application in the last quarter of the furrow and the total amount infiltrated (Merriam and Keller (1978)). The coefficient of uniformity is more commonly used for sprinkling:

$$CU = 100 (1 - SD/M)$$

- where SD is the standard deviation and M the average water depths measured with rain gauges placed in the centre of the mesh of a network squaring the plot or the part of the plot under study.

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- Trickle irrigation is evaluated by measuring the flows of a set of drippers according to their position in the plot; various standard procedures are available in the literature (e.g. Keller and Bliesner, 1990).
 - Burt et al., (2000) stressed the role of watering uniformity in increasing yields, whence the advantage of choosing this performance indicator as well. When uniformity is poor, the farmer increases the application amount, thus reducing efficiency.
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Environmental impact indicators

- soil salinity
- Water Logging



Table I. Hydraulic indicators at farm level

	Aim	Effectiveness	Efficiency
<i>Result indicator (value)</i>	Maximizing total application (including water for leaching) for a farming system	<ul style="list-style-type: none"> • Water application depth: \sum (applications per plot) • (Application performed)/ (Accessible resource) 	<ul style="list-style-type: none"> • $TPE = \sum (AE_i * V_{it}) / \sum V_{it}$ • $TPECE = \sum (AE_i * CE_i * V_{it}) / \sum V_{it}$
<i>Objective indicator (in relation to a standard or a target)</i>	Apply the volume necessary (including water for leaching) for a farming system and yield targets	<ul style="list-style-type: none"> • $Ts1 = \text{volume allocated} / \text{volume required}$ • $Ts2 = \text{volume allocated} / \text{volume requested}$ • $Ts3 = \text{volume received} / \text{volumes allocated}$ 	<ul style="list-style-type: none"> • $TPE/TPES$ • $TPECE / TPECES$
<i>Environmental impact indicator</i>	Leaching salts applied but with control of water losses and fertilizer leaching	<ul style="list-style-type: none"> • \sum (total loss)_i • \sum salts leached • \sum N leached 	<ul style="list-style-type: none"> • \sum (losses)/V_t • \sum (salts leached)/V_t • \sum (N leached)/V_t
<ul style="list-style-type: none"> • losses • leaching of nitrates • leaching of salts 			

■ The objective indicators

- make it possible to refer to a volume allocated and to evaluate the degree to which it meets crop requirements (to achieve yield objectives) on the one hand and the farmer's demands on the other. A distinction is made between:

- $T_s1 = \text{allocation received} / \text{allocation required}$
- $T_s2 = \text{allocation awarded} / \text{allocation requested}$
- $T_s3 = \text{allocation received} / \text{allocation awarded}$

- T_s2 is defined at the beginning of the season in the light of the reservoir storage reserved and the quota allocated to farming; the farmer uses this information to design his cropping plan.
- In contrast, T_s1 and T_s3 are only available at the end of the season. The amount actually received incorporates the effects of climate and different water uses, failures, etc. The levels defined are of great interest for large hydraulic operations and collective networks.

- A distinction is made in result efficiency indicators between overall efficiency for all the irrigated plots on the farm and TPE (total plot efficiency), without allowing for conveyance efficiency. The former describes the quality of application at farm level. This must then be completed by conveyance efficiency CE_i , leading to a second index, TPECE. This gives the aggregate values:

$$TPE = \sum (AE_i * V_{Ti}) / \sum V_{Ti}$$

$$TPECE = \sum (AE_i * CE_i * V_{Ti}) / \sum V_{Ti}$$

- where in plot i : VT_i ($m^3 ha^{-1}$) is the volume at the field intake for plot i with application efficiency AE_i and conveyance efficiency CE_i . For objective efficiency, the indicators TPE and TPECE are divided by TPES and TPECS in which the efficiency values correspond to standards that are coherent with set targets, like those mentioned by Clemmens (2002).

Environmental indicators

- Are the part of Environmental Impact assessment

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GRUSSE et al (2009)

Agricultural performance indicators

- Field level. As regards agricultural performance, the focus is on the different inputs including water, and their combination in the crop management sequence, as the agro-ecological environment governs production potential in a given zone.
- In this case, the reference value for indicators is yield, with the exception of the evaluation of environmental impact for which we propose first to use nitrogen – to allow for water pollution by possible excess nitrogen fertilizer – and energy – to evaluate the consequences of the choice of crop management sequences and crops. These values are easier to determine or will subsequently become easier as work progresses and the databases for life-cycle analyses are built.

- The aim of calculating the performance indicators is to improve production with irrigation, and effectiveness is expressed directly by the increase in yield compared with rain-fed farming:

$$\Delta YL = (YL - YLr)$$

- where YL is irrigated yield and YLr is rain-fed yield.

- **Agricultural efficiency** or water use efficiency (WUE, kgm^{-3}) is generally defined as the relation between yield YL (kg ha^{-1}) and the amount of water required to attain this yield (Viets, 1962), which is total evapotranspiration over the season, AET ($\text{m}^3 \text{ha}^{-1}$):

$$\text{WUE} = \text{YL}/\text{AET}$$

AET is often calculated from the water balance (Howell, 2001) by examining the moisture in soil sampled in the root zone. This is a satisfactory index for the comparison of water productivity in different crops with cycles at different times of the year.

- **Marginal water use efficiency, MWUE**
- However, the contribution of irrigation is not shown in this index and Bos (1980, 1985) consequently proposed to characterize the efficiency of irrigation water use by calculating the increase in yield resulting from irrigation. To be consistent with terminology used by irrigation economists (Agudelo and Hoekstra, 2001), we propose to call it marginal water use efficiency, MWUE:

$$\text{MWUE} = \Delta YL / V_T$$

- The ratio is expressed in kgm^3 of irrigation water. This productivity performance indicator should be handled with care. It can give very different results depending on whether or not the crop can be grown under rainfed conditions. Rainfed yields of wheat (for example) display huge inter-seasonal variations in North Africa and maize and vegetable yields are generally nil without irrigation.
- The production targets set by farmers for each plot (which explain the amounts of inputs applied) are based on a target yield. Target yields are also used in project design by developers. It is thus logical to define target indicators and an efficiency index based on the relation between real and target yields. The index shows the percentage attainment of the target.

	Aim	Effectiveness	Efficiency
<i>Result indicators</i> (ratio: value/potential value; value)	Maximizing production by irrigation	$\Sigma [IAC_i (YL/YL_{pot})_i] / \Sigma IAC_i$ Overall rate of cultural intensification CIR: (cropped area/irrigated area)	<ul style="list-style-type: none"> • $TWUE = \Sigma(IAC_i * WUE)_i / \Sigma IAC_i$ • $TMWUE = \Sigma [IAC_i[(\Delta YL_j) / V_j]] / \Sigma IAC_i$
<i>Objective indicators</i> (in relation to a standard)	Maximizing production by irrigation according to local objectives	$\Sigma [IAC_i (YL/YL_{obj})_i] / \Sigma IAC_i$ Overall CIR / Target CIR	<ul style="list-style-type: none"> • $\Sigma[IAC_i (YL/ AET)_i / (YL_{obj}/ AET_{obj})_i] / \Sigma IAC_i$ • $\Sigma\{IAC_i [(\Delta YL) / V_{Ti}] / [(\Delta YL_{obj}) / V_{Tiobj}]\} / \Sigma IAC_i$
<i>Environmental impact indicators</i>			
Nitrogen	Limit unused nitrogen residues.	Unused N	$\Sigma (N_{used} / N_{applied})$
Energy	Minimize energy used in production	Energy used	$\Sigma (E_{output} / E_{input})$

Framework for Performance Assessment

- The performance of a system may be defined as the acquisition of inputs, and the transformation of these inputs into intermediate and final outputs, as well as the effects of these activities on the system itself and its environment. The performance of a system is represented by its measured levels of achievement in terms of one, or several, parameters, which are chosen as indicators of the systems' goals (Abernethy, 1989).

Important aspects in performance Assessment

- Scale and audience.
 - The irrigation management (impacts the water delivery system up to the national level).
 - The level of achievement (can have different contexts and implications according to the perceptions and objectives of the reference level).
 - Change in performance expectations over time. (the changes, both within the system itself, as well as in the external environment).
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Categories of monitoring of performance Assessment :

- Operational Performance Monitoring
- Accountability Assessment
- Intervention Assessment
- Environmental Impact Assessment.

After Small and Svendsen (1992)

- The operational performance monitoring deals with day-to-day monitoring of operational performance. The scheme managers need a consistent and continuous inflow of data to enable them to decide on operational matters. The data include river discharges and reservoir levels, water levels and discharges at various regulation points in the off-taking canals, cropped area, climatological and hydrological data, and water demands. The accountability assessment can be applied to the internal processes of the irrigation organization, the relationship and procedures of the Public Accounts Committees, and the relationship between irrigation agencies and the farmers. For accountability assessment to be fair and objective, the active participation of the various interest groups at different levels needs to be institutionalized.

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- The intervention assessment deals with monitoring of strategic interventions in the system, and is undertaken to determine the ways and means to improve some aspects of the scheme's performance. This may range from modest changes in water distribution procedures to major institutional reforms. The intervention analysis involves assessment of scheme performance at a given time, evaluation of the performance with a view to identifying constraints in effective management, and taking appropriate corrective action.
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- Irrigation management experts point out that evidence of an effective performance assessment framework, which would help management to evaluate and improve overall performance is still lacking (Murray-Rust and Snellen, 1993).
 - Setting a framework for irrigation system performance is a first step towards analyzing the functions of the irrigation system. This framework needs to be evolved in the context of various components of the system: the irrigation service, the agriculture service and the farmer (FAO, 1991).
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Minimum set of indicators for performance assessment of irrigation schemes.

Indicator	Definition / Description
Output / unit land	Standardized gross value of output/ area irrigated (\$/ha)
Output / unit irrigation supply	Standardized gross value of output/ irrigation delivered ($\$/\text{m}^3$)
Output/unit water consumed	Standardized gross value of output/ all water consumed($\$/\text{m}^3$)
Return on investment	Standardized gross value of output/ cost of system

(After ASRAR UL HAQ Punjab-Irrig-Deptt)

Minimum set of indicators for performance assessment of irrigation schemes.

Indicator	Definition / Description
Financial self-sufficiency	Water charges / cost of O&M
Relative water supply	Total irrigation supply / irrigation demand
Water capacity	(Sub) system capacity / peak consumptive demand
Environmental indicators	<ul style="list-style-type: none">- area lost to waterlogging and salinity- groundwater level fluctuations, etc..

Performance Indicators Used by the Punjab Irrigation Department

- The present management information system is based on manual record keeping and data analysis, which depends on irrigation managers' skills and the experience of dealing with day-to-day operation of the canal network within the framework of the organizational structure. In order to help system managers to assess the irrigation performance and for Decision Support Systems (DSS) on operational controls, the departmental codes and manuals prescribe a systematic procedure for data collection, its analysis and reporting. The important performance indicators used by the PID include: operational indicators, accountability indicators, impact indicators, and others. These indicators are listed in Table

(After ASRAR UL HAQ Punjab-Irrig-Deptt)

- Another important dimension of the performance indicators has been that these were evolved in the context of the Irrigation Department's objectives. The main consideration in this regard has been the boundaries of the operation of irrigation schemes. The irrigation management follows a segregated system in Pakistan, whereby the irrigation agency's responsibility is limited to operation and maintenance of barrages, canals, drains, tubewells and flood works. The policy formulation related to agriculture, marketing and pricing mechanism that greatly influences irrigation management goals of higher order on one end, and the watercourse maintenance, farming practices, cropping patterns and use of non-water inputs that affect productivity on the other end of the spectrum, are beyond the jurisdiction of the irrigation agency. Therefore, it can be understood that output indicators involving yields, crop production and socio-economic impacts of irrigation have not been included for performance assessment. (After ASRAR UL HAQ Punjab-Irrig-Deptt)

- The main concern about the performance assessment of departmental activities is the current practices that inhibit an effective evaluation of the performance. The problem areas include reporting delays, quality of data, inadequate analysis, erratic control and inaction on the part of the managers. In a departmental management study, the consultants attributed delays in monitoring and reports to lengthy procedures, inefficient / inadequate staff, lack of control by the upper echelons, defective format of reports and lack of staff training (UCL, 1985). In addition, PRC / CHECCHI (1986) identified that individual performance standards are not specified and monitored, the chain of command is either ignored or proper communication is lacking, and procedures and organization for enforcement against standards of accountability are not adequately developed.

(After ASRAR UL HAQ Punjab-Irrig-Deptt)

Table Performance Indicators of the PID.

S. No.	Indicator Type	Description
1	Operational Indicators	<ul style="list-style-type: none">• Indicators that measure/equity of canal water distribution, like tail gauge statements and actual discharge in each off-take, compared to the design/authorized discharge. The specific indicators in this regard are tail gauges and H-registers of outlets and off-take.• Delta statement, comparing actual depth of irrigation supplies to that of the designed values.• Actual water and bed profiles of the channels, compared to the design profiles.• The incidence of cuts and breaches.• General conditions of maintenance of irrigation channels and structures.

(After ASRAR UL HAQ Punjab-Irrig-Deptt)

Table Performance Indicators of the PID.

S. No.	Indicator Type	Description
2	Accountability Indicators	<ul style="list-style-type: none">• Performance evaluation reports.• Number of public complaints.• Number of disciplinary/enquiry cases.• Number of audit paras.

(After ASRAR UL HAQ Punjab-Irrig-Deptt)

3	Impact Indicators	<ul style="list-style-type: none"> • Cropping intensities and patterns vs. the designed and historic trends (Efficiency Diagrams). • Groundwater fluctuations (well measurements) and salinity monitoring. • Revenue generation. • Public complaints.
4.	Other Indicators	<ul style="list-style-type: none"> • Related to construction / implementation of works / projects. These include : <ul style="list-style-type: none"> ✓ No. of projects implemented. ✓ Timely completion of projects. ✓ Progress monitoring of implementation vs. planned. ✓ Delayed contracts. • Related to revenue works, it may include the no. of delayed revenue cases, farmers' complaints, etc..

(After ASRAR UL HAQ Punjab-Irrig-Deptt)

Monitoring and Evaluation System

- The monitoring and evaluation of the Punjab Irrigation System includes collection and processing of river and canal flow data on a daily basis. The canal gauges and discharges are observed at head, tail and at suitable intermediate points (falls, regulators, etc.). Information pertaining to the tail gauges are very important in a canal flow distribution network, as these are indicative of the equity and reliability of the canal supplies, and thereby, are representative of the overall channel and system performance. In addition, outlet discharges are observed periodically to monitor actual discharges delivered to the farmers at the head of the watercourse.

(After ASRAR UL HAQ Punjab-Irrig-Deptt)

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- In order to help system managers to assess the irrigation performance, the departmental codes and manuals prescribe a systematic procedure for data collection, its analysis and reporting. Various statements which, have been specified, are presented in Table
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Table PID Reporting System.

S. No.	Type of Report	Description (After ASRAR UL HAQ Punjab-Irrig-Deptt)
A	Monthly Reports	<ol style="list-style-type: none">1. Statement of daily gauges and discharges of water received and used during the month.2. Monthly Delta Statement.3. Rainfall Statement.4. Monthly realization of water rates by the Deputy Commissioner.5. Monthly Irrigation Operation Statement.6. Statement of unauthorized irrigation and waste of water.7. Report on cuts and breaches in irrigation canals.
B	Quarterly Reports	Statement of delayed revenue cases.
C	Half-year Reports	<ol style="list-style-type: none">1. Statement of assessment and realization of water rates.2. Statement of rainfall during the half year as compared to the half year of the previous year

D	Yearly Returns	<ol style="list-style-type: none">1. Budget Estimates of revenue receipts and expenditure.2. Outlet efficiency diagrams.3. Assessment and remission statements for both the crops.
E	Other Records	<ol style="list-style-type: none">1. Outlet Registers.2. Irrigation Registers.3. Register of petitions regarding alterations to outlets and chaks.4. Measurements and check measurement books.5. Record of expenditures.6. Register of stock, tools and plants.

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- The monitoring activity at the farm level includes collection of data on irrigated and cropped areas, cropping patterns and planting dates, and conditions of crops. The rainfall data and ground water levels are observed at designated sites. At irrigation water user level, there is interaction between the farmer and irrigation manager that relates to arbitration of water disputes among shareholders, addressing the problems of shortage of canal supplies and alteration of source of canal supply from one outlet to another.
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- Monitoring and evaluation of the irrigation system also involves identification of operational problems of channels, such as the level of freeboard, stability of banks, extent of siltation of channel bed, and conditions of structures, etc.. This helps to plan maintenance and repairs of the irrigation network. On the operational side, the irrigation manager has to respond to a host of field conditions for the distribution of supplies that involves real time decision-making. These include fluctuating canal water demands, distribution criteria during water-short periods, management of excess flows during monsoon rains, sediment control and canal closures during floods, and remodelling of channels and structures, etc.
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Review of PID Performance Indicators

- Most of the performance indicators of the PID had been evolved at the time the irrigation system was developed during British colonial rule. At that time, modern concepts of irrigation management were not in place. Therefore, performance indicators were simple, representing the state of knowledge at that time. The more sophisticated indicators, like relative water supply, interquartile ratios and potential productivity, were not prescribed. Nevertheless, the indicators used were quite effective to assess the performance of the irrigation system in the context of its objectives. Some of these indicators are relevant even today, despite considerable differences in the environment and the time horizon. The set of performance indicators, however, need to be reviewed, updated and made more responsive to the present day requirements in keeping with the contemporary management concepts and new challenges. (Asrar-ul-Haque) (After ASRAR UL HAQ Punjab-Irrig-Deptt)

Impact of Institutional Reforms on Irrigation Agency Objectives and Functions

- As a result of implementation of the institutional reforms, the objectives and functions of irrigation agency will have to be redefined. The agreed institutional reforms focus on decentralization, participatory management, improved service and sustainability.
- With the establishment of the Punjab Irrigation and Drainage Authority (PIDA), the Area Water Boards (AWBs), and the Farmers Organizations (FOs); the management functions of various entities would undergo a transformation and the current functions of the Irrigation Department would be shared by the proposed new institutions. For example, the Irrigation Department would retain the role of overall policy regulation and oversee.

(After ASRAR UL HAQ Punjab-Irrig-Deptt)

- PIDA, as an autonomous entity, would be responsible for all the functions of the Irrigation Department, with emphasis on improving irrigation performance, optimizing water use efficiency, introducing the concept of participatory management, undertaking measures to improve assessment and collection of water rates, and making the Authority self-sustaining. The Area Water Boards would perform most of the above irrigation functions at the canal command level and would also adopt and implement programs aimed at promoting the formation and growth of FOs. The FOs would be expected to operate and manage the minors / distributaries in their jurisdiction, obtain irrigation water from the Area Water Board at the head of the distributary and supply it to their members, assess/ collect the water charges from the water users, and perform any other functions assigned to them.

(After ASRAR UL HAQ Punjab-Irrig-Deptt)

- The reforms process is expected to be implemented in a phased manner. The redefinition of the irrigation management functions and objectives, therefore, would evolve over time, consistent with the main theme of institutional reforms that focuses on decentralization and participatory management. In order to expedite the process, the aiding agencies are funding an institutional reforms consultancy under the on-going National Drainage Program (NDP). The Consultancy, expected to be commissioned by October 1998, would propose the broad contours and working details of the new institutions. This would include identification of their functions and duties, organizational set-up, operations management, legal framework, financing / accounting systems, transition management, and monitoring arrangements. The proposed institutional set-up will be field tested in the pilot AWB and its performance would be closely monitored to learn from the experience and to spot the necessary adjustments in the roles and operating rules of the new upcoming institutions to optimize the process of reforms.

(After ASRAR UL HAQ Punjab-Irrig-Deptt)

Recovery Cost Ratio (RCR)

- The ratio of cost of recovery to the cost of distribution cost.
 - $RCR = R/D$
 - Where, 'R' represents the recovery; the water fees paid by the farmers to the irrigation department. 'D' is the distribution cost which is the sum of operation and maintenance (O&M) and establishment costs for the main and secondary canals from head to the farm gate.
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Economic Delivery Efficiency (EDE)

- The ratio between the operation and maintenance cost (O&M) and the distribution cost (D) and is given as:
 - $EDE = O\&M \text{ cost}/D$
 - A low value of EDE for an irrigation system shows that the system is bureaucratic and requires a lot of money on administration, as compared to the operation and maintenance (O&M)
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Relative Water Cost (RWC)

The ratio between the total irrigation cost (I) and total production cost (P). The cost of irrigation water has a very important role from the farmer's perspective. This indicator shows the share of irrigation cost in the total production cost of a certain crop. It is given as follows:

$$\blacksquare RWC = I/P$$

Total production cost includes the cost of irrigation, land preparation, fertilizer, pesticide, seed and labour etc.

Relative Farm Irrigation (RFI) Cost

The ratio between on-farm irrigation cost OFI and total irrigation cost (I).

- $RFI = OFI / I$
 - High values of RFI show that there is potential for the reduction of on-farm irrigation cost. Groundwater irrigation is the major part of the on-farm irrigation.
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Benefit Cost Ratio (BCR)

■ The ratio between irrigation benefits (IB) and irrigation costs (I) given as:

$$\blacksquare (BCR) = IB / I$$

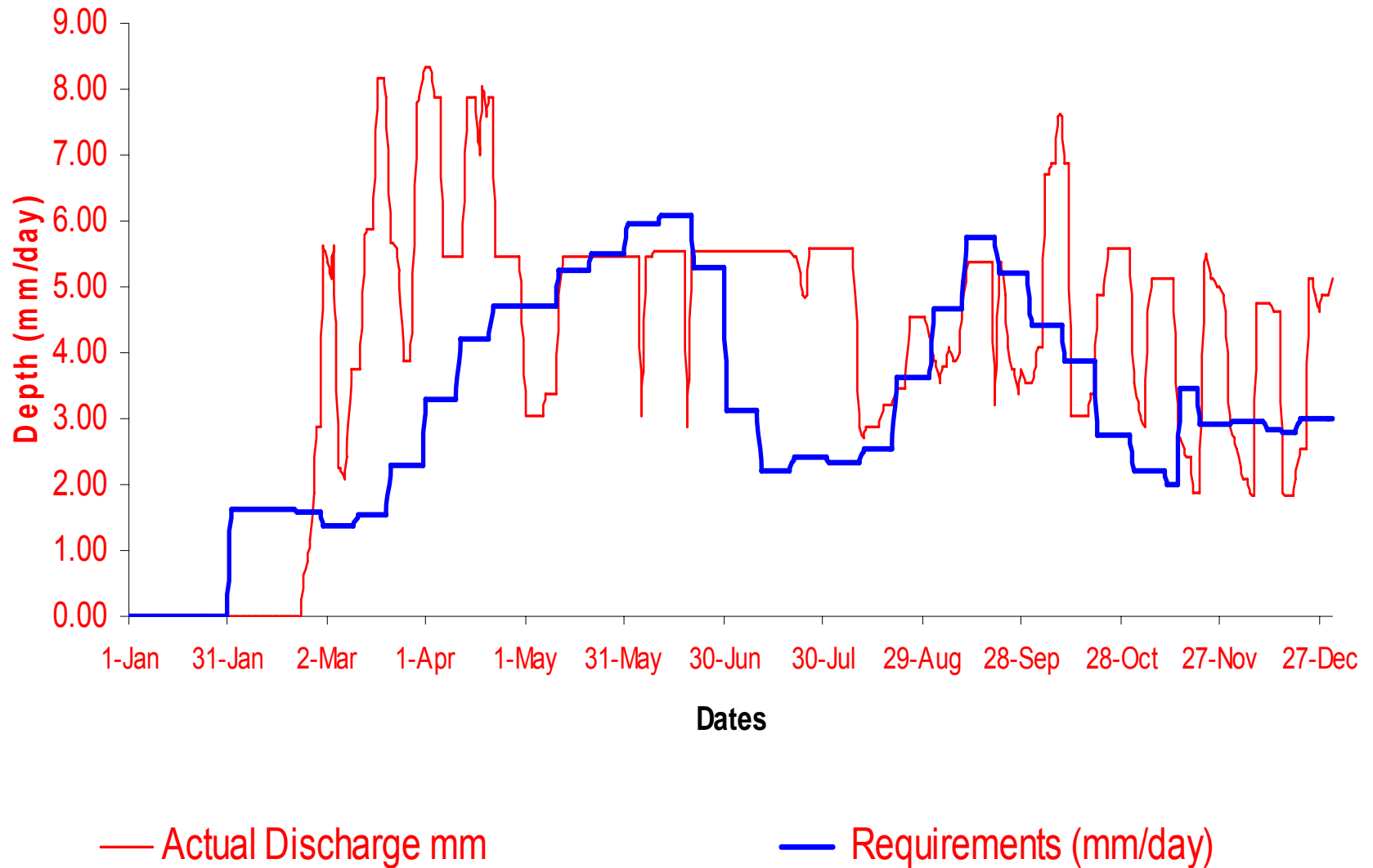
For a successful irrigation system, the value of irrigation benefits must exceed the irrigation costs.

Delivery Performance Ratio (DPR)

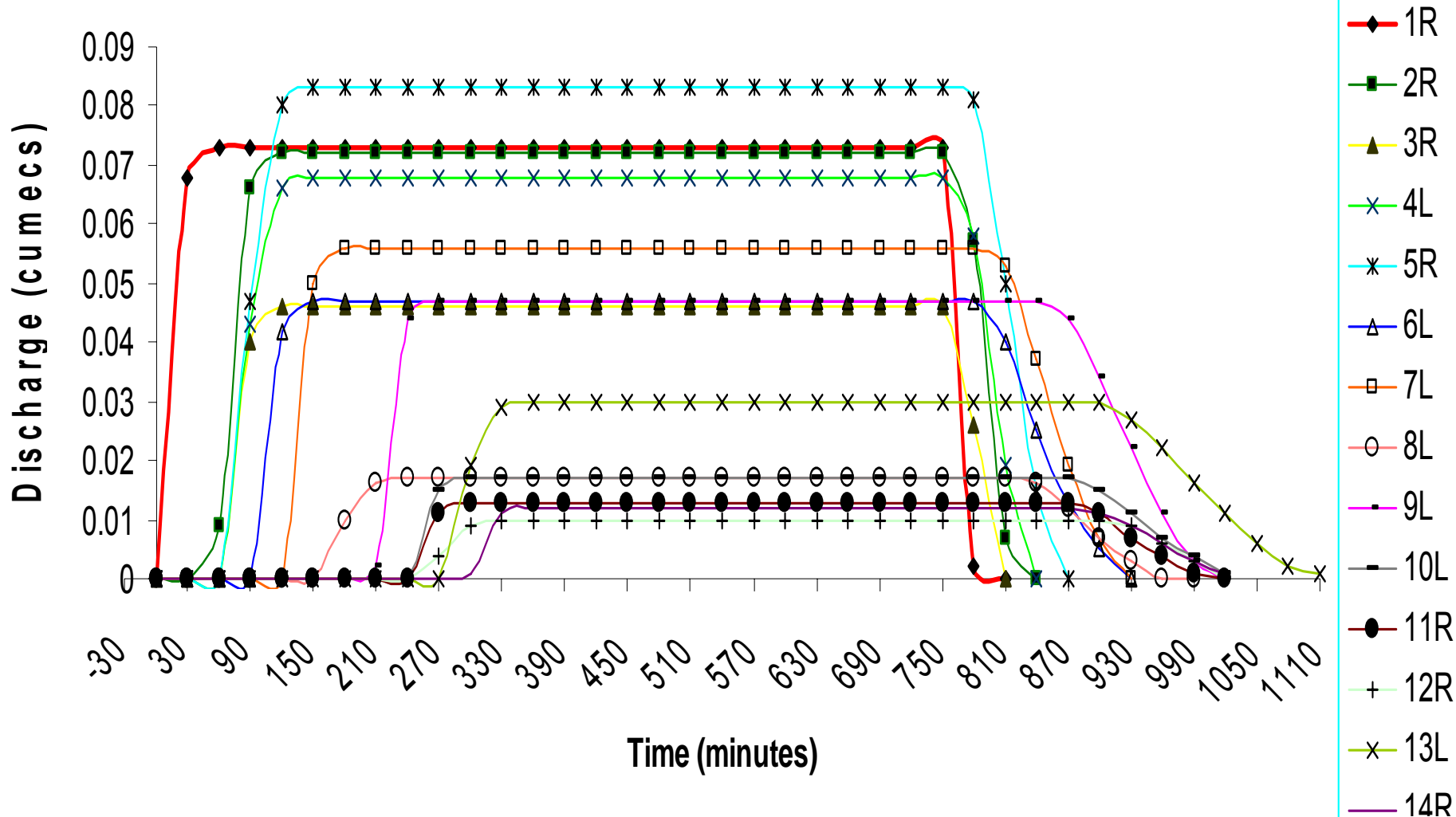
- The ratio of an outlet is the ratio between the observed discharge (Actual Discharge Q_o) and target discharge (Design Discharge Q_d).
 - $DPR = Q_o/Q_d$



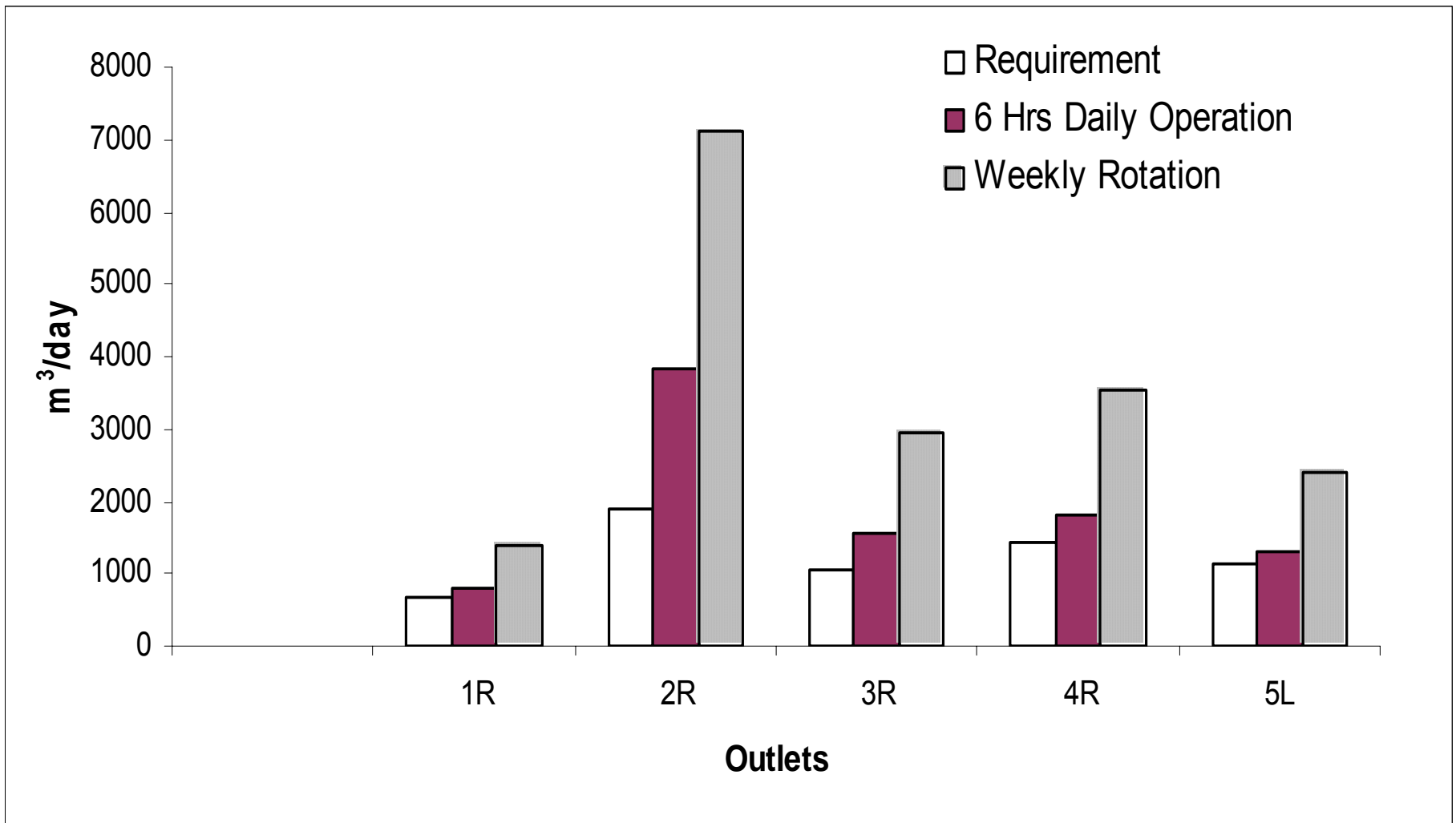
Machai Branch



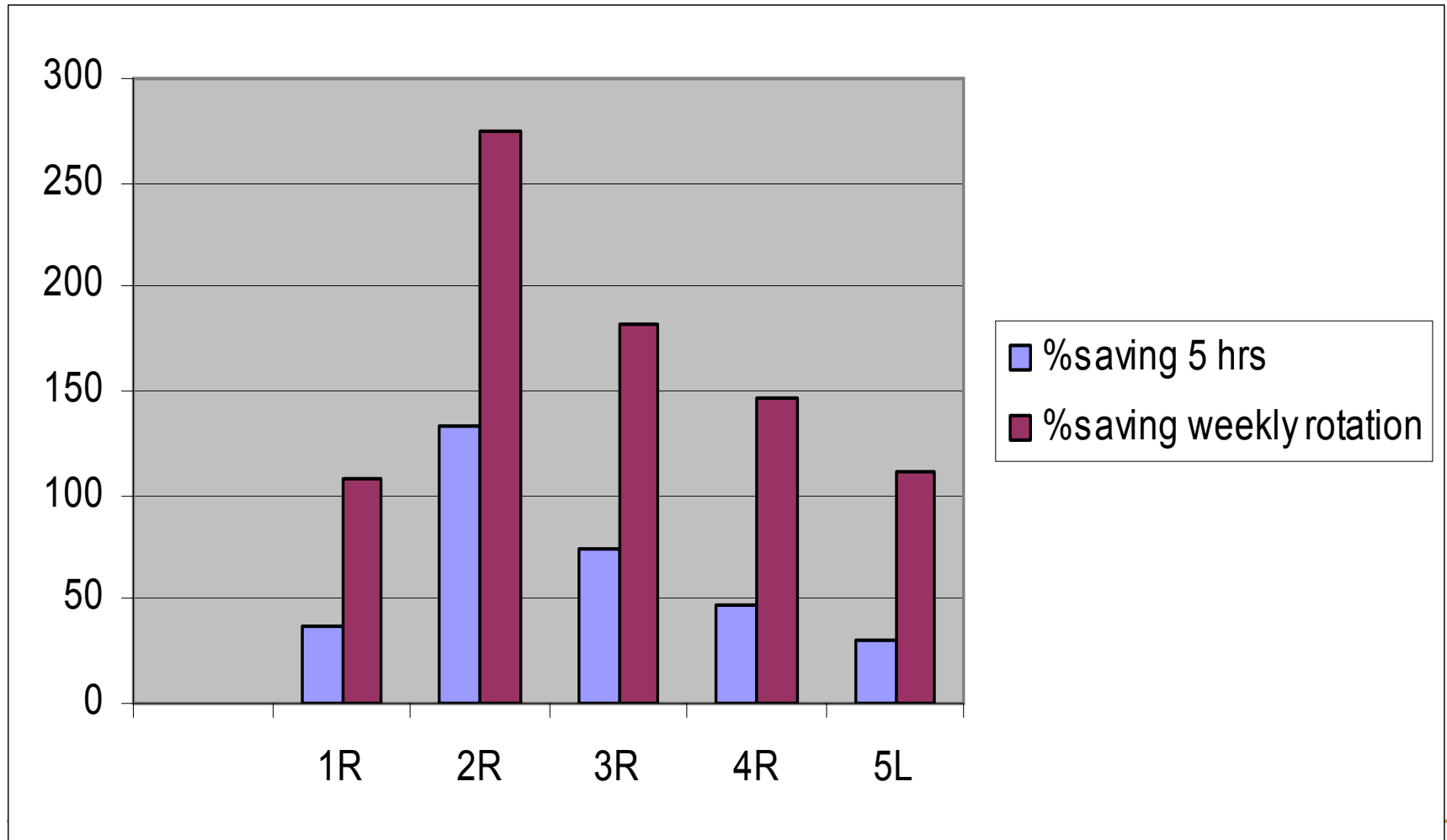
Hydrographs for Night closing and Morning opening



Modelling for Night Clising of canals and water saving (NWFP) Dr Zubair Khan



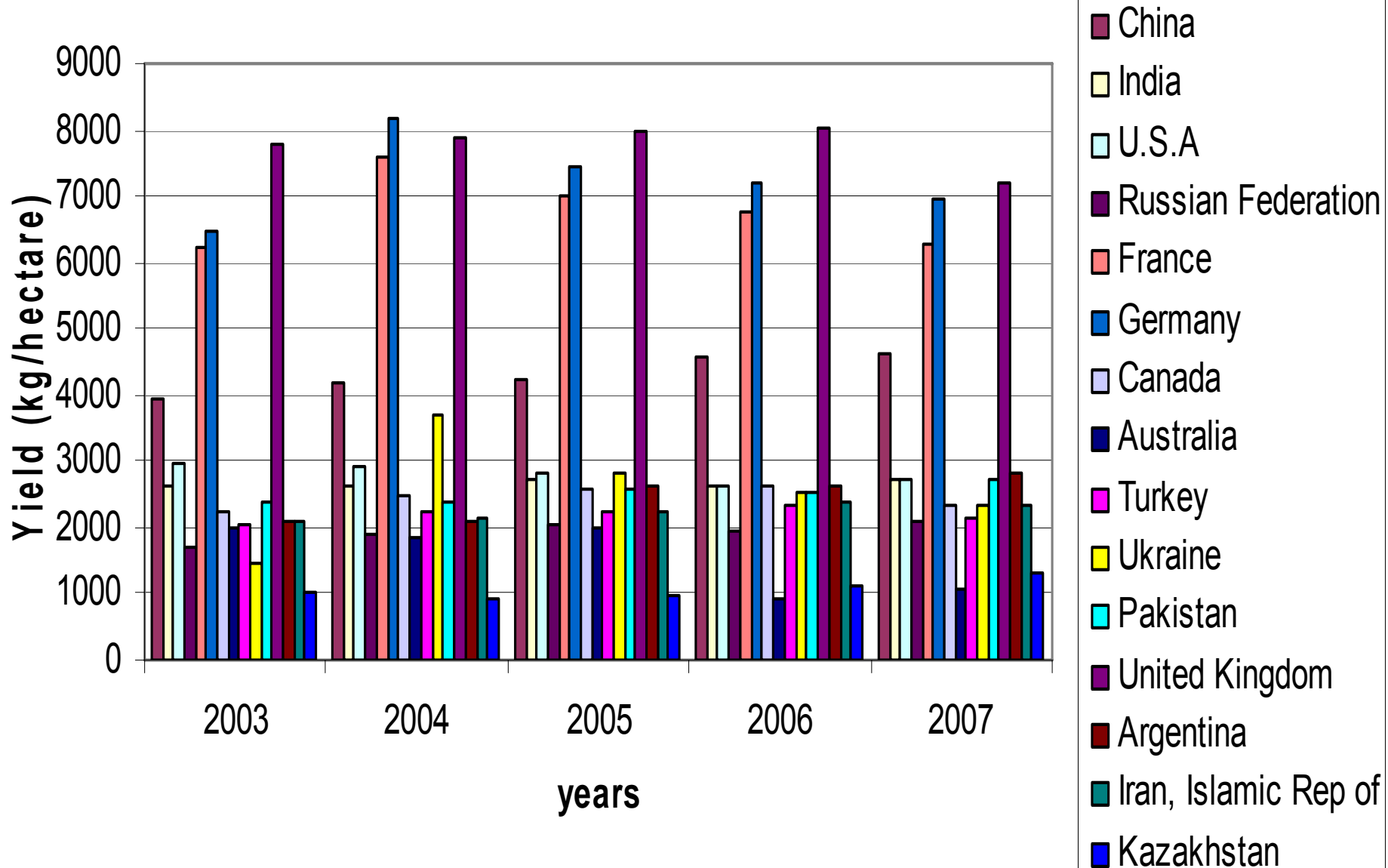
Modelling for Night Clising of canals and water saving (NWFP) Dr Zubair



Modelling for Night Clising of canals and water saving (NWFP) Dr Zubair



Wheat yield



Decision Support System (DSS)

The model programming uses an objective function to schedule water deliveries to lateral service areas Eq. 1. Constraints on variables within the objective function are specified and must be satisfied in determining the optimum solution. This process achieves the result that water delivery to laterals with more immediate crop water needs is favored, and delivery to laterals that have sufficient water in a given time step is minimized

$$\text{Minimize } Z = MP_{D-0}X_{D-0} + MP_{D-1}X_{D-1} + MP_{D-2}X_{D-2} \\ + MP_{D-3}X_{D-3}$$

INTRODUCTION

In North Africa, irrigation contributes substantially to production and to maintaining minimum food security, the importance of which is revealed by current market conditions (Abaab, 2002; Troin, 2006). However, with the exception of the substantial progress made in export farming (Moroccan fruit and vegetables, olive oil and dates from Tunisia) and certain crops destined for agro-industrial commodities (milk, sugar crops, etc.), the sector as a whole displays low productivity. The average yields of most staples are 40–50% lower than world standards. The difference between existing and potential yields is 50–60% (Cen~a et al., 2005).

■ Interventionist policies were implemented in a context of planned decisions with the prior definition of farming and of the allocation of water. The vast majority of intensification targets for public-sector irrigation systems were only partially met. Current capacity for the mobilization of resources is more and more limited and costs are rising in an increasingly unfavourable climatic setting.

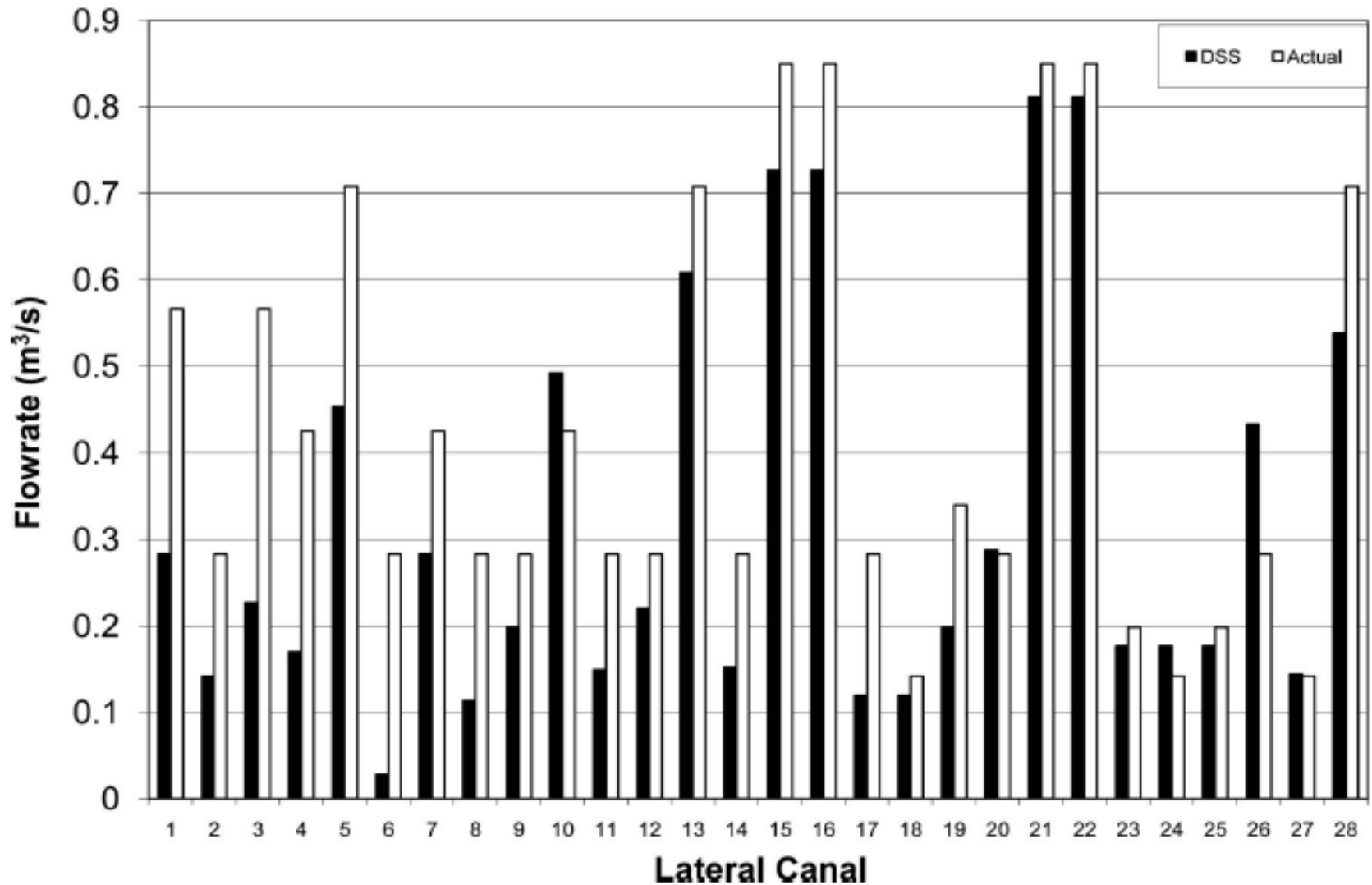
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- Hydro-agricultural facilities are inefficient in many irrigation schemes. Most of the existing infrastructure is old and began breaking down after the withdrawal of state support, and inadequate maintenance is becoming chronic.
 - The rehabilitation and modernization of irrigation schemes is an important question in the light of these serious equipment problems. In addition, projects also exist to extend irrigation and the opportunity cost of these investments (the equipping of irrigation systems and the building of new dams), as well as the technical and institutional options being called into question by decision makers.
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- In this context, progress in technology offers new ways for individuals to access water resources by means of boreholes, wells and the pumping of surface water. The unregulated increase in private withdrawal of water, even in public irrigation schemes, can be observed in all North African countries, in many cases in competition with the supply of water to public irrigation schemes, increasing environmental problems (with the rise or drawdown of groundwater), salinity, and pollution by nitrates and pesticides.
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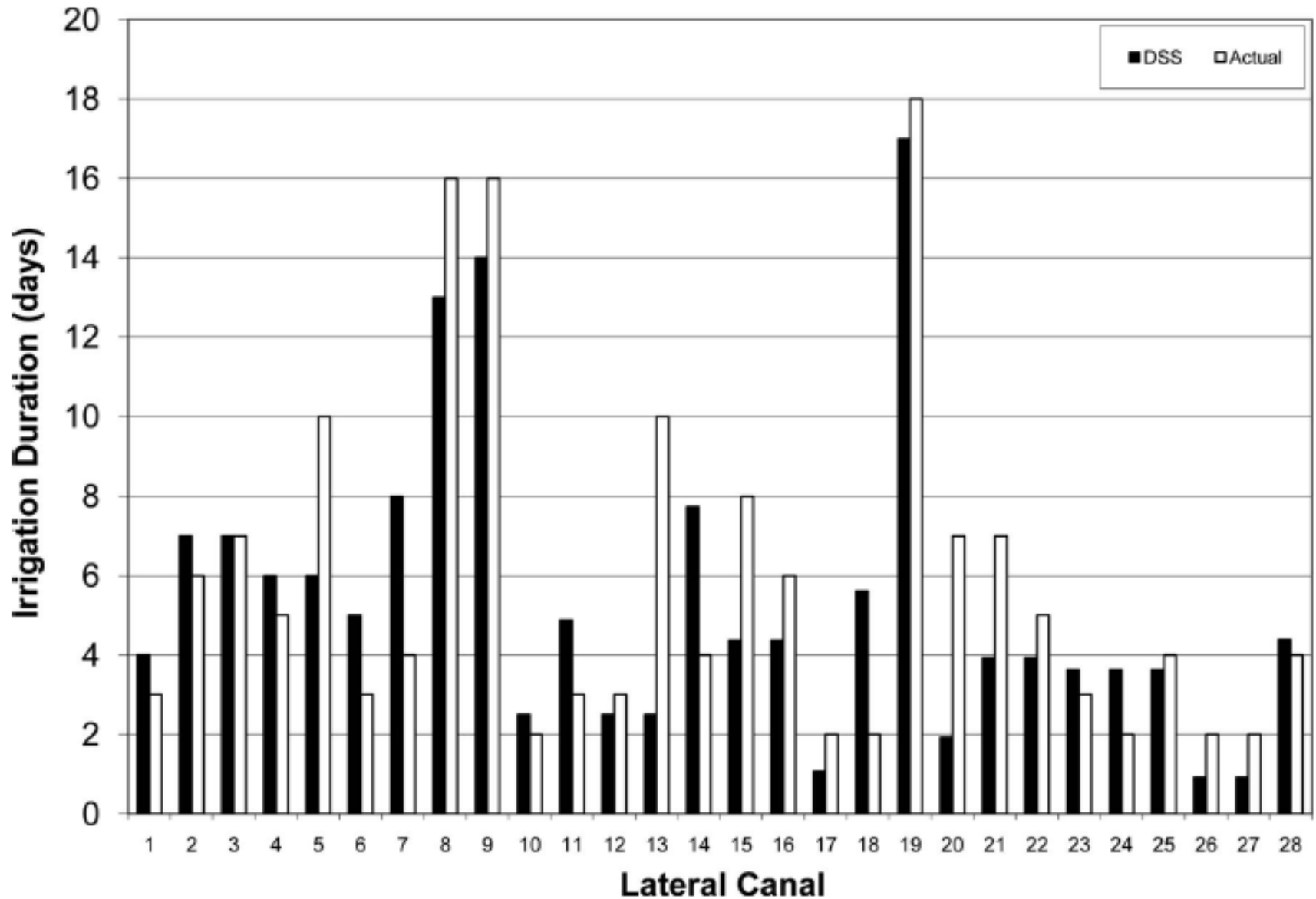
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- Identifying possible pathways and priorities requires tools to characterize the existing situation so as to be in a position to identify ways to progress and to rank the necessary actions in order of priority. As regards the scientific aspect, many studies have been conducted on efficiency and especially on technical efficiency at field and irrigation scheme levels. Significant technical progress has been made at field level, but not at the farm holding level, and in addition, attention has often been given only to economic aspects.
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- The approach proposed here is original in that it aims to simultaneously take into account the technical (hydraulic and agricultural), economic and environmental aspects of an object – the farm, considered to be the relevant decision unit. This implies formalizing criteria for the analysis of hydraulic, agricultural, economic and environmental performance at farm level.
 - Indicators must be defined for water management to allow stakeholders to make reliable comparisons of the different water management contexts concerned, including comparing access to water resources in private, public and mixed systems.
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Decision Support System (DSS) Flow Rate Compared to Actual Flow Rate ---Rio USA



DSS Irrigation Duration Compared to Actual Irr- Dur--- Rio USA



DSS Irrigation Interval Compared to Actual Irr- Intrv--- Rio USA

