UNIVERSITY OF SOUTHAMPTON
FACULTY OF ENGINEERING AND APPLIED SCIENCE
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

THE PERFORMANCE OF MEDIUM SCALE JOINTLY MANAGED IRRIGATION SCHEMES IN SUB-SAHARAN AFRICA: A STUDY OF THE WURNO IRRIGATION SCHEME, NIGERIA.

By:

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A Thesis submitted for the degree of **Doctor of Philosophy**

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DEDICATION

For my first son, **BABY TERFA,**
who was stillborn on 04/03/92 while I was undertaking the
fieldwork for this study.

UNIVERSITY OF SOUTHAMPTON

ABSTRACT

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The performance of medium scale jointly managed irrigation schemes in Sub-Saharan Africa: A study of the Wurno Irrigation Scheme, Nigeria.

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The subject of 'irrigation performance assessment' has grown in importance since the early 1970s. This has been as a result the increasing realization that irrigation schemes around the world, particularly those in developing countries, do not live up to their expectations. There has therefore been an increasing interest in probing into the operations of existing irrigation schemes in order to understand their strengths and weaknesses, and to developing methodologies and indicators for performance assessment, with a view to improving their performance and water use efficiency.

This study presents a conceptual methodology and performance indicators for evaluating the performance of medium scale irrigation schemes in Africa with joint participation between smallholder farmers and an irrigation agency. The proposed methodology provides a logical sequence of the main processes involved in irrigation performance assessment with emphasis on the 'whole system' or 'farming system' approach. Performance indicators have been proposed which relate to the inputs, processes of transformation, and outputs, which is a marked variation from existing approaches which focus only on the evaluation of outputs. The indicators describe qualitatively and quantitatively the level of attainment of the objectives of an irrigation scheme, or parts thereof.

The methodology and concepts outlined in the first part of this work are applied to study the operation and performance of the Wurno Irrigation Scheme, Nigeria, a typical formal medium scale jointly managed irrigation scheme in sub-Saharan Africa. The results of the case study show the performance of the Scheme to be unsatisfactory. This raises questions regarding the views of international lending agencies and governments of developing countries who are looking to smaller, as opposed to large, scale irrigation schemes as the way forward. The study argues that the critical issue is not that of size *per se*, but of the linkages between the primary characteristics of the physical design of the irrigation infrastructure, and the structure of the organizational and institutional arrangements for the operation and management of the scheme. In the case of Wurno both aspects are inadequate, hence the low performance. The case study provides a useful contribution to the growing literature on the performance of irrigation schemes, and a basis for making comparisons between similar types of schemes.

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Timothy Aondona IJIR
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ABBREVIATIONS

ABL -	Actual Bed Level
ADB -	Asian Development Bank
ADP -	Agricultural Development Programme
ANGL -	Adjacent Natural Ground Level
ASCE -	American Society of Civil Engineers
CEC -	Chemical Exchangeable Cations
CI -	Cropping Intensity
CPDI -	Crop Planting Date Index
CY -	Crop Yields
CYVCP -	Crop Yields Variation due to Cultural Practices
DA -	Diagnostic Analysis
DAP -	Di-Ammonium Phosphate
DWL -	Design Water Level
EC -	Electrical Conductivity
EEC -	European Economic Community
EIRR -	Economic Internal Rate of Return
EMSC -	Efficiency of Main System Capacity
EMSFL -	Extent of Main System Flow Lengths
ERP -	Efficiency of Roads Passibility
ESI -	Environmental Stability Index
ET_c -	Crop Evapotranspiration
ET_o -	Potential Evapotranspiration
FAO -	Food and Agriculture Organization of the United Nations
FGN -	Federal Government of Nigeria
FMIS -	Farmer-Managed Irrigation Systems
FSL -	Full Supply Level
Ft -	Foot/Feet
HBL -	Hydraulic Bed Level
HND -	Higher National Diploma
Hr -	Hour/Hours
IAR -	Institute for Agricultural Research, Zaria
IBRD -	International Bank for Reconstruction and Development (The World Bank)
ICID -	International Commission for Irrigation and Drainage
IFPRI -	International Food Policy Research Institute
IIMI -	International Irrigation Management Institute

ILRI - International Institute for Land Reclamation and Improvement
IRRI - International Rice Research Institute
ISFRR - Irrigation Service Fees Recovery Rate
ISOPI - Irrigation System Overall Performance Index
K_c - Crop factor
Kg - Kilogramme
Km - Kilometers
MANR - Ministry of Agriculture and Natural Resources
MBO - Management By Objectives
MBR - Management By Results
MBR - Maintenance Budget Ratio
MBTL - Minimum Bank Top Level
mm - Millimetres
MNR - Manpower Numbers Ratio
MQR - Manpower Quality Ratio
NIV - New International Version of the Holy Bible
°C - Degrees Centigrade/Celsius
ODA - Overseas Development Administration
ODI - Overseas Development Institute
O & M - Operation and Maintenance
OND - Ordinary National Diploma
PA - Performance Assessment
RBDA - River Basin Development Authority
RRA - Rapid Rural Appraisal
SARDA - Sokoto Agricultural and Rural Development Authority
SCAC - Scheme Command Area Capacity
SCI - Structures Condition Index
SDR - Scheme Development Ratio
SEP - Sokoto Environmental Protection Programme
SFAF - Scheme Financial Autonomy Factor
SFSF - Scheme Financial Self-Sufficiency Factor
SMBC - Second Main Bakra Circle
USAID - United States Agency for International Development
Yr - Year
WAI - Water Availability Index
WIS - Wurno Irrigation Scheme
WMSP - Water Management Synthesis Project
WUA - Water User Associations

CHAPTER 1: INTRODUCTION

1.1 Preamble

Global population is expected to increase from about 5 billion today to at least 8 billion by the year 2025. The population of Africa, estimated at 470 million in 1982, is projected to increase to 830 million by the year 2000, and 1.6 billion by 2025 **(FAO, 1987).** It is expected that agricultural production will have to expand by at least 2% per annum to keep pace with population growth, with the majority of this expansion coming from irrigated agriculture **(Hennessy, 1993).** Unfortunately, in many parts of the world there are limited land and water resources available for the further expansion of irrigated agriculture. Thus, increases in output must come from improved agricultural productivity. It is projected that as much as 80% of the required increase in food grain production over the next few decades must come from yield increases **(Moigne *et al* 1990).**

It is widely recognized that irrigated agricultural development is a strategic tool that can feed rural populations and help to reduce the flow of the rural population to the already crowded urban centres of developing countries. International donor and aid agencies and governments of developing countries have already invested billions of dollars for irrigation development, and are further planning to invest more in the coming decades. The World Bank directed $26.7 billion to the agricultural and rural development sector between 1948-1982; this represented about 27% of the Bank's total loans **(Hotes, 1982 P.1.).** The Food and Agriculture Organisation of the United Nations **(FAO)** disbursed $20.9 billion for the period 1973-1980 to the agricultural sector **(FAO, 1982: Table 19, Annexe).** In both cases the agricultural sector occupied first place in loan disbursements, with 38% and 28% of the loans meant for irrigation development from the World Bank and FAO respectively **(FAO, 1982).**

There are many reasons why irrigation receives such a high priority in agricultural development strategies. Irrigated lands increase agricultural productivity - not only by reducing the risks associated with drought related crop failures but, perhaps more importantly, by increasing the number of crops that can be planted over a certain period of time; and for growing of high value crops, which otherwise may be impossible. It is estimated that although only about 20% of the world's agricultural land is irrigated at present, this accounts for over 40% of the global agricultural production **(Biswas, 1990; Kay 1986)**. Irrigated agriculture supports more than two thirds of the food production for developing countries **(Lowdermilk *et al*, 1983)**.

Most of the early investments in irrigation, up to the 1980s, were in the design and development of capital works (dams, canals and lining, regulatory and measurement structures, rehabilitation and modernization). However, since the early 1970s there has been a growing concern that many irrigation schemes, particularly in the developing countries, have not performed as well as anticipated. As a result of the inability of those 'hardware' items to meet expected targets, attention has been turning to the 'software' solutions of management. The management issues which are currently receiving high priority include performance assessment, institutional and policy reform, awareness and information systems, turnover and farmers participation (including development of water users' associations), and privatization.

In Africa, irrigation development has been described in 3 main types: large, medium and small **(FAO, 1987)**, and much of the disappointing performance comes from the formal large-scale small-holder projects. Consequently attention has recently been turning increasingly to small and medium scale irrigation schemes as the way forward. However, despite the attractions of these irrigation schemes, their size does not necessarily guarantee success. There is little documented knowledge about the performance of these irrigation schemes at present, and the reasons why they appear more successful.

There is, therefore, the need to study the performance of existing small and medium scale irrigation schemes. This is with a view to understanding their behaviour, strengths, weaknesses, opportunities and constraints. A better understanding of the actual and potential performance of these irrigation schemes, and the criteria to be used in quantifying their performance will lead to an improved knowledge of their role as a vehicle for increasing agricultural and economic development.

1.2 Thesis

The performance of irrigation schemes is a complex function of many factors. These include: physical environment (soils, temperature, topography, etc.); socio-economic conditions (land tenure, markets, prices, etc.); management and institutional environment (staff quality, incentives, motivation, farmers involvement, social cohesion, etc.); and the infrastructure (water diversion, channels, structures, roads, etc.).

Ideally it is desirable to study the interactions of all these factors and their influence on irrigation performance in a holistic farming systems approach. However, this is constrained by limited resources. Following a wide ranging literature review, and as a consequence of the situation found on the irrigation project studied (the Wurno Irrigation Scheme, Nigeria), the research focused its attention on the design-management interactions and the socio-economic environment. The thesis of the research was thus formulated:

> "The performance of irrigation schemes is, amongst others, a function of the technical design and development of the irrigation infrastructure as well as the management of the system. A poorly designed and developed irrigation scheme will not perform well even with the best of management. Similarly, a well designed and developed scheme will perform below its potential if the management is deficient. This design-management

complex[1] in turn is influenced by the interactions of the socio-economic, physical and political environments within which the given scheme is expected to operate or perform. An understanding and quantification of the design-management complex and socio-economic conditions is essential as a basis for understanding the actual and potential performance of an irrigation scheme."

It is clear that the design and physical quality of an irrigation schemes's infrastructure will influence its productivity, viability, and performance; as does the organization for the management, operation and maintenance. Ideally, there should be complementarity between these aspects if high levels of performance are to be expected. Physical facilities need to be designed in a way that is appropriate to the available management skills and resources.

Similarly, operating organizations should be established and equipped in a manner that is adequate for effective utilization and management of the physical facilities. Good management could, within limits, even transform a poor physical system. However, deficient management is likely to result in poor performance, even when the physical system is adequate. When both the physical system and management set-up are deficient, there can hardly be any scope of high performance. In such circumstances, we need fundamental structural adjustments (improvements) and/or management reform, or be prepared to accept low performance.

It is also recognized that the socio-economic circumstances of the irrigators are also crucial factors that influence irrigation scheme performance. Farmers are well known to be willing to participate and invest their resources only when they can expect to receive reasonable benefits. Therefore,

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[1]This phrase "design-management complex" is applied in the sense used by **Murray-Rust et al. (1991)** to describe the linkages between the primary characteristics of the physical design of the irrigation infrastructure, typical water allocation principles, and the types of organizational and institutional arrangements within which the system is managed.

supporting investigations were undertaken in this study to take such factors into account.

A feature of this work is that although the author set out to study water management and performance with respect to initial objectives he found that both objectives and water management were poorly defined and implemented, and that performance at lower levels of the 'system' precluded any sensible study of water management. He thus had to 'step back' and investigate these 'lower levels' - principally the poor state of the infrastructure, and the design-management complex.

1.3 Objectives

This study was motivated by the growing concern about low performance in existing irrigation systems, and the interest in understanding the behaviour, operation and performance of various types of irrigation systems, particularly those in sub-Saharan Africa. There is a lack of consensus at the moment on the methodologies and indicators for performance assessment of irrigation systems. The existing approaches do not yet provide adequate tools for analysing an irrigation scheme to supply the required management information. Thus, this study set out make a contribution to these important subjects, particularly on small and medium scale irrigation schemes to which much attention has been shifting in recent years. The specific objectives of the study were to:

i. Develop a conceptual framework and methodology which could be used to assess the performance of medium scale jointly managed irrigation schemes
ii. Identify appropriate performance indicators and criteria for these schemes, and detail how they can be measured
iii. Provide a detailed case study on the operation and performance of a medium scale irrigation scheme in order to apply and test the conceptual framework and performance indicators and thereby develop an understanding of the functioning of such schemes.

The study presents a methodology which, it is believed, could be used to assess the performance of medium scale irrigation schemes in Africa with joint participation between smallholder farmers and an irrigation agency. Appropriate performance indicators for describing and quantifying the performance of such irrigation schemes have been proposed, and the data requirement for their determination identified. Through the case study the research identifies the central constraints limiting the performance of a medium scale irrigation scheme in Africa, and how they can be removed to improve performance. The case study makes a contribution to the relatively limited literature on this type of scheme. The framework presented here will enable comparisons to be made between similar types of irrigation schemes. It is hoped that this improved understanding of the behaviour of medium scale irrigation schemes will enable us to better plan, design, operate and assess such schemes.

1.4 Research Approach

This approach adopted in this study consisted of:

- desk study and literature review
- field work and data collection, and
- data analysis and formulation of methodology.

The first phase involved familiarization with the concepts of performance assessment, and a review of the available literature on the present state of knowledge on the subject. This included a critical reexamination of the existing approaches for performance assessment of irrigation schemes. Reports of performance evaluations were also studied, particularly on schemes in Africa. Through this process an understanding of the subject was gained. This enabled the formulation of the main focus of the research and its objectives. An initial conceptual framework and selection of performance indicators was made at the end of this phase.

The second phase, the field study, was conducted on the Wurno Irrigation Scheme (WIS), Nigeria, between November 1991 and June 1992. The aim of the field study was to test the proposed methodology and indicators, by using them to measure the actual performance of the irrigation scheme. By testing the proposed approach, it was expected that deficiencies would be identified and rectified, and the methodology thus refined. This was found to be the case, the approach was significantly altered as a result of the conditions experienced on the Wurno scheme.

The final phase was the analysis and interpretation of the collected data. This focused on evaluating the actual performance of the scheme studied from the measured factors. The results of the analyses and further review and comparison with other similar studies led to the discussions, recommendations and conclusions given in this report.

1.5 Structure of the Thesis

This thesis is divided into 10 Chapters. The introduction in Chapter 1 is followed by a review in Chapter 2 of the historical development of irrigation in Africa, Nigeria and the Wurno Irrigation Scheme, and the performance of irrigation development in these and other places. Chapter 3 documents some of the existing approaches, objectives and indicators commonly used for performance assessment of irrigation schemes. The shortcomings in these approaches are identified, and a proposed performance assessment methodology appropriate for medium scale jointly managed irrigation schemes in Africa is presented in Chapter 4.

Chapter 5 provides a description of the scheme evaluated, an outline of fieldwork done, and evolution of methodology, while Chapter 6 provides background information on the irrigation scheme studied. Chapters 7, 8 and 9 deal with engineering, management, and socio-economic and crop production assessments respectively. Chapter 10 discusses the application of performance indicators and identification of causes and effects of poor performance on the irrigation scheme studied. Finally, Chapter 11 describes the applications of the proposed methodology and areas for further research. This chapter also discusses the key issues in the scheme studied and draws conclusions and recommendations for improving its performance.

CHAPTER 2: IRRIGATION IN AFRICA

This chapter outlines the development of irrigation systems in Africa, Nigeria, and the Wurno Irrigation Scheme. It also reviews the performance of irrigation systems in Africa and elsewhere.

2.1 Irrigation Development in Africa

Irrigation in Africa is not as well developed as in other parts of the world due to a variety of reasons. Some of the most cited reasons are that the need for irrigation and irrigation potential do not often coincide; inadequate water supplies; difficult terrain; absence of irrigation traditions among small farmers; relatively lower population densities (compared to say Asia); and availability of alternative farming systems including rain-fed and livestock agriculture. Where irrigation need and potential coincide - as along the Senegal and Niger rivers in West Africa or the Nile in the Sudan - a substantial development of irrigated agriculture has already occurred (**WMS 37, 1987; FAO, 1987; The Courier, 1990**).

The FAO has proposed four size categories for describing irrigation systems in sub-Saharan Africa (**FAO, 1987**):

- Very large-scale schemes (over 10,000 ha)
- Large - scale schemes (from 1,000 to 10,000 ha)
- Medium-scale schemes (from 100 to 1,000 ha), and
- Small-scale schemes (under 100 ha).

The earliest attempts at irrigation development in Africa evolved from farmers' own adjustments to a tropical environment as seen in many small-scale indigenous systems in Nigeria, Burindi, Chad, Sudan, Ghana, Guinea, Sierra Leone, Senegal, Somalia, Mali, Madagascar, Niger, Tanzania, and Kenya. However, of recent the adoption of irrigation has tended to be in response to governmental initiatives. By 1982 the total irrigated areas by modern systems was almost equal to traditional systems (see Table 2.1).

Table 2.1 Sub-Saharan Africa: estimates of irrigated areas in 1982, in relation to irrigation potential.

COUNTRY	AREA DEVELOPED BY 1982 ('000 ha)				
	Irrigation Potential ('000 ha)	Modern	Small scale or Traditional	Total	Developed as % of Potential
Angola	67,000	0	10	10	< 1
Benin	86	7	15	22	26
Botswana	100	0	12	12	12
Burkina Faso	350	9	20	29	8
Burundi	52	2	50	52	100
Cameroon	240	11	9	20	8
Central African Republic	1,900	0	4	4	< 1
Chad	1,200	10	40	50	4
Congo	340	3	5	8	2
Equatorial Guinea	n.a.	n.a.	n.a.	n.a.	n.a.
Ethiopia	670	82	5	87	13
Gabon	440	0	1	1	< 1
Gambia	72	6	20	26	36
Ghana	120	5	5	10	8
Guinea	150	15	30	45	30
Guinea Bissau	70	n.a.	n.a.	n.a.	n.a.
Ivory Coast	130	42	10	52	40
Kenya	350	21	28	49	14
Lesotho	8	0	1	1	13
Liberia	n.a.	3	16	19	n.a.
Madagascar	1,200	160	800	960	80
Malawi	290	16	4	20	7
Mali	340	100	60	160	47
Mauritania	39	3	20	23	59
Mauritius	n.a.	9	5	14	n.a.
Mozambique	2,400	66	4	70	3
Niger	100	5	50	55	55
Nigeria	2,000	50	800	850	43
Rwanda	44	0	15	15	34
Senegal	189	30	70	100	56
Sierra Leone	100	5	50	55	55
Somalia	87	40	40	80	92
Sudan	3,300	1,700	50	1,750	53
Swaziland	7	55	5	60	>100
Tanzania	2,300	25	115	140	6
Togo	86	3	10	13	15
Uganda	410	9	3	12	3
Zaire	4,000	4	20	24	1
Zambia	3,500	10	6	16	< 1
Zimbabwe	280	127	3	130	46
TOTAL	33,641	2,638	2,381	5,019	14.9

Source: Food and Agriculture Organization of the United Nations, **FAO, 1986, p.14.**

Thus irrigation developments in Africa has been classified into two categories: formal and informal. **Carter *et al* (1983)** use the term 'formal irrigation' to mean:

> "the development and management of irrigated agriculture in a structurally formal way, usually by a government body ... Formal irrigation projects planned or under construction are large scale (up to 100,000 ha each); they are often established with very little prior involvement from farmers or landholders; and are usually managed by a structured government organisation on behalf of the resettled small-holders."

In contrast, 'informal' (traditional, or small scale) irrigation may be defined as:

> "those schemes which are under local responsibility, controlled and operated by the local people in response to their felt needs" **(Underhill, 1990)**.

Carter (1989) further refines the definition of small scale irrigation to:

> "irrigation, usually on small plots, in which small farmers have the major controlling influence, and using a level of technology which the farmers can effectively operate and maintain."

A wide range of traditional agricultural practices are often included in this definition of informal or small scale irrigation. These include cultivation of rice by wild or controlled flooding; flood recession cultivation; inland valley swamps; coastal swamps and estuaries; ground water development from shallow wells; and irrigation of vegetables by means of the shadoof: a simple device consisting of a pole, bucket and counterpoise **(Carter *et al*, 1983; Underhill, 1990)**.

It is debatable whether all these methods can be referred to as irrigation in the strict sense, but they are, nevertheless, important as agricultural water management techniques. They also reveal the fact that small scale irrigation in Africa needs to be seen in the wider context of the total farming system. In Nigeria, for example, it has been estimated that the area under small scale farmer-managed water control systems increased from about 120,000 ha in 1958 to 800,000 ha in 1978 **(World Bank, 1979).** In the past few years the informal small-scale irrigation sector has been receiving considerable attention from international agencies. The attractions of these schemes include low investment costs, greater farmer participation and control, and less ecological disturbance.

Formal irrigation development in Africa has a fairly recent history, unlike other continents such as Asia where irrigation has been a part of cultural tradition for many centuries. **Underhill (1990)**, states that:

> "with the exception of the Nile Delta, large scale irrigation was unknown in Africa until this century. In contrast, small scale irrigation has been practised since time immemorial, in many varied forms according to local circumstances."

The development of formal irrigation in sub-Saharan Africa dates from the colonial period, and in particular after World War II **(Underhill, 1990).** This category of development usually refers to large scale irrigation projects with full water control. Most of these schemes were designed primarily to produce cash crops, and are managed by state organizations or private companies. The Gezira scheme in the Sudan (over 1 million ha) and the Office du Niger in Mali are examples of such schemes. In some areas on which the schemes were built, the land was already occupied by small farmers, who often lost their traditional land usage rights to become tenants on the new schemes. Other schemes were constructed in more arid and less populated areas where there was little or no traditional farming, and farmers were brought in from outside, either as tenants or labourers, under a central management which left few decisions to the farmers.

The medium-sized schemes show greater variation. Some were developed and run by public bodies or cooperatives, with or without the help of the State, and some are private (commercial) plantations. In Nigeria some of the medium-scale schemes were developed as 'exploratory' schemes in areas with apparent potential in order to investigate the possibilities and farmers' attitudes. Other examples of this size of development can be found in Niger, Mauritania, Madagascar and Zimbabwe. The study reported here focuses on this group of schemes.

2.2 Irrigation Development in Nigeria

2.2.1 Evolution of irrigation policy objectives in Nigeria

Objectives for irrigation and water resources development in Nigeria have been set, but have changed from time to time. They are generally vague and unquantifiable, thus making it difficult to test performance.

It is clear that the motivation for the early attempts by the British colonial administration at irrigation development in Nigeria was more explicitly to investigate potential resources and possibilities. Indeed, the primary objective for the construction of small village irrigation schemes was:

> "to collect data and provide facilities for training indigenous technical staff, which were in short supply, in the investigation, design, and construction of irrigation schemes of all types" **(File IRR/12:- 'Irrigation Sokoto Province, 1937-1975.' History Bureau, Sokoto).**

Initially attention was paid to the cultivation of rice which was already being grown by farmers during the wet season in the flood plains of the major rivers and their tributaries.

A major step in developing the water resources of Nigeria was the setting up of an irrigation division in the Northern Ministry of Agriculture in 1949, and the establishment of an Irrigation Survey School at Sokoto in the same year (the school was moved to Kaduna Polytechnic in 1971). This Division was responsible for the development of new small village irrigation schemes and handing them over to the Native Authority after 2 - 3 years. According to a Mission organized by the World Bank in 1955:

> "The immediate objective of the irrigation branch has been to gain experience in the problems of water control, and to determine the attitude of farmers with respect to water control projects rather than bring large new areas under cultivation quickly" **(IBRD, 1955, p336).**

Poor planning, design and construction were a common feature of the early schemes. This was due mainly to inadequate data, equipment and qualified staff. This resulted in inadequate protection against floods and frequent damages, which affected the farmers' confidence in the new schemes. However, the high cost of repairs and reconstruction demanded intensive wet season cropping and high value dry season cash crops to justify the schemes, and to raise revenue to cover capital and recurrent expenditure. This became the main motivation for continuing work on some of the early projects.

After Nigeria's independence in 1960, political and economic changes further reinforced the need to give new goals for these 'exploratory irrigation schemes.' Some of the main reasons for this were the oil boom, growth of urbanization and higher incomes leading to changing tastes and increasing demand for bread and wheat **(Andrae and Beckman, 1985).** Attention was therefore turned to wheat, which could be produced in some of these schemes, though in several cases it was not an ideal crop for the given environment. However, wheat was seen to have a rising market potential and its import was on the rapid increase. Since then wheat import substitution, foreign exchange savings, and export crop production became the major objectives of irrigation planning and development in Nigeria.

Following the Sahelian drought of the early 1970s (1972-1974) coupled with increasing oil revenues (oil boom), drought alleviation, food security, employment generation, and rural and regional development were also added to the list of objectives for irrigation development. This led to the establishment of federally controlled multipurpose River Basin Development Authorities **(RBDAs)** in the late 1970s across the whole country. These Authorities embarked on the development of large scale irrigation schemes.

It is clear from a review of the literature that the government policy objectives for water resources and irrigation development in Nigeria have been, and still are, too general, conflicting, and difficult to evaluate. Translating these broad objectives into operational targets (system objectives) is neither easy nor straightforward, and there have been no guidelines for doing so. Moreover there have hardly been any internal attempts at thorough evaluation of performance and previous experiences. Criticisms by individuals and external experts have largely been ignored.

2.2.2 Classification of irrigation schemes in Nigeria

Irrigation schemes in Nigeria can be categorized into the following (after **Carter *et al*, 1986**):

i. small scale, informal, or traditional irrigation;
ii. small to medium scale formal irrigation schemes;
iii large scale formal smallholder irrigation schemes; and
iv. estates and large scale private or parastatal irrigation

The distinguishing features of these four categories relate to their size, ownership, and management styles and methods adopted by each. The first group comprises of schemes owned and managed by individual farmers or independent indigenous groups. Land holdings are small (0.5 - 2 acres) and the entire scheme may be just a few hectares. The crops grown are usually vegetables with the use of traditional irrigation and water conveyance methods.

The second category consists of schemes under the control of State Ministries of Agriculture and Natural Resources (MANR) and State parastatal organizations such as the Agricultural Development Programmes **(ADPs)**, and Directorate for Food, Roads, and Rural Infrastructure **(DFRRI)**. The ADPs also support the development of the traditional sector. Since the early 1980s the World Bank has supported ADPs in the northern States in promoting the use of shallow ground water resources in the low-lying areas **(fadamas)** for small scale irrigation. The size of these schemes range from a few hundred to about a thousand hectares. Smallholder farmers are involved but they have limited control in the management of the schemes. The farmers grow both cash and subsistence crops such as rice, wheat, and vegetables. It is into this group that the project studied, the Wurno Irrigation Scheme, falls.

The third group is characterized by federal government control, bureaucratic management, rigid civil service staff and salary structures, and overt social and political objectives in addition to economic ones. Most of these schemes originated from 1976 when the **RBDAs** were established by Decree **(FGN, 1976)**. The RBDAs control a number of smallholder irrigation schemes which range from a few hundred to several thousand hectares. Only cash crops were intended for these schemes, but the farmers grow both cash and subsistence crops such as rice, wheat, maize, and so on.

The fourth category is commercially oriented and managed, staffed largely by technically qualified personnel with management training and experience. The major objectives are crop production and profit maximization. Examples of these types of schemes include the Bacita Sugar Company and the Savannah Sugar Company, Numan.

2.2.3 Historical developments

The early history of traditional irrigation in Nigeria is difficult to ascertain, but it is thought to be practised for centuries. The shadoof, which is now commonly found throughout Northern Nigerian fadamas (flood plains), was probably adopted as a result of technology transfer from Egypt - either brought in by Arabs or seen by Nigerian moslem pilgrims on their way to Mecca **(Carter *et al*, 1986)**.

The development of formal irrigation schemes in Nigeria began fairly recently, and was initiated by the British colonial administration. The first survey of irrigation potential in Nigeria is said to have been carried out in the north prior to 1918 by **Colonel Collins,** a military engineer with experience in India **(Taylor *et al*, 1978)**. These surveys resulted in the establishment of the first flood control and irrigation scheme at Kware, near Sokoto, in 1925/26 **(Swainson, 1944)**. Many problems were encountered on this project including inadequate flood control, inadequate technical knowledge, lack of inputs (particularly oxen for cultivation), and poor farmers response. The scheme was abandoned in 1940 **(IBRD, 1955)**, and then rehabilitated in the 1950s.

The Irrigation Branch of the Northern Department of Agriculture established in 1949 with responsibility for constructing small scale irrigation schemes was slow in getting its work under way because of the difficulty of recruiting staff. By 1953 it had reconstructed the Kware scheme and was quite active in the Sokoto Province (Gummi, Bukwuim, etc.). It had also undertaken a number of small irrigation and flood control schemes near Bida in the Middle Belt (Badeggi and Edozhigi). The preliminary study of the Lake Chad pilot irrigation project in the north-east had also begun, with the project commencing in 1958.

Between 1956 and 1965 many other small schemes were established. These included Daya and Abadan on the Yobe river and Gamboru on the Ebeji river in the north-east; Wurno Irrigation Scheme on the Rima river in the north-west; and Kano project on the Hadejia river in the north-central. Table 2.2 is a summary of the chronology of formal irrigation development in Northern Nigeria. Many of the schemes shown in the table are still in operation at present, some on expanded areas. A few have since been abandoned. By 1973 it was estimated that about 15,000 ha were under formal irrigation in Nigeria **(Erhabor, 1982)**.

The 1970s was a decade more marked by very ambitious plans for irrigation development in Nigeria. These plans culminated in the establishment of 11 River Basins Development Authorities by Decree 25 of 1976. These federal authorities were given responsibility for the multipurpose development of water and land resources in their areas throughout the country. Accordingly they embarked on the development of large scale, capital intensive schemes. The most significant of these are the Kano River Project (Kano

State), the South Chad Project (Borno State), and the Bakolori Project (Sokoto State). Due to poor planning and unforseen problems, the development and performance of these large projects have been much lower than envisaged.

The development of estate irrigation schemes started in the mid 1960s with the Bacita Sugar Estate (5500 ha) in the flood plains of the Niger River. The Savannah Sugar Company, was begun in the early 1980s near Numan in the north-east.

Table 2.2: A chronology of formal irrigation development in Northern Nigeria: 1900 - early 1970s

Approximate Date	Water Source	Project Location	Project Area (ha)	Crops Grown
1918 - 25	Sokoto & Rima River valleys	Sokoto Areas	Small Plots	Sugarcane, Cassava, Potatoes, & Maize.
1925 - 40	Sokoto, Rima & Zamfara valleys	Kware Project	243	Sugarcane, Cassava, Potato, Maize, Wheat
1949	Niger River	Mokwa	405	Rice.
1950 - 55	River Kaduna	Wuya Edozhigi	700	Rice.
1950 - 65	Yobe River	Daya Yau Abadan	1558	Rice and Wheat.
1950 - 65	Ebeji River	Gamboru	810	Wheat.
1956 - 65	Rima River	Wurno	800	Rice and Wheat.
1964	Natural Artesian Spring	Tungan Tudu	100	Rice.
?	Flood Protection	Tungan Kawo Nr. Wushishi	809	Rice.
1967	Lake Chad	Chad Pilot Scheme	51	Various crops under trial.
1969 - 73	Kano River	Kadawa Pilot Scheme	500	Wheat, Rice.

Sources: Compiled from **Erhabor, P.O., 1982, and Framji, K.K. et. el., 1969, 1982.**

2.3 Development of the Wurno Irrigation Scheme (WIS)

Preliminary investigations into the possibility of a flood protection and controlled water irrigation schemes along the plains of the Rima river were commissioned by the British colonial administration in the dry season of 1955/56. These reconnaissance surveys recommended, as a first stage, a flood protection rice scheme at Wurno. This was to be achieved by constructing a bund to protect an area of approximately 2000 ha (5000 acres). The strategy was to provide protection to farmers already engaged in wet season rice farming in the protected flood plain (fadama) believed to be under constant threat of floods from the Rima river. It was intended that later on the bund could be extended to make a reservoir for dry season cultivation on a limited area of the flood plain. The gross irrigable area within the bund was estimated to be about 3600 acres (1457 ha).

Designs commenced in 1957, and the construction of the main bund of the WIS with field channels and distributaries started in late 1958. This was being undertaken through direct labour using available personnel and machinery from government establishments as well as local labourers. The slow progress of work, coupled with frequent breaching of the bund in the wet seasons led to thoughts of abandoning the project in 1960. However contracted experts who were called to advise on the situation recommended completion of the scheme. They also suggested raising of the bund to store more water for dry season cultivation and provision of a spillway. Wheat was the recommended main dry season crop, initially on a limited area of about 1600 acres (648 ha), with possibility of later expansion to the entire irrigable area of 3600 acres (1457 ha).

Following these recommendations, a contract was awarded by the end of 1963 for completion of the scheme. The contract was expected to be executed within 6 months (dry season 1964), but it was not until May 1965 that the first phase of the scheme was actually completed. The initially developed area, equipped with canals and drainage network was 600 ha.

Responsibility for operation, maintenance and expansion of the scheme has since passed through the Irrigation Division of the then Northern Region Ministry of Agriculture, the Native Authority, and now the Sokoto State **MANR** with Headquarters at Sokoto.

2.4 Performance of irrigation schemes in Africa.

It is widely recognized that irrigation development has the potential for increasing food production and attaining food self-sufficiency in many countries. However there is an increasing realization that the majority of the irrigation systems in the developing world, particularly Africa, perform below their potentials; some have simply failed. This is equally true in Nigeria.

Small scale private irrigation schemes in sub-Saharan Africa are said to be relatively successful. The World Bank presents interesting examples of successful small scale private strategies in the Sahel and several sub-Saharan African countries **(Barghouti *et al*, 1990; Brown *et al*, 1992).**

On the contrary, the performance of formal large scale smallholder irrigation schemes that have been developed, operated and maintained by government agencies in Africa has been the target of much criticism for some time. In fact, with a few exceptions such as Mwea in Kenya **(Chambers and Moris, 1973)** and the Gezira in Sudan, the experience of large scale irrigation development in Africa over the past 30 - 40 years has been disappointing **(World Bank, 1979; Hotes, 1984; FAO, 1987; WMS 37, 1987; Van Steekelenburg, 1985; The Courier, 1990; Adams, 1991; etc.).** The success of these few exceptions stem in part from their larger farm sizes, mechanization and production incentives such as price and value of crops.

Nigeria's experience with irrigation development is typical of many African countries. **The World Bank (1979)** concluded as follows with reference to Nigeria's massive investments in such irrigation projects:

> "there can be no doubt that this sum [nearly 1 billion dollars], if spent judiciously on the promotion of rain-fed agriculture and small scale irrigation schemes, would have produced vastly superior returns [and] Nigeria should shift ... the emphasis towards cost effective small scale irrigation development on bottomlands and riverain fadamas."

The performance of large scale irrigation schemes in Nigeria has also been criticised by many other authors **(eg. Adams, 1991; Are, 1989, 1991, 1993; Baba, 1984; Palmer-Jones, 1977, 1980; Wallace, 1981, etc.)**.

An evaluation **(Van Steekelenburg *et al*, 1985)** of a number of smallholder irrigation projects in Africa funded by the European Economic Community **(EEC)** also found faults with many large scale irrigation schemes, and concluded that:

> "In irrigation projects in sub-Saharan Africa, it would appear that the larger the projects are, and the higher the level of their technology, the poorer is their performance."

Carter (1992) lists over 20 factors that have been identified by evaluators for poor performance of large scale irrigation projects in Africa and around the world. In Nigeria the main causes of failure on the large scale schemes include reckless planning without heeding previous experiences, administrative corruption, shoddy staff quality and low motivation, and unprofitability to small holder farmers.

The low performance of irrigation projects in sub-Saharan Africa has been found to be the case in other parts of the developing world. Even in Asia where irrigation is generally believed to be relatively more successful, there are indications that there are still large opportunities for improvement **(Wade, 1976; Bottrall, 1981; Plusquellec *et al*, 1990)**.

The World Bank's worldwide experiences with Bank assisted irrigation projects were summarized by **Hotes (1984)**:

> "Basically, the Bank's experience indicates that there is a general tendency to underestimate the managerial and staffing problems and the time required to implement projects, as well as the time needed to organize and derive the benefits of the projects."

A second lesson is that:

> "most planners tend to be over-optimistic in terms of rates of change arising from the projects. The most noticeable area of over-estimation is the anticipated rate of increase in output, usually expected increases in yields."

On the whole, the management of irrigation systems in Africa and elsewhere has proved more difficult that foreseen. Deficiencies in system design and management, combined with poor operation and maintenance have resulted in lower than expected irrigation benefits in terms of area irrigated, the levels of yield and production achieved, and return on investments. These deficiencies have also led in many instances to social inequalities, and extensive areas of irrigated lands being degraded by waterlogging and salinization.

Hence there is an urgent need to study the performance of particular irrigation systems, and to formalize the approaches for the study of irrigation performance. That is the contribution that this study sought to make. The procedures for performance assessment and the proposed methodology will be discussed in the following Chapters.

CHAPTER 3: PERFORMANCE ASSESSMENT

This chapter outlines the rationale for carrying out performance assessment on irrigation schemes and the common existing approaches and indicators for doing so. It also specifies the desirable characteristics of a performance assessment methodology and performance indicators.

3.1 Reasons for Doing Performance Assessment

There might be several cases for carrying out performance assessment on an irrigation scheme. For example:

- When we know something is wrong (as it is very evident) and we wish to find out what is causing it (diagnosis)
- When we want, as part of the management process, to know how we are doing so that we can improve it
- When a researcher, using the case study approach, seeks to understand the detailed workings of an irrigation scheme in order to draw generalized inferences.

Obviously the approach to performance assessment will be different in each case. **Small and Svendsen (1992)** categorize these three broad types of performance assessment as:

- Operational performance monitoring
- Accountability assessment, and
- Intervention assessment.

Operational performance monitoring is designed to provide, to those who have management responsibility for a scheme, information that can be used in making daily operational decisions. *Accountability assessment* is designed to provide information with which to judge the activities of those responsible for a system's performance. *Intervention assessment* is generally undertaken because of a desire to improve some aspects of a system's performance. *Intervention assessment* is also useful in applied research and case studies that attempt to understand the causes of particular levels of irrigation performance, even when no intervention is immediately contemplated. The aim of such research is typically to improve our ability to understand and predict the level of performance likely to result from particular combination of system configurations and environments, ultimately leading to the design of improved interventions and better targeting of intervention in particular cases.

The need to develop comprehensive methodologies to evaluate the performance of irrigation schemes has long been recognized. The concluding remarks of a workshop on irrigation water management held at the International Rice Research Institute (IIRI) in 1979 stated that:

> "what is most needed is an established methodology to determine the efficiency of an irrigation system in physical, economic, and social terms as well as in terms of water use; and to show how the efficiency can be improved..." **(IRRI, 1980)**

Bhuiyan (1981) states that:

> "there is a need for more research work to develop appropriate system evaluation criteria that could be used for systematic but rapid identification of irrigation systems weaknesses and strengths, and also for the better evaluation of management improvement efforts."

Against this background, there have been several attempts over the past two decades or so to address this problem. The interest in the subject of 'irrigation performance' further gained momentum in the 1980s, and has presently become one of the top issues of discussion in irrigation circles. This is evident in the many national and international activities undertaken on the subject in the past decade, of which some of the most significant ones are listed below.

In 1983, the **FAO** organized an Expert Consultation on Irrigation System Performance in an early effort to develop guidelines and methodologies for assessing irrigation systems performance, and for identifying their problems and solutions

In 1985 (17 - 20 December), the Royal Thailand Government, in collaboration with the FAO Regional Office for Asia and the Pacific, organized a National Workshop on Evaluation of

Small-Scale Irrigation Project Performance. The objective of the workshop was: "to discuss, not only factors affecting the performance of small-scale irrigation projects, but also suitable methodologies for the rapid evaluation of project performance which would subsequently need testing in a number of projects."

In June 1989, the International Commission on Irrigation and Drainage **(ICID)**, widened the task of its Working Group on 'Irrigation Efficiencies' to 'Irrigation Performance Assessment.' This marked a move away from viewing performance as purely technical (i.e. losses in canals) to broader issues.

The International Irrigation Management Institute **(IIMI)** and the International Food Policy Research Institute **(IFPRI)** conducted a study, including an expert consultation (February, 1990) on the subject of Irrigation System Performance. In fact IIMI considers this subject as one of its current priority research areas **(Manor, 1990)**.

In 1990 (22 - 26 October), the FAO organized a Regional Workshop on Improved Irrigation System Performance for Sustainable Agriculture in Bangkok, Thailand. One of the workshop recommendations was that:

> "further studies are required to develop practical and effective procedures to assess irrigation system performance ..."

The international journal *'Irrigation and Drainage Systems'* devoted a whole issue **(Volume 4, Number 4, November 1990)** on the concepts of irrigation performance from different perspectives, "to assist in the establishment of acceptable [performance] indicators." **(Editorial)**.

The above examples highlight the interests and concerted efforts that have been made on the subject of irrigation performance. Nevertheless, a lot still remains to be done, particularly in terms of analytical procedures and criteria (indicators) for irrigation performance assessment.

3.2 Existing Approaches to Performance Assessment

The first example of methodologies for appraisal of irrigation systems is the Diagnostic Analysis **(DA)** methodology developed by the Water Management Synthesis Project, WMSP **(Lowdermilk *et al*, 1983)**. The DA methodology evolved from the irrigation management research conducted in Pakistan with the assistance of Colorado State University in the 1970s. It is defined by **Lowdermilk *et al* (1983)** as:

> "an inter-disciplinary method of examining both the values, that is [the] benefits and constraints, and [the] restrictions on a system."

This involves detailed multidisciplinary professional fieldwork and analysis of farm irrigation or the 'on-farm system.' The team usually includes an agricultural engineer, an agronomist, an agricultural economist, and a sociologist or extensionist. The DA methodology has been widely accepted because of its field realism and 'bottom-up' approach.

Another example is the appraisal of large scale irrigation projects in four Asian countries carried out by Anthony Bottrall **(Bottrall, 1981, 1983)**. One of the objectives of this study was to develop, on the basis of case studies, a generally applicable analytical framework which could subsequently be used to evaluate the management of large scale irrigation schemes over a wide range of conditions. Unfortunately this objective was not quite met **(Hotes, 1981)**.

With the benefit of hindsight, **Bottrall (1983, p.112)** considered that an additional person would have been useful for more detailed research at the watercourse and farm levels, to balance the tendency of a management study to take a 'top-down' view. The main focus was on the organization and management of large irrigation schemes.

Robert Chambers and others have applied the techniques of Rapid Rural Appraisal **(RRA)** to irrigation schemes. The RRA methodology, according to **Chambers (1983, 1987)**, seeks to answer the question: how best to organize an irrigation system performance study to identify the optimal mix and sequences of actions which will improve system performance?. **Potten (1985)** states that the aims of RRA are:

> "to provide and analyze information on rural conditions as quickly as possible; to obtain this information in a cost-effective manner; to avoid biases ...; and to ensure that the results are made available in an easily usable format for decision-makers and implementing agencies."

RRA involves teamwork with a combination of such disciplines as irrigation engineering, hydrology, agronomy, agricultural engineering, agricultural economics, management science and sociology. Some of the key approaches and techniques involved in rapid appraisal include **(Potten, 1985):**

- good organization before starting RRA
- use of existing information
- escape of spatial and project biases
- taking time and a low profile, and
- use of multiple approaches to obtain data.

A cooperative research project with Cornell University developed a methodology for evaluating the performance of Philippine rice irrigation systems **(Garces, 1983).** The model estimates the irrigation system overall performance **(ISOPI)** for a crop season. The model divides an irrigation system into four sub-systems:

- water
- environment
- human
- economic.

Performance indicators are selected for each of these sub-systems and appropriate variables measured to evaluate the values of the selected indicators. Each of the sub-systems, indicators and variables are weighed to establish scores for quantitative estimation of the ISOPI for a season.

According to **Lenton (1983),** performance monitoring consists of setting standards, evaluation of actual performance, analysis of reasons for performance gaps, analysis of interventions, and implementation of interventions (see Figure 3.1).

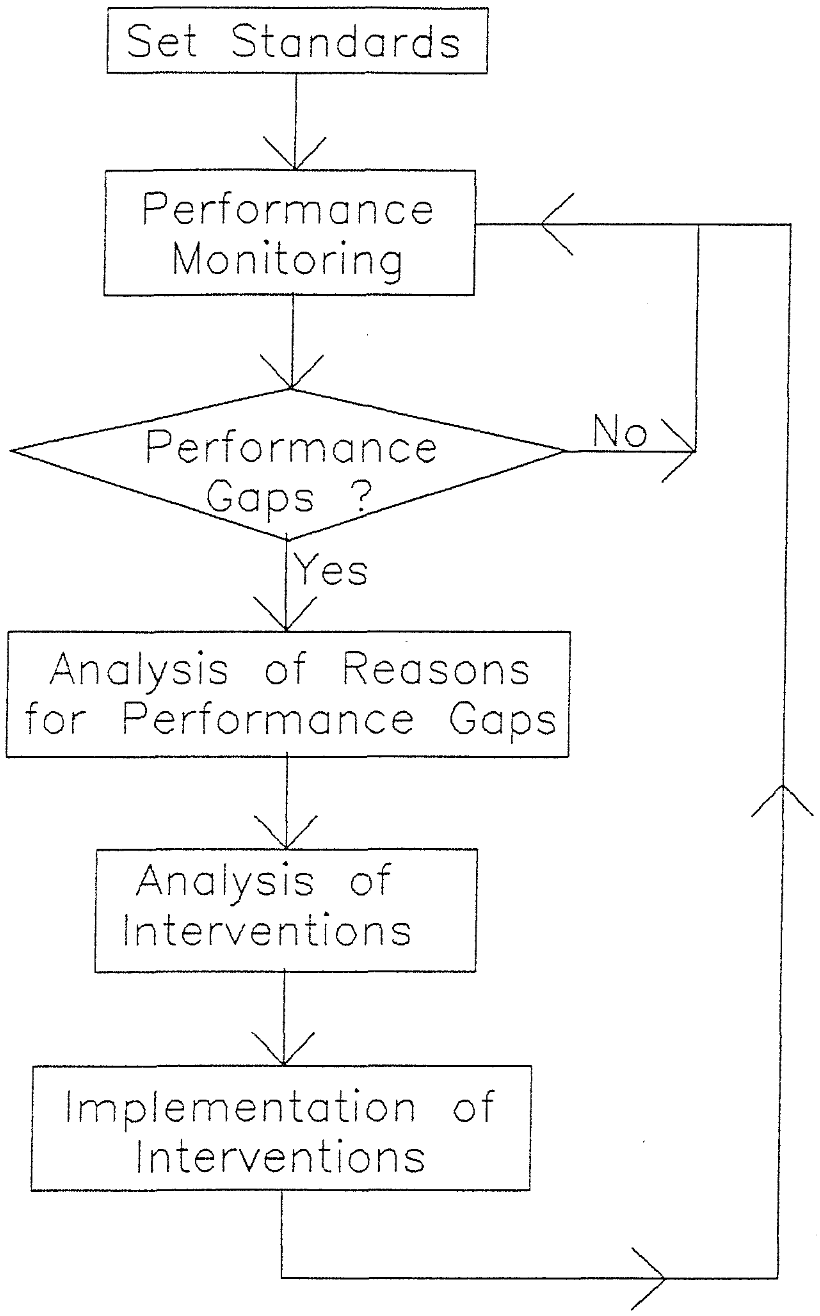

Figure 3.1 Performance monitoring and feedback **(After Lenton, 1983)**

Malhotra, Raheja, & Seckler (1984) also report on a methodology to monitor performance of large scale irrigation systems with existing staff. The methodology is a direct application of the theory of *'management by results'*, **MBR (Seckler, 1983)** - a theory similar to, but not identical with, the well known *'management by objectives'* **(MBO)** in management science. The object of the study was one sub-system of the 'Second Main Bakra Circle' **(SMBC)**, the Phabra distributary, which is 55 km long and has a command area of 21,174 ha. The collaborators in the study included a former manager of the SMBC, a statistician, and an economist.

A sample of 10 out of the distributary's 52 watercourses, each serving an average of 50 farmers, were selected at the head, middle, and tail of the canal. In each watercourse, a sample of farms were selected for performance estimation on the basis of a simple single proxy performance criterion: - *the relationship between the sum of the areas of the farm wetted in each irrigation during the crop season, and the command area of the farm.* By analysing this relationship across the sample farms, a quick estimate of the performance in terms of the amount of water delivered to farms and the variability in water delivery among farms was obtained.

This methodology is perhaps quick and easily applicable on a large area, but the study lacks intensity as no direct measurements of flows through the conveyance system and soil moisture in the fields were taken to verify the *'wetted area'* indicator. In addition, the use of a single proxy indicator for performance assessment can lead to a misleading picture about the actual functioning of an irrigation scheme.

Based on analysis of case studies of irrigation sector reviews, project design papers, and DA workshops, **Oad and McCornick (1989)**, report on their development of a reference methodology for assessing the performance of irrigated agriculture (Figure 3.2). The reference methodology is based on the concept that a successful assessment of irrigation system performance must begin with a sound understanding of the overall goals and objectives towards which the system is managed. After establishing system objectives, the

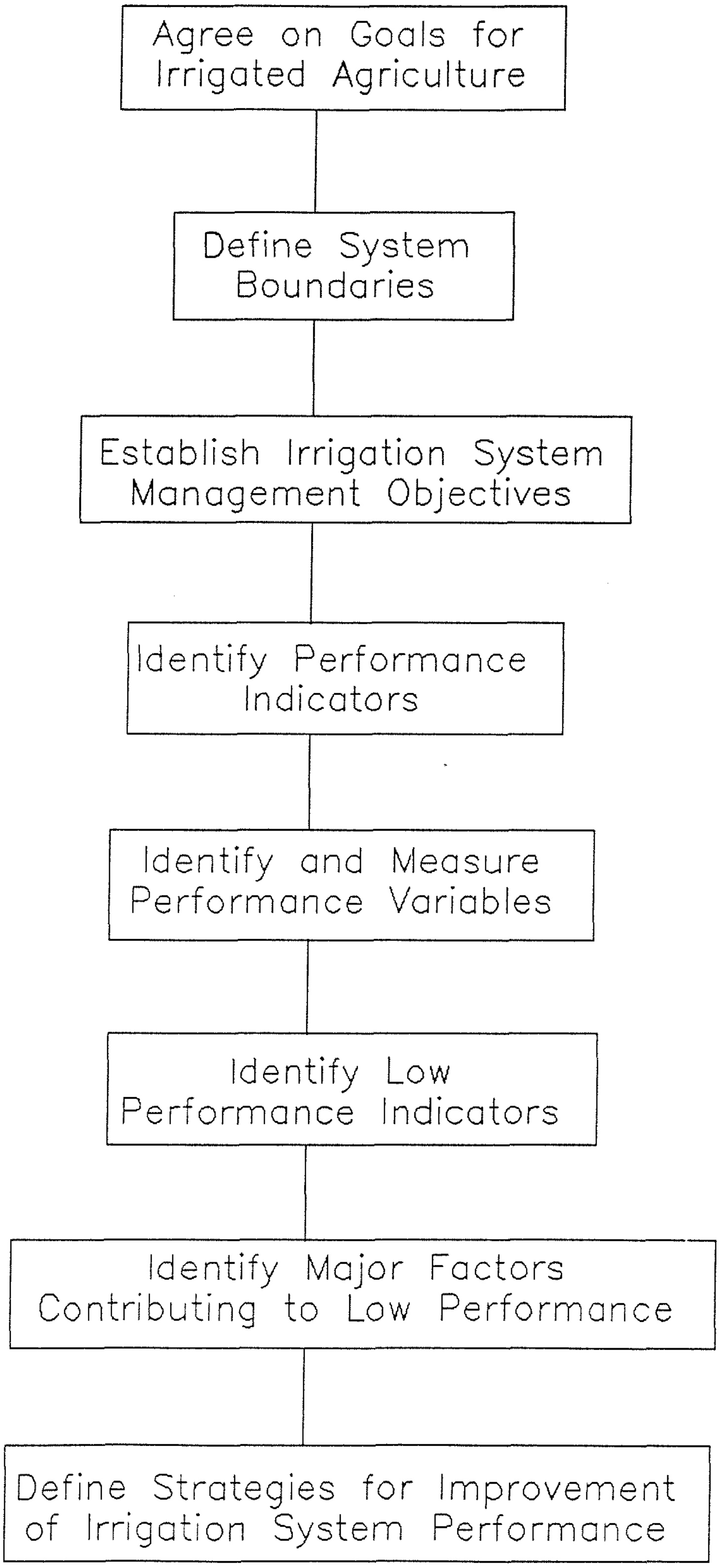

Figure 3.2 Reference methodology for irrigation performance assessment **(After Oad and McCornick's, 1990)**

performance is evaluated by determining whether or not the objectives were being achieved. This is done by comparing the actual with the desired performance of the system. If the objectives were not being achieved, the contributing factors causing low performance are identified. Recommendations could then be made for the irrigation system improvement. This approach was used initially in this study, difficulties were encountered however when it was found that the objectives of the Wurno scheme studied were ill-defined.

Small and Svendsen (1992) propose a conceptual framework for evaluating irrigation system performance. The framework delineates boundaries on *what is to be evaluated, and the types of evaluation available*. The boundaries on what to evaluate are defined in terms of the following:

1. The system to be evaluated (irrigation system only, irrigated agriculture system, agricultural economic system, etc.)
2. The functions performed by the irrigation system (acquisition of water, distribution, application, etc.)
3. The project life-cycle processes (planning, design, construction, operation, maintenance, support)
4. The geographical extent corresponding to either the physical or social elements that comprise the system.

In delineating the types of evaluation, they examine the concepts associated with performance assessment, including:

1. Models of performance assessment (goal-oriented model and natural system model)
2. Rationale for assessment (operational monitoring, accountability, and intervention assessments)
3. Types of performance measures (process, output, impact, achievement, efficiency, direct, and indirect measures)
4. Sources of performance standards (internal, external, and relative standards)
5. The time dimension of assessments (single point in time or "snapshot" assessment, and continuous monitoring).

This conceptual framework presents a good clarification of some of the broad concepts involved in irrigation performance assessment. However, it falls short of any specific application as a procedure for performance assessment of any particular irrigation system, and does not provide a sequence of activities on how performance assessment can be done.

All of the above mentioned approaches have their strengths and weaknesses. Some of the common limitations of these existing methodologies include the following.

The first is that most of them focus on large scale, publicly administered irrigation systems, particularly those in South and Southeast Asia. Very little attempt has been made at developing specific performance assessment procedures for small or medium scale irrigation systems in Africa. Only a few examples can be found in literature of methodological studies on performance assessment of small or medium scale irrigation schemes in Africa. Notable among these is the on-going work at the Hydraulic Research Limited, Wallingford **(Chancellor-Weale, 1990; Pearce *et al*, 1990; Tiffen, 1990).**

Secondly, these approaches only deal with components of the irrigation system, and the 'whole system' approach is neglected. Some take a 'top-down' approach, thus, overlooking the farm level, while others adopt the 'bottom-up' approach without considering the main system.

Thirdly, apart from the Diagnostic Analysis methodology which has been tried in various places, all the existing approaches lack depth in practical field application. Although all the approaches give an impression of general applicability it is doubtful how they can be adapted to every type of scheme.

Finally, researchers often seem to have made a prior choice of the issues they wish to assess in the field, and to have preconceived ideas of how the system works. Such an inflexible approach fails to learn from the existing situations in order to focus performance assessment on the real and most critical issues in a given irrigation scheme.

3.3 Definition of objectives for irrigation development

Before moving on to discuss performance criteria and performance indicators it is worthwhile looking at the objectives set for irrigation development, as it is against these that performance should be measured. It is widely accepted that the issue of irrigation performance is closely linked to objectives. Therefore, in the process of understanding the behaviour of irrigation systems and assessing their performance it is necessary to have a clear idea of the objectives for which these projects were developed, and what they aim to achieve.

In the planning, design and construction of irrigation schemes, there is always a built-in expectation, whether explicitly declared or not, of what the scheme can or should achieve. This expectation may depend on the particular group of actors concerned with the project. In addition, with the passage of time and accumulation of experience some of the expectations (objectives) may be revised, or some actors may change their behaviour regarding the desired performance. In any case there is general consensus that in order to tackle the issue of irrigation performance, it is necessary to identify, or at least imply, the objectives of the scheme and to establish the criteria by which the performance of the scheme, or parts of it, can be measured.

Small scale informal irrigation schemes which are developed and controlled by farmers in Africa form part of their subsistence strategy. Hence their primary objective is to provide food for themselves and their families. Seldom are commercial objectives paramount in their minds, although in times when they produce in excess of their family food requirement they could gladly dispose of the excess for cash.

Svendsen and Small (1990) describe farmers concerns in irrigated agriculture as "... tend to be local, intensely personal, and longer-term." This is because in most cases their immediate objective in the irrigated agricultural enterprise is centred around their self-interest: to produce crops to satisfy their personal livelihoods and provide their family's sustenance. In contrast, government sponsored irrigation projects generally constitute part of a much larger development process, and as such often have multiple objectives. The objectives are usually geared towards benefiting the society as a whole. Very often the goals of governments, international funding agencies, and irrigation agencies tend to be geographically broad, impersonal, and relatively short-term. These include improving the peoples' standard of living, saving or earning of foreign exchange, increasing and securing farmers' incomes, achieving balanced regional development, upgrading the rural environment with minimum ecological damage, and, of course, achieving self sufficiency in staple food **(ADB, 1980).**

The general government policy objectives for irrigation development in some Commonwealth countries were well documented in a Workshop on irrigation management held in India in 1978 **(Commonwealth Secretariat, 1978).** Seven of the countries represented at the Workshop described their government's policies in irrigation (see Table 3.1).

Keller (1990) summarizes the objectives for irrigation development by categorizing them into four. These are:

- for commercial production
- for socio-political reasons
- for environmental reasons, and/or
- for geo-strategic reasons.

A commercial production objective refers to a development where the principal purpose is to produce food and fibre for markets. *A socio-political* (or social benefit) objective refers to a project that is principally directed at improving the well-being of a rather large number of existing or resettled farmers with small land holdings. An *environmental* objective might be to provide more hospitable living conditions or to reduce flooding. By *geo-strategic,* he refers to projects that are initiated as political favours or for regional development or security reasons. The Bura irrigation scheme in north-eastern Kenya is an example of a geo-strategic development.

Table 3.1 Highlights of national irrigation objectives in some Commonwealth Countries.

Country	Main Irrigation Objectives
India	- Reduce fluctuation in food crop production - Employment generation - Save foreign exchange and increase foreign exchange earnings - Income distribution
Indonesia*	- Increase food production - Support transmigration programme - Promote farmers participation and responsibility for operation and maintenance of tertiary system
Kenya	- Raise food production and reduce probability of crop failure - Earn foreign exchange and reduce imports - Employment generation - Equitable income distribution - Settlement programme
Malaysia	- National self-sufficiency in rice - Raising productivity and income of rural paddy farmers
Bangladesh	- Increase domestic food production and reduce import - Create employment - Flood control - Income redistribution
Nigeria	- Security of food production - Import substitution and foreign exchange earnings - Employment generation - Income distribution
Sri Lanka	- Self-sufficiency in food - Increased cropping intensity - Yield increases

*Not part of the Commonwealth, invited delegation.

Source: **Commonwealth Secretariat, London, 1978.**

Not all of these objectives can be achieved within a single setting. In many cases some objectives will be conflicting, and a set of priorities would have to be defined. However, the fact that a government might be able to establish a clear set of objective priorities for its irrigation projects is no guarantee that they will agree with those of the other actors involved in the projects. In fact, the private interests of individuals and groups involved in public irrigation systems may not coincide with the objectives of governments.

The incongruence between public and private objectives has been cited as a possible cause of project failures. Human beings often try to optimize their own positions and benefits at a point which may be sub-optimal with respect to the overall objectives of the system. The farmers may be more interested in making a living for their families, the administrators in making the system viable to produce surplus for the market, the engineer in keeping the physical lay-out in good condition even at the expense of curtailing production, while the politicians will give support to whichever of these groups that seems more likely to sustain them in power **(Harris, 1976).**

Chambers (1976) also points out that the objectives that an irrigation system is to achieve may very well depend upon the particular view of the organizations or individuals involved. For example, a ministry of agriculture will most likely be concerned with food production while for a provincial government the interest may lie in the settlement of landless peasants. From the actors' point of view the public objectives may vary from the efficiency of water management of the engineer, to that of crop production by an agronomist, or social harmony of the sociologist to the large, timely and reliable water supply by the farmer.

3.4 Performance Criteria and Indicators

Various researchers and authors have developed and used a number of performance indicators for studies in irrigation performance. Usually these indicators are related to some objectives or targets of the irrigation system. It is widely recognized that irrigation systems' general objectives have to be translated into specific criteria by which the performance can be evaluated. As the interest in performance assessment has developed, so has the specification of which performance indicators should be used. A summary of the common indicators is presented in Table 3.2.

Table 3.2 Summary of irrigation performance indicators/criteria developed and commonly used.

AUTHOR/REFERENCE	PERFORMANCE INDICATORS/CRITERIA
Wolters & Bos, 1989	- Nilometers
Wolters *et al*, 1989	- Complaints
Chambers, 1979	- Productivity - Equity - Stability - Utility to irrigators
Bhuiyan, 1981	- Crop yields - Cropped area - Water use efficiency - Relative water supply - Water distribution equity
Vander Velde, 1980	- % of crop land planted to irrigated crops
Maholtra, 1982	- 1 ft depth of water on the gauge at the tail end of distributaries
Early, 1981	- Efficiency - Equity - Productivity
Barker *et al*, 1982	- Production - Equity - Efficiency - Adequacy - Reliability - Predictability - Flexibility
Lenton, 1982	- Actual area irrigated - Water delivery: quantity & timing - Crop yields from irrigated land - Variations in the above within the system (equity)
Bottrall, 1981	- Productivity of water - Equity of water distribution - Environmental stability - Cost - Cost recovery
Rosegrant, 1982	- Conveyance, distribution & water use efficiencies - Total area irrigated - Yield and production - Cropping intensity - Input use yield - Crop income per hectare
Bos & Nugteren, 1974; Wolters & Bos, 1989	- Irrigation Efficiencies
Plusquellec *et al*, 1990	- Water availability - Water use efficiency - Equity of water distribution - Cropping intensity and yields - Project economic rate of return
Abernethy, 1990a (Water Delivery Systems)	- Conveyance efficiency - Relative water supply - Inter-quartile ratio (equity) - Water delivery performance
Abernethy, 1990b (Whole System Perspective)	- Productivity - Equity - Profitability - Sustainability - Quality of life

The indicators proposed for measuring performance have ranged from the very simple to complex, from specific to general. Examples of simple indicators include:

- Nilometers **(Wolters and Bos, 1989)**
- Complaints **(Wolters *et al*, 1989)**
- Percentage of irrigated crop land **(Vander Velde, 1980)**
- 1ft depth of water at the tail end of distributaries **(Malhotra, 1982).**

An early example of performance indicators in irrigation is the use of *'Nilometers'* in ancient Egypt **(Wolters and Bos, 1989).** The flood level was used as an indicator of the area that could be irrigated, because that corresponded with the taxes that could be levied. Too low a water level meant famine, and the Pharaoh's subjects had to be fed from the granaries. A higher water level secured a rich yield, too high a level however caused floods!.

Another example of a simple indicator of irrigation performance also comes from Egypt, from studies in the Fayoum Governorate **(Wolters *et al*, 1989).** The farmers there have considerable influence in the day-to-day management of the system as they can file complaints with the Governor of the Fayoum. In this way, the *'complaints'* act as a performance indicator. They are also used in managing the system: if there are no complaints at all, the water supply is probably too generous, and water can be saved. **Vander Velde (1980),** in a study in India indicates that historical performance could be measured in terms of *the percentage of crop land planted to the irrigated crops*. **Maholtra (1982),** in the same country and within the context of the Warabandi system, states that the system is so designed that the gauge at the tail end of distributaries is of great importance: *one foot depth of water at these points is an index of the correct performance* of water distribution.

Some authors generalize the criteria by which performance should be measured, the ones commonly used are:

- Productivity
- Equity
- Efficiency
- Adequacy

Chambers (1979) proposes four indicators for the evaluation of irrigation systems. These are:

(a) *Productivity* - as measured by the ratio of production and scarce resources used such as water, land, labour or their combination.

(b) *Equity* - as a fair distribution of resources and livelihoods with emphasis on water distribution among farmers.

(c) *Stability* - the capacity for long-term sustained irrigation without environmental depletion, deterioration or loss of productivity, and

(d) *Utility to irrigators* of the quantity, timing and predictability of the water they receive.

Early (1981), also uses *efficiency, equity and productivity* as key indicators where *efficiency* refers to a ratio of water use and water input into the system expressed as a percentage. *Equity* refers to some measure of distribution of participation in decision-making and resource use available to farmers. *Productivity* refers to the yield as the primary output from the system.

Bhuiyan (1981) is more specific as the indicators he states are commonly used to evaluate irrigation systems:

- *crop yields*
- *cropped area*
- *water use efficiency*
- *relative water supply, and*
- *water distribution equity.*

He cautions against using these indices individually to assess system performance, and suggests that when combined a better picture of what took place in the system could emerge.

Lenton (1983), in addressing the performance of very large scale irrigation systems in Asia stresses that it is important to identify a small number of key performance criteria that can be evaluated over these large areas. Otherwise the large amount of data to be handled would make the evaluation task impossible. He proposed four measures:

a. actual *area* irrigated

b. water delivery: *quantity and timing*

c. *crop yields* from irrigated land, and
d. variations in the above amounts within the irrigation system *(equity)*.

According to him, (a), (b), and (d) define the performance of an irrigation system, while (c) & (d) define the performance of the entire agricultural system.

Barker *et al* (1982) proposes seven performance indicators for studying irrigation development in Asia. These are:

(a) *Production*: increased unit area yields through either intensification or extensification
(b) *Equity*: usually associated with social factors, refers to the quality of irrigation services of head- verses tail-enders, large verses small farms, or tenants verses landless labourers, etc.
(c) *Efficiency*: usually in the technical perspective of an output-input ratio
(d) *Adequacy*: the amount and timing of water delivery
(e) *Reliability*: both of water source and management
(f) *Predictability*: the degree to which changes in the water supply can be foreseen and the degree of arbitrariness associated with the system management actions, and
(g) *Flexibility*: the ability of the system to respond to changing needs.

In the comparative study of the management and organization of irrigation systems in India, Pakistan, Indonesia and Taiwan, **Bottrall (1981)** evaluated system performance in terms of five indicators which were:

- productivity of water
- equity of water distribution
- environmental stability
- cost, and
- cost recovery.

Rosegrant (1982) proposes that performance measures for irrigation schemes can be classified as intermediate and final. The former includes:

- *water distribution* or *conveyance efficiency* along selected sectors of canals, and

- *water use efficiency* in the fields estimated at chosen locations.

The latter includes:

- total *area irrigated*
- *yield and production* per season for the entire system
- *cropping intensity*
- *input use yield*, and
- *crop income per ha* for selected farms in different sections of the system.

Final benefits from the scheme can then be compared with the cost of physical structures and management in assessing the overall relative effectiveness of alternative systems.

Several authors including **Bos & Nugteren (1974) and Wolters and Bos (1989)** have often used *irrigation efficiencies* as the primary performance criteria. Until the early 1980s this was almost all we thought about for assessing irrigation performance. Irrigation efficiency is often used to encompass many components, such as conveyance, distribution, application, and water use efficiencies among others. They caution that measured efficiency values should be compared with a target value and not with 100%.

Plusquellec ***et al*** **(1990)** conducted comparative performance assessment studies of gravity irrigation projects in six countries with different climate and social environments. The performance parameters they used pertain to their original objectives which were:

- water availability
- water use efficiencies
- equity of water distribution
- cropping intensity and yields, and
- project economic rates of return.

Abernethy (1990a) reviewed some of the principal criteria proposed for measuring and evaluating the performance of canal water delivery systems and recommends a list of indicators which could be adopted as the basis of standard assessment practices. These are:

a. for main system performance, from water source to field channel: *Conveyance Efficiency*

b. for adequacy of water supply: *Relative Water Supply;*

c. for equity of water distribution: *Inter-quartile Ratio*

d. for overall performance of a system (or of a system component such as a tertiary block): *Water Delivery performance.*

In a latter paper **Abernethy (1990b)** lists the parameters from the viewpoint of managing the irrigation system as a whole. These are:

- Productivity
- Equity
- Profitability
- Sustainability, and
- Quality of life.

The literature review points towards a multiplicity of criteria that can be and have been used to evaluate the performance of irrigation projects. What is important, however, is that we do not fall into the oversimplification or over-inclusiveness trap. It is necessary to keep the volume of data to be generated by the proposed criteria to a tolerable and reasonable level, otherwise it will be very unlikely that the evaluation procedure would be implemented by irrigation agencies. As suggested by **Chambers (1976):**

> "the more objectives, criteria and factors have to be taken account of, the more there is a danger of requiring armies of engineers, system analysts, economists, agronomists, and others (not forgetting the token sociologist to take care of the 'social constraints') who in turn will expose more objectives, criteria, and factors, all leading to a chronic constipation with data which will hinder rather than help management."

Small and Svendsen (1990) provide a useful framework for performance assessment by classifying performance measures into three groups:

- process measures
- output measures, and
- impact measures.

Process measures of performance relate to a system's internal operations and procedures. *Output measures* of performance examine the quantity and quality of the system's final outputs. *Impact measures* pertain to the effects that the system's outputs induce on its larger environment. This approach has been included in the proposed methodology.

It can be observed that the indicators listed above are mostly aimed at large scale irrigation systems where the level of cultivation is generally quite high (except those in India where the cultivated area is rationed). They are also focused on the evaluation of the outputs, particularly on water management issues of efficiency, equity and adequacy, or economic returns on investment. Not much consideration is given to medium scale schemes and the conditions of the inputs or production processes.

3.5 Other Performance Assessment Instruments

Checklists are among the most important survey tools used in data collection and performance assessment of irrigation schemes. Various authors have produced different checklists to highlight the key elements in establishing the performance of distinct types of irrigation systems.

The most well known checklist for documenting and assessing the performance of large scale irrigation schemes is the one presented by **Bottrall (1981)**. It is divided into three parts:

- inventory of the resource base
- indicators of project performance, and
- identification of causes of performance.

Yoder and Martin (1985) developed a question guide for appraisal of farmer-managed communal small scale irrigation systems in Nepal. The guide is divided into four sections:

- General information
- Organization
- Historical development of existing irrigation systems
- Technical information.

Their question guide is also quite popular and has been adapted for use in different situations, such as Zimbabwe **(Tiffen, 1985)**. Other reported use of this approach for agricultural and irrigation research include **Hildebrand (1981), Collinson (1981), De Los Reyes *et al* (1980, 1981)**.

Of all the approaches reviewed, only **Yoder and Martin (1985) and De Los Reyes *et al* (1980, 1981)** dealt with schemes which are not large scale government run. However, both authors did not aim at performance assessment *per se*. **De Los Reyes *et al*'s** work was part of a pilot programme in the Philippines with the express purpose to "identify methods of building up strong and enduring irrigators' associations on small irrigation schemes" **(Bagadion *et al*, 1980)**. **Yoder and Martin (1985)** aimed to provide a guide for identification and utilization of local farmer resources for irrigation development.

Other survey methods for performance appraisal include key informants, questionnaires, group interviews, participant observation, and direct and physical measurements.

3.6 Desirable Features of a P.A. Methodology and Indicators

The attributes of a good performance assessment methodology include the following:

- sequence of main activities in doing performance assessment
- distinction between general applicability and site-specificity
- show different levels of performance assessment, depending on the type of scheme
- assessment of the overall picture from a whole system perspective: what happens, how and why. This should identify causes and effects
- set boundaries and specify what is being assessed, and
- set realistic standards commensurate with system background conditions.

A joint **IFPRI/IIMI project (IFPRI, 1991)** on irrigation performance assessment identified a number of criteria typifying ideal properties for performance indicators as:

- Orthogonality:- indicators comprising a set should be mutually independent with minimal overlap
- Related to an objective with potential for linking to standards
- Universality and broad applicability, as opposed to site specificity
- Objective rather than subjective
- Simple, communicable, easily understandable, user-friendly
- Inexpensive, cost effective and reliable
- Reproducible and verifiable:- different people should be able to use the methodology and get the same results
- Robust, with a high signal to noise ratio in the data
- Low data requirement - the fewer the data collected, the better
- Ease of application, including collection of data
- Purposive - should be related to change opportunity and useful to decision makers
- Comprehensive - taken together, the indicators should provide a comprehensive view of performance and each indicator should contribute to that view.

The author believes that performance indicators from a whole system perspective ideally should relate to:

- *the inputs*
- *the process* of transforming inputs into outputs, and
- *the outputs*.

An evaluation of the *inputs* reveals the potential capability of the system to meet the set objectives. *Process* indicators bring to light the internal transformation processes that occur within the irrigation system to produce the desired output. *Output* measures compare the final outcomes with the set targets. By evaluating all three sets of measures in a systems context, a better understanding of the system can be obtained; by revealing what has happened (outputs), how it happened (process) and why (the determinants).

Traditionally studies on irrigation performance assessment concentrate on the evaluation of the outputs and management processes. In particular, the assessment of irrigation water distribution in terms of adequacy, equity and efficiency has received much attention. Scarcely has any attention been given to evaluating the conditions of the inputs and processes, which of course determine the outputs.

This observation is evident in the literature relating to performance assessment studies and indicators used for evaluating irrigation schemes. Perhaps this may be due to presumptions that the inputs constitute no constraint to the attainment of the outputs, or due to oversight. This position needs to be changed, particularly in the context of African irrigation.

The reason for this opinion is that infrastructure, management capability and input levels in Africa are generally low, and there is relatively lower irrigation experience and culture. Consequently, efficiency and output standards also have to be lower. Performance assessment in Africa needs to start at a lower level, dealing more with the infrastructure, management capability and socio-economic conditions.

This, of course, is not to undermine the importance of efficient irrigation water management. But the fact is that in Africa some of these other issues may be more critical in improving the productivity and sustainability of irrigated agriculture. The methodology proposed in the following chapter for performance assessment, and the case study presented further develops this theme.

This Chapter discusses some of the concepts involved and the choices that have to be made in carrying out performance assessment. It also presents a methodology which consists of steps and sequence of main activities that can be used in the study of irrigation system performance.

4.1 Concepts and Classification

4.1.1 System approach to irrigation performance

A systems approach is a research strategy with the objective to study all the components pertaining to a specific research problem. Any irrigation scheme, at whatever level it is observed, is composed of interrelated mutually dependent component parts. The components could be grouped under any taxonomy, such as economic, physical, social, agricultural, social, institutional, environmental, etc. These may be sub-systems within themselves, or a hierarchy of systems.

Historically, researchers have been inclined to look at irrigation performance from disciplinary perspectives. For instance, economists study performance by looking at the global picture, concentrating on economic returns and costs. Sociologists/anthropologists focus on farmers' perceptions and decision making processes, gender issues, institutional aspects, farmers participation and settlement of disputes. Agronomists concentrate on farm management practices, cropping patterns and intensities, farm technologies and inputs. Engineers study irrigation performance in terms of the efficiency of water supply and removal.

Until recently, *'irrigation efficiency'* **(Bos and Nugteren, 1974)** and *'economic rate of return (ERR)'* **(Tiffen, 1987)** have been the most used indicators of performance, emphasizing mainly the physical and economic aspects of an irrigation system. Of late however, there has been growing consensus that broader concepts focusing on assessment of the overall use of water and the entire irrigated agriculture system give a more accurate picture of performance.

Distinguished scholars such as **Robert Chambers, Anthony Bottrall** and others have been advocating this approach for a 'whole system analysis' for the past decade **(eg Early, 1981; Lenton, 1986; Keller, 1990; Smith, 1990; Kirpich, 1993).** As a result, there has been a shift from the use of single performance indicators to a combination of indicators representing different aspects of an irrigation system. This study adopts the whole system approach to performance assessment. It proposes that in order to understand the performance of irrigation schemes, we need to look at the entire irrigated agricultural system.

4.1.2 Classification of irrigation systems and hierarchies of performance assessment.

Small and Svendsen (1990) and Smith (1990) describe irrigation schemes in terms of a logical hierarchy of objectives. They argue that there exists a gradation of purposes for irrigation, from the very narrow to the very broad. These purposes tend to be related to each other in that the achievement of a narrow purpose is a means by which a broader purpose is realized. They conceptualize irrigation purposes in a nested means and ends framework. Thus, beginning with the narrowest or proximate purpose of irrigation, one moves outward through a series of broader purposes, the achievement of each of which is partly dependent on attaining the purpose of the previous level. This process continues until one arrives at the 'ultimate' purpose (see Table 4.1 and Figure 4.1).

In a similar fashion, this study proposes that different levels of 'performance assessment' can be defined within a framework for different irrigation schemes depending on the purpose of the performance assessment. Beginning with the basic assessment of low level irrigation schemes, one can move up to higher levels of performance assessment relating to water management, efficiency of resources utilization etc.

for highly developed schemes. This approach is based on the fact that certain prerequisites need to be satisfied for any given level of performance assessment to be possible. From practical field experience it has been found that a level of performance assessment and indicators designed for one type of irrigation scheme may not be appropriate for different types of schemes. This is because much of the choices and mix of actions in irrigation performance assessment depend on the type, condition, and level of development of the scheme. Different situations make different demands on the objects, performance indicators, type of data collected, and the type of evaluation possible. It is therefore possible to link the particular configuration of an irrigation scheme with the type and level of performance assessment.

Table 4.1: Examples of irrigation purposes as nested means and ends (From Small and Svendsen, 1990)

Level and end	Means	End
Proximate	Operation of irrigation facilities	Supplying water to crops
Intermediate-1	Supplying water to crops	Sustained increase in agricultural productivity
Intermediate-2	Sustained increase in agricultural productivity	Increased incomes in rural sector
Intermediate-3	Increased incomes in rural sector	Rural economic development
Ultimate	Rural economic development	1. Improved livelihoods of rural people 2. Sustained socio-economic development for entire economy

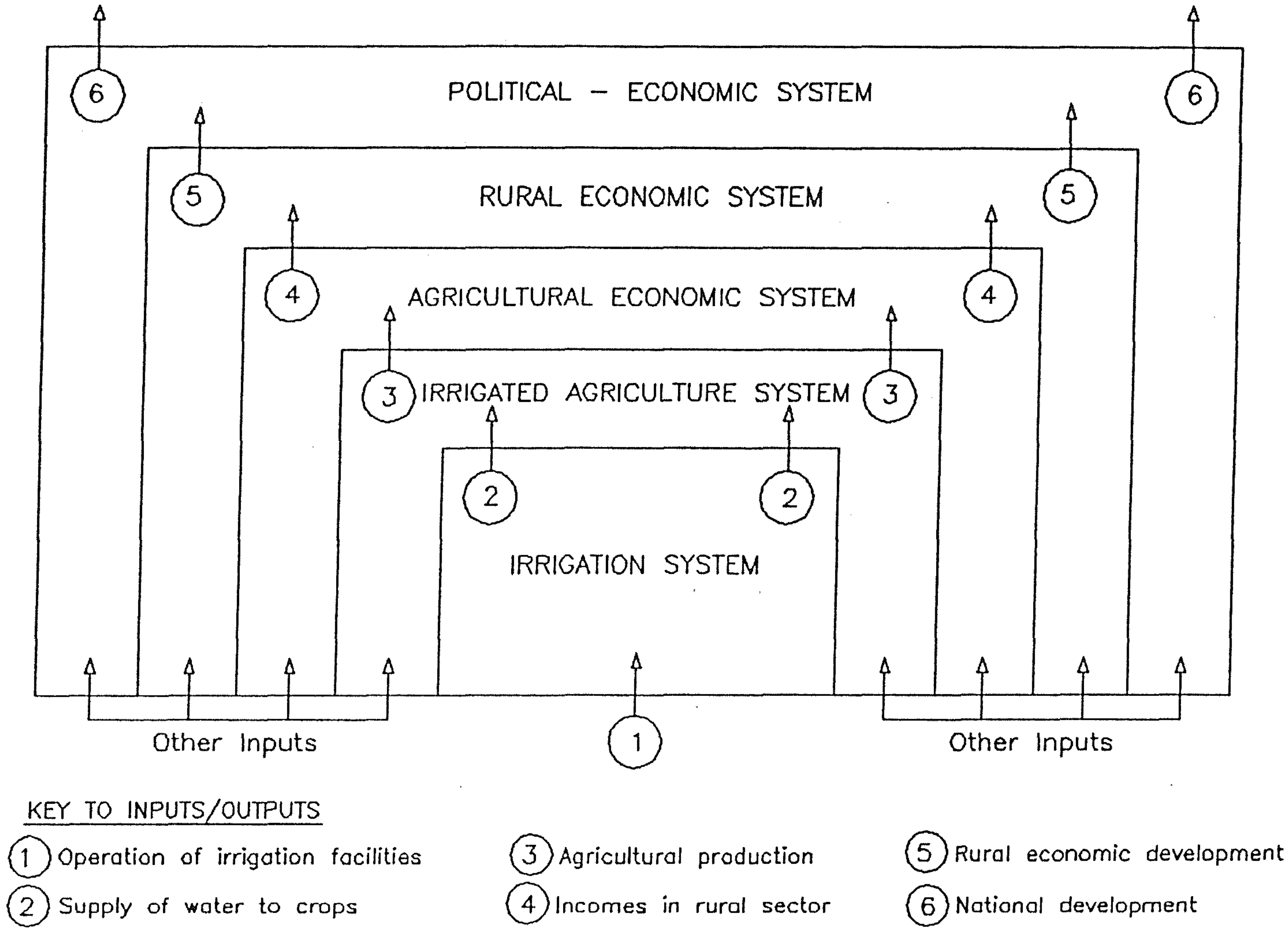

Figure 4.1 Inputs and outputs: Irrigation in the context of nested systems **(After Small and Svendsen, 1992)**

This study recognizes the complex nature of irrigation schemes and performance assessment. Apart from a few broad features which could be similar in different schemes, nearly every irrigation scheme is unique. Each has its own locality-specific characteristics such as physical environment, water resources, farmers, management, crops, irrigation facilities, agricultural and economic conditions, social organizations, etc. Thus performance assessment of irrigation schemes is possible only when a proper inventory has been undertaken in a particular scheme to establish bench-marks and verify existing possibilities. This sets a precise perspective for understanding the performance of the scheme being studied.

One of the interests in the current era of irrigation performance studies is the desire to make comparisons of the level of performance between different schemes. This is difficult unless the schemes are similar in nature, goals, environment, etc. and thus the assessment measures employed are comparable. Thus a systematic approach for classification of irrigation schemes, scope and types of performance assessments is required if comparisons across individual schemes, geographical regions, or nations is to be achieved.

The author believes that one of the key needs in performance studies is the categorization of types of irrigation schemes and of performance assessments. We can then begin to build a database of studies of different types of irrigation schemes and can start to compare like with like on the basis of the similar attributes. Table 4.2 and Figure 4.2 presents an outline of some of the features in irrigation systems and techno-management conditions which may determine the appropriate type of performance assessment. The areas applicable to this study are shown highlighted in **boldface type *italics*** in the Table and bullets (•) in the Figure. Surprisingly not much can be found in the literature on attempts to categorize irrigation schemes. This is perhaps a potentially new area for further research. Of all the literature consulted only **Carter *et al* (1986)** and **FAO (1987)** have tried to classify irrigation schemes in Africa according to size and ownership, while **Murray-Rust *et al* (1991)** have specified the different design-management environments.

Table 4.2 Some factors characterising irrigation schemes and the type of performance assessment.

A. Type of irrigation scheme
- Small scale, informal, or traditional irrigation
- ***Small to medium scale formal irrigation***
- Large scale formal smallholder irrigation
- Estates and large scale private or parastatal irrigation

B. Size of scheme
- Large scale schemes (> 10,000 ha)
- ***Medium scale schemes (500 - 10,000 ha)***
- Small scale schemes (<= 500 ha)

C. Average irrigated farm size
- ***< 2 ha***
- 2 - 10 ha
- 10 - 20 ha
- 20 - 100 ha
- > 100 ha

D. Management responsibility and style
- Highly bureaucratic irrigation agency
- ***Joint management between farmers and agency***
- Solely farmer-managed

E. Age of irrigation scheme
- New scheme (< 10 years)
- ***Moderately aged scheme (10 - 50 years)***
- Old and well established scheme (> 50 years)

F. Stage of scheme development
- Recently developed, partly completed
- ***Some phases fully completed***
- Maximum potential area fully developed

G. Irrigation culture and farmers experience
- Well established (over 100 years)
- Moderately established (50 - 100 years)
- ***Low irrigation experience (< 50 years)***

H. Necessity of irrigation in the area
- Absolutely necessary for survival (arid)
- ***Moderately necessary or supplementary (semi-arid)***
- Irrigation makes little or no difference

I. Level of infrastructure and investment
- Highly developed permanent infrastructure, high investment
- ***Moderately developed infrastructure***
- Simple, temporary, poor or no infrastructure

J. Access to markets and produce prices
- Good: urban centres within say 50 km and competitive prices
- ***Moderate: Linked to towns 50 - 300 km by good roads and fair prices***
- Poor: towns over 300 km away; poor roads and low prices

K. Water availability

- *Good and secure water supply. Water shortage generally not a problem*
- Occasional or seasonal water shortage. Variable supply
- Constant water scarcity

L. Source of water supply

- Run-of-the-river diversion system
- *Dam and storage reservoirs*
- Wells and underground water sources only
- *Combination of surface and underground water sources*

M. Type of irrigation system

- Gravity flow system only
- Pumped/lift irrigation system
- *Combined gravity and lift system*

N. Field application methods

- *Surface irrigation (basin, border, furrow, etc.)*
- Sprinkler system
- Drip/sub-surface system
- Mixed system

O. Main irrigated crop choices

- High water demand crops (rice, sugar cane, etc.)
- *Dry foot crops*

P. Type and purpose of performance assessment

- *Intervention or independent research assessment*
- Accountability assessment
- Operational performance monitoring

Q. Scope of assessment

- *"Whole System", i.e. Irrigated agriculture scheme*
- Irrigation system only (physical system)
- Management operation and maintenance
- Farmers' performance

R. Goals and standards for assessment

- National/external: formal and informal
- *Local economy/scheme level: formal and informal*
- Management objectives and targets: formal and informal
- Farmers' goals: mostly informal

S. Ownership of the scheme/land

- Owner/occupier
- Private tenancy
- *Government tenancy*

Figure 4.2 Categorization of irrigation schemes for purpose of performance assessment and comparison

	SMALL SCALE			LARGE SCALE
VARIABLE	SS	SS - Med	Large	Estate
A: TYPE OF SCHEME	Small, informal	Small - medium, formal	Large scale, formal	Estate, private or State
		●		
B: SCALE/SIZE	<= 500 ha	500 - 1000 ha	1000 - 10,000 ha	> 10,000 ha
		●		
C: AVERAGE FARM SIZE	< 2 ha	2 - 10 ha	10 - 100 ha	> 100 ha
	●			
D: MANAGEMENT STYLE	Farmer-managed	Joint management	Bureaucratic agency	
		●		
E: AGE OF SCHEME	< 10 years	10 - 50 years	> 50 years	
		●		
F: STAGE OF DEVELOPMENT	Recent, partly completed	Some phases fully completed	Total potential area developed	
		●		
G: IRRIGATION CULTURE	Low experience (<50 years)	Moderate (50-100 years)	Well established (>100 years)	
		●		
H: IRRIGATION NEED	Not desperate (humid)	Supplementary (semiarid)	Absolutely necessary (arid)	
		●		
I: LEVEL OF INFRASTRUCTURE	Simple, temporary or poor	Moderate infrastructure	Highly developed infrastructure	
		0		
J: MARKETS & PRICES	Poor, over 300 km to markets	Moderate, within 50 - 300 km	Good, close to urban centers	
		●		
K: WATER AVAILABILITY	Constant water scarcity	Variable, occasional scarcity	Good and secure water supply	
			●	
L: WATER SOURCE	Run-of-the-river system	Wells and underground water	Dam/storage reservoirs	Surface/underground
				●
M: IRRIGATION TYPE OF FLOW	Gravity flow system	Pumped/lift irrigation	Combined gravity/lift	
			●	
N: FIELD APPLICATION METHODS	Surface methods	Sprinklers	Drip/Sub-surface	Mixed system
	●			
O: IRRIGATED CROPS	Dry foot crops	'Water thirsty' crops (eg. rice)		
	●			
P: PURPOSE OF ASSESSMENT	Operational monitoring	Accountability assessment	Intervention/research	
			●	
Q: SCOPE OF ASSESSMENT	Farmers' performance	Irrigation system (infrastructure)	Management, O & M	Whole irrigation scheme
				●
R: STANDARDS FOR ASSESSMENT	Farmers' goals	Management objectives	Local economy	National or external
			●	
S: OWNERSHIP OF SCHEME/LAND	Owner/occupier	Private tenancy	Government tenancy	
			●	

Irrigation schemes to be compared do not necessarily have to fall in the same category for all of the factors listed in Table 4.2 and Figure 4.2. The key characteristics of schemes that define their particular configuration are summarized in Table 4.3 from low to high (**Note:** low in this sense is not pejorative, it relates to relatively low levels of irrigated area, number of water users, etc.). Between the limits indicated there can, of course, be a great variety of intermediate situations. The final decision of similarity between schemes depends on the judgement of the assessor based on the basic features. The main point being emphasized is that the level of performance assessment needs to be planned to suit the type and configuration of an irrigation scheme. This can be envisioned as a hierarchy of assessments ranging from basic to highly sophisticated, depending on the particular conditions of a given scheme. Figure 4.3 depicts the conceptual hierarchies of irrigation schemes and the corresponding levels of performance that may be possible.

Table 4.3 Key characteristics in the configuration of irrigation schemes.

KEY CHARACTERISTICS	SMALL SCALE	LARGE SCALE
Total irrigated/irrigable area	Small	Large
Number of water users	Relatively small	Large
Average landholding size	Small	Small or Large
Number of Operational levels	Small	Large
Flexibility and divisibility of technology[2]	High	Low
Ownership	Owner/occupier	Generally government tenancy
Management responsibility	Largely with water users	With a separate agency
Emphasis of production goals	Of water users emphasizing personal needs & subsistence	Strongly oriented towards national & international markets

[2]This refers to the degree of constraint imposed on the system by its design and construction. Low level schemes are flexible in that they can easily be adapted and modified to suit changing circumstances. High level schemes on the other hand have prefixed design choices and configurations which are difficult to alter.

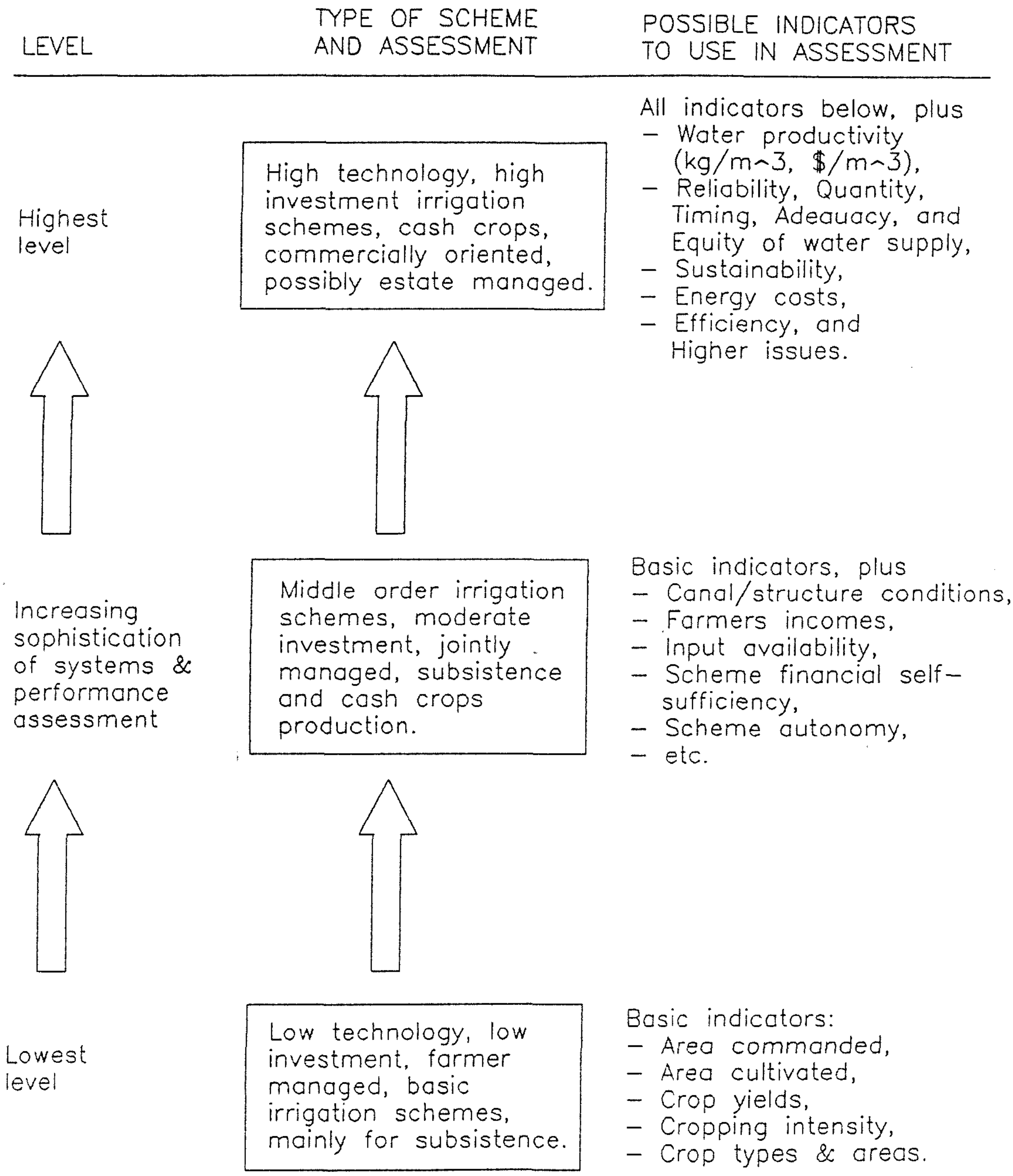

Figure 4.3 Hierarchies of irrigation schemes and corresponding types of performance assessment

The increasing complexity of system configurations and sophistication of performance assessments implies that the basic approach and some indicators for performance assessment may be applicable to all systems. However, the sophisticated procedures designed for higher systems may not be suitable for lower systems. For example, in a well developed irrigation scheme, it may be fundamental to study the efficiency of water management (as this is where improved performance will come from); in a poorly developed scheme however, water management may not be the crucial factor, it may be more beneficial to concentrate on the state of scheme infrastructure, management and socio-economic factors.

It is important to note that the boundaries between different levels may not be clear-cut. In addition a transition could take place on a scheme from low to high status, and vice versa. This involves modification of the prime features of a scheme, such as total area, number of farmers, or change in management set-up. In such cases it may become possible to use a type of performance assessment that was previously unsuitable. For instance, following rehabilitation of a scheme with poorly developed infrastructure more sophisticated levels of assessment would be merited.

Performance assessment is linked to the ability to control and manage water. For 'low-tech' systems the control is poor so no amount of effort could increase the productivity per unit of water above a certain threshold. Thus it would not be worthwhile using much effort if only a little can be achieved in bringing about improvements. It would be more profitable to use a 'lower order' of performance assessment, in line with the ability of the scheme to make changes to improve performance, or the level of investment made, or the level of production expected.

4.2 Proposed Reference Methodology

The following section provides an overview of the proposed methodology and detailed procedures for performance assessment and data collection and analysis.

4.2.1 Overview

The reference methodology proposed in this study is presented in Figure 4.4. The author asserts the management concept that performance assessment needs to be linked with the aims and objectives for which a scheme is managed. After establishing a scheme's objectives and background conditions, appropriate performance indicators are selected, targets are set, and the performance is evaluated by determining whether or not the objectives are being achieved. This is done by comparing the actual performance with the desired performance standards. If the objectives are not being achieved, contributing factors causing the low performance need to be identified and understood in order that recommendations can be made for removal of constraints. Where the performance is acceptable strategies need to be defined for maintaining those levels and deriving lessens for similar schemes.

This approach differs from other proposed methodologies in proposing a rapid appraisal first, and in trying to identify factors which contribute to good or adequate performance as well as those that identify poor levels of performance. Surprisingly others have tended to concentrate on poor performance **(Lenton, 1983; Oad & McCornick, 1989)**

Since the performance of an irrigation scheme depends on the interactions of the many inputs and processes for production, it could well be determined by the weakest link in the chain. Figure 4.5 tries to outline this point by showing that the weak link can occur at any point, in the input, process or output, and can be technical, social, political, or economic in nature. Thus, in carrying out performance assessment, it is important to test the strengths and weaknesses of the inputs and processes, as well as the supporting background conditions in order to determine if they constitute constraints on the outputs or not.

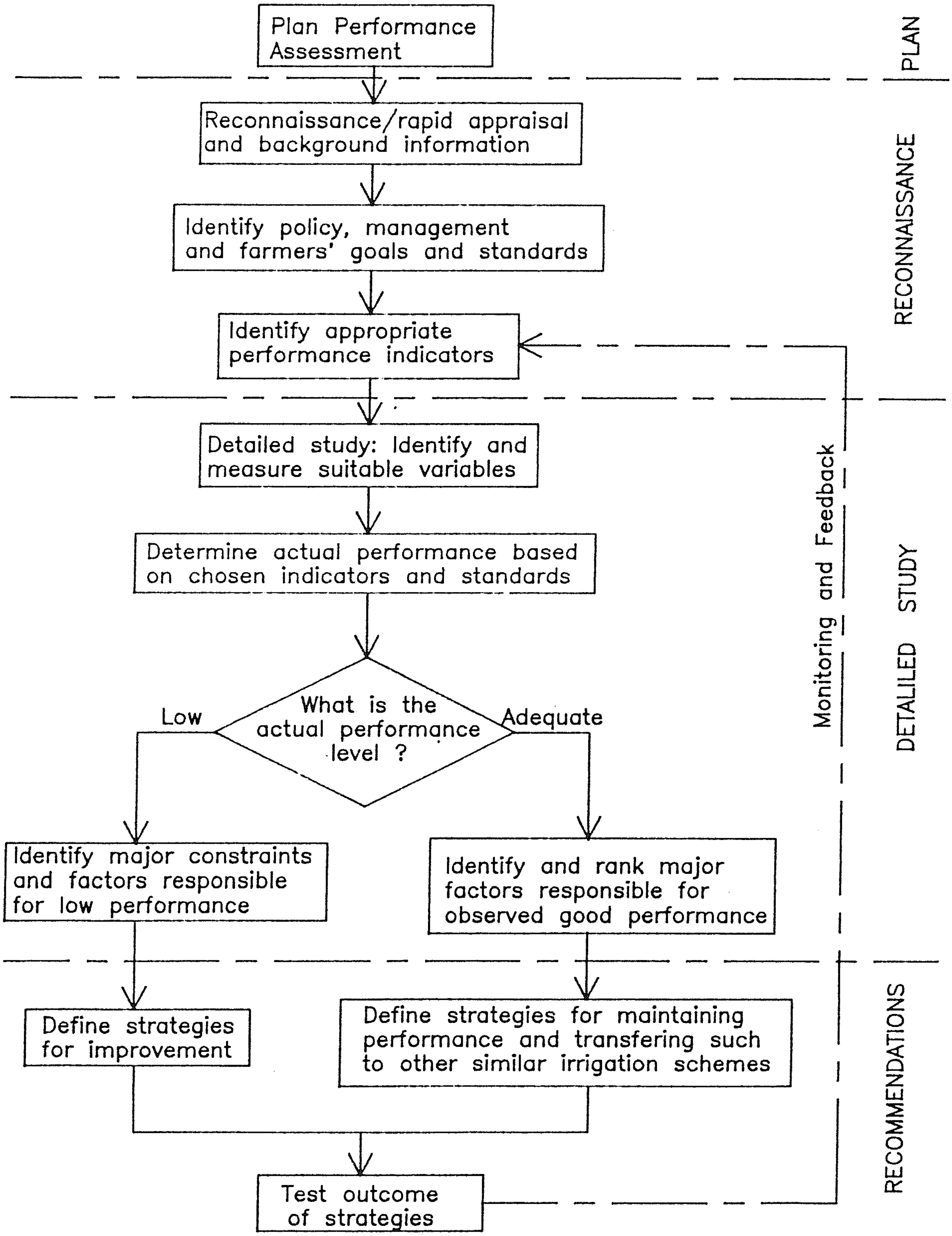

Figure 4.4 Proposed reference methodology for performance assessment of medium scale irrigation schemes

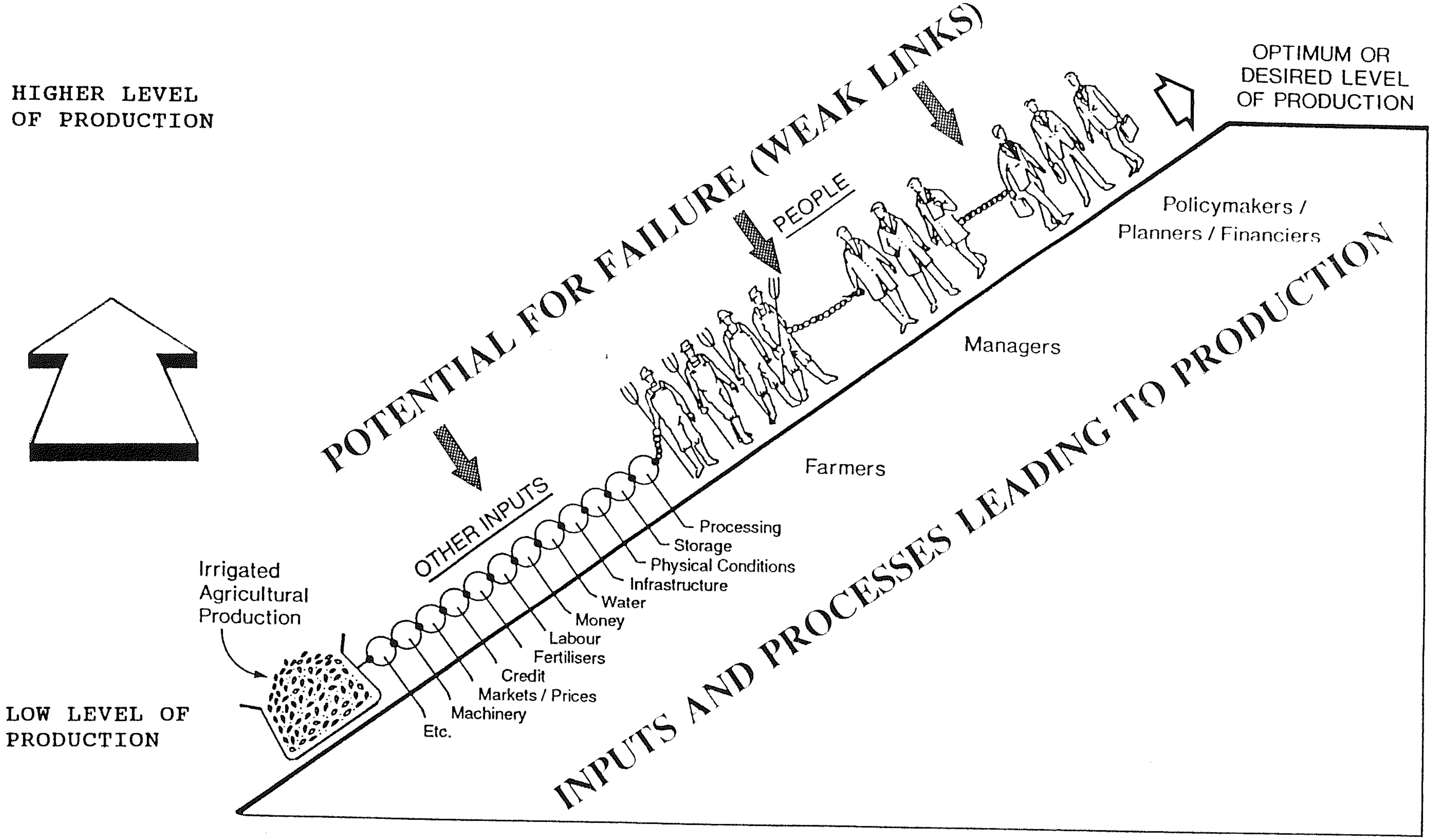

Figure 4.5 Graphical representation of the linkages between inputs and processes in the production and performance of irrigated agriculture.

If we only have low inputs, the potential of the scheme is low, and we should be relatively satisfied with low output performance. This is because the level of 'success' depends to a significant degree on the level of inputs. A scheme could be considered a 'success' with low outputs if the input levels are low, since this reflects the return on investment - the basis of economic internal rate of return (EIRR). It would be foolhardy to set high standards or expectations for a scheme with deficient inputs, or a scheme which is severely constrained by the production processes and natural environment. Whilst it is possible that a low investment approach might achieve high returns (relative to investment), low investment may not produce adequate levels of production.

This approach was found particularly applicable on small and medium scale irrigation schemes. The farmers' decisions and motivation on such schemes is a result of their evaluation of the whole irrigated farming business including availability of input resources, production processes, and marketing possibilities. The critical factors which limit farmers' production and performance of the irrigation scheme could be fertilizer, pesticides, labour, irrigation, weeding, credit, prices, or any combination of them. Hence this study strongly argues that effective performance assessment of irrigation schemes and the standards against which performance is measured should be centred on a proper perspective of the conditions of the schemes' resource base.

It is only when appropriate management strategies are adopted which are compatible with the physical system, management capabilities, and irrigator's socio-economic circumstances that it would be possible to predict the resulting performance of an irrigation system, and to assess the longer term sustainability of the whole system. Thus, it is essential to assess the system resource base in order to determine what it can realistically be expected to achieve. In other words, *the performance of an irrigation scheme needs to be measured by comparing the actual performance against its capabilities and potentials.*

It should be noted that while the proposed performance assessment methodology can effectively measure quantitatively the actual performance of an irrigation scheme in terms of the chosen criteria, it may not be able to identify all the real causes of the observed performance levels. To this end supporting investigations need to be undertaken in order to identify the causes of low or high performance.

For monitoring purposes the mechanism of this methodology includes a feedback of information from the results of the actions taken in order to regulate the inputs and outputs on a regular basis. In the event of low performance where the constraints cannot be removed within the available resources or given environment, the solutions might lie in reevaluating the objectives or changing the expectations of the various interest groups. This could take place at the farmer, policy or management levels, where the goals and expectations may be too high for the given resources and prevailing conditions.

4.2.2 Detailed procedures

The following sections provide a specific detailed framework and sequence of the main activities for carrying out successful performance assessment of irrigation schemes. The main steps are:

- Planning and organization of performance assessment
- Reconnaissance and rapid appraisal
- Detailed field study, data collection and analysis
- Recommendations for action and assessment report.

The detailed components of each activity are outlined in Table 4.4. Although the framework is aimed at medium scale irrigation schemes, it might also be adapted for use in the design of performance assessment of other types of irrigation systems. It should be observed that differences may occur at points where choices have to be made on specific issues depending on the type of irrigation scheme and the level of sophistication of the performance assessment.

Table 4.4 Outline procedure for irrigation performance assessment.

1. PLANNING AND ORGANIZATION OF PERFORMANCE ASSESSMENT.

- Clarify purpose of assessment/type of assessment.
- Set system boundaries.
- Identify system goals and objectives.

2. RECONNAISSANCE AND RAPID APPRAISAL.

- General overview of the system.
- Preliminary data collection and analysis.
- Identify and prioritize opportunities and constraints.
- Review initial plans and objectives.

3. DETAILED STUDY.

- Choose feasible performance standards.
- Identify suitable performance indicators.
- Identify measurable variables for chosen indicators.
- Formal detailed data collection and analysis.
- Evaluation of actual performance.

4. RECOMMENDATIONS.

- Identify and rank causes and effects of observed levels of performance.
- Define strategies for maintaining performance, if it is satisfactory, and transferring such levels to other similar systems.
- Define strategies for improving performance, if it is unsatisfactory.
- Feedback to policy makers, managers and farmers.

1 Planning and organization

Clearly the logical first step in performance assessment of any irrigation scheme is good planning and organization of why the assessment is to be carried out and what is to be evaluated. This is because the nature of an assessment depends on the rationale for its being conducted, and the scope of the assessments.

Following clarification of purposes of assessment and the type of assessment to be undertaken, delineation of boundaries on what components of the system to be evaluated needs to be made. One of the most controversial issues in performance assessment of irrigation systems concerns the system and sub-system boundaries to be used. System boundaries in irrigation performance assessment can be defined in many ways. This may be in terms of the extent and functions of the system (irrigated agriculture system, water acquisition, distribution, or application), the stage of development (design, construction, operation, or maintenance), or the geographical area (design area, net irrigated area, surrounding locality).

This study supports the view that performance assessment should be related to the functioning of the whole irrigated agricultural system, with emphasis on the operation and maintenance phase and within the context of the local economy. It argues for an integrated approach and a broad view of irrigation performance in order to determine the impact of the various components. The integrated approach is particularly suited to medium and small scale irrigation systems. This is because, to farmers in such schemes, water supply is just one of many inputs that affect their decisions and operations in agricultural production. Also irrigated agriculture may only be one part of the 'farming system.' In many cases other factors are more critical to them than water supply. This is especially true in Africa where rain-fed and livestock farming can be important alternatives for use of farmers' resources.

Irrigation systems are generally created as part of a formal or informal goal-oriented process. Moreover, efforts to improve irrigation performance reflect concern that the goals underlying irrigation investments are not being fully realized. They represent attempts to bring about changes that will enhance the achievement of some set goals. Hence the *goal-oriented model of performance* is more useful even when the goals are not explicitly stated. This implies that identification of the goals and objectives of the irrigation system to be assessed must be part of the planning process. It should be recognized that various interest groups involved in irrigation schemes, such as national governments, funding agencies, irrigation bureaucracies, farmer organizations, and individual farmers etc. may have their own set of objectives. These actors have varying degrees of influence on a scheme's performance. Hence, the objectives and values of each party in the scheme need to be understood so as to determine the conflicts, trade-offs, and complementarities between them. Generally it is most appropriate to evaluate the performance of a system in terms of the goals of a variety of constituent groups, since effective performance of the system depends on the active cooperation of the different constituencies.

2 Reconnaissance and rapid appraisal

Reconnaissance and rapid appraisal are used here to refer to preliminary techniques of field data collection and analysis of an irrigation system. This allows the researcher to get information to serve as a means for providing direction for detailed research activity. The goals of the reconnaissance and rapid appraisal phase are to gain a general overview of the particular irrigated agricultural system, and to isolate the major opportunities and constraints that influence effective performance. This phase permits the subsequent phases to be planned according to the realities of the system, rather than presuppositions or guesswork.

In order to gain an overview of an irrigation system one needs to quickly examine all dimensions of the whole system as it operates. This involves looking at the background and current operation to identify both the positive and negative aspects of the system. The objectives of reconnaissance can be attained by quickly acquiring preliminary information about the system. This calls for maximum use of available existing information from all sources, and field level surveys and observations. Useful information could also be obtained by informal conversations with staff and farmers.

Through analysis and synthesis of the preliminary data collected the main issues requiring detailed study will be identified. Analysis and synthesis are sequential activities. First, the system is taken apart in order to look at all its components so as to provide an understanding and areas of major focus. Synthesis indicates a putting together of the various parts so that different relationships can be observed, causes and effects can be discerned, and new insights can be formed. These processes help to identify and separate symptoms from the problems themselves.

Based on the outcome of the reconnaissance, the original general objectives may be refined, the problems may be redefined, questionnaires may be redrafted, and priorities may be reordered. The initial assumptions and hypotheses may also be validated or rejected leading to a restatement of more specific designs based on the realities of the system.

3 Detailed field study

Detailed field studies are designed and implemented to confirm opportunities and constraints in the performance of an irrigation system, particularly those identified in the reconnaissance investigations. Many of the steps and methods within the detailed studies are similar to those of the reconnaissance phase. The principal differences are those of time and depth. Detailed studies are conducted over a longer period of time using formal investigative procedures. The period of detailed studies consists of field investigations, data collection and analysis.

Having clarified the plans and 'zeroed in' on the core issues influencing irrigation performance, the detailed study phase is used to carry out a methodological analysis and quantification of the specific factors based on the initial insights.

One of the vital steps in planning a detailed study is the choice of feasible performance standards and appropriate indicators which are consistent with the system conditions. The identification of areas for detailed assessment and selection of appropriate performance indicators and their measurable variables is a complex process. These also depend on the locality-specific circumstances of the scheme being studied. Thus, the choice of appropriate performance indicators and their measurable variables need to be based on an initial assessment of the objectives of the system and the conditions of the resource base.

Performance standards are the criteria against which the data collected on any particular performance measure can be compared to allow formulation of normative statement about aspects of irrigation performance. These standards may be derived from sources either internal or external to the irrigation system. They may also be relative standards derived from the performance of other similar irrigation schemes. Performance standards and indicators need to be related to the objectives of the system, or its components. For example, the management objectives of water control are often evaluated by analysing the equity, reliability, efficiency, and adequacy of irrigation water supply to farmers. Agricultural productivity is often evaluated by the criteria of yields, cropping intensities, cropped areas, etc.

It must be noted that the variables that need to be measured in order to evaluate chosen performance indicators may be direct or indirect (proxy). Yield performance, for instance, can be evaluated directly by measuring the actual crop yield and comparing with target yield, or yield from other similar systems. Evaluation of equity of water distribution requires the measurement of flow discharges at various points within the system. In situations where data on direct measures are not available, or for variables which are otherwise hard to measure, proxy indicators and variables could be used.

Much has been written on the issue of detailed field data collection and analysis for the purposes of agricultural and irrigation performance monitoring and evaluation **(eg. Casley & Kumar, 1988; Fowler, 1988; Murphy & Sprey, 1982; Tanton, 1987; Brown, 1979; etc.).** Different methods are more suited to varying circumstances. Thus judgement is required on the part of the assessor in identifying the most suitable survey techniques. It is important to stress, however, the need to have a clear idea of the data that is required and the appropriate methods of handling and analysing it.

Data analysis should ideally be an on-going process of evaluation and codification of the information collected throughout the detailed studies. This way the results can be confirmed in the field and any missing information quickly discovered and filled. However, certain circumstances, such as non-availability of computers, may warrant the analysis to be done away from the field.

4 Recommendations and assessment report

Interpretation of results and recommendations for appropriate actions in the form of a report is usually the final phase of a performance assessment. The output of the exercise provides an input to the development of solutions. These include strategies to maintain the level of performance, if it is already satisfactory, or overcome any observed flaws in performance so as to improve it.

If the evaluation reveals that the objectives are not being achieved according to the chosen criteria, then the contributing factors and constraints hindering effective performance need to be identified. This should clearly indicate the order of priority, and separate causes from effects. Recommendations could then be made so that appropriate strategies can be formulated and implemented in order to improve performance of the system. Similarly, where the results of an assessment are adequate and the system is achieving its set objectives, it would also be valuable to identify the factors responsible for the satisfactory performance. This is with the view to sustain the performance and possibly transfer the appropriate strategies and effective measures to other similar systems.

In order to improve irrigation performance, governments and aid agencies often embark on a broad spectrum of programmes. These range from management reorganization and increased farmers participation to complete physical rehabilitation and modernization of irrigation systems. These programmes need to be based on results of performance assessments if they are to treat the real problems rather than the symptoms.

Reports of performance studies should be communicated in a way that can be understood, particularly bearing in mind the audiences for which the findings are intended. These include farmers, managers, researchers, aid agencies, and strategic planning departments and policy makers in government. Even for internal operational monitoring, formal reporting and feedback of information from performance assessment is useful for management decisions, and can also serve as a record to get early warning of any deteriorating conditions.

4.2.3 Data collection and analysis

The many existing approaches used to collect data for performance assessment could broadly be grouped into two types:

- direct measurements, and
- indirect data collection (secondary sources).

Indirect techniques involve the assembly of already existing information which are relevant to a study. This information is usually available from many secondary sources including previous studies, project reports and files, maps, historical documents, statistics, special programmes, books and other written material about the irrigation system.

The direct approach to data collection consist of physical observations, informal discussions, questionnaires, check-lists, direct measurements and monitoring of field actions. Survey methods used for direct data collection require randomization and sampling, key informants, group interviews, direct field measurements and observations, and sometimes laboratory work. The specific techniques used in this study are outlined in Chapter Five (Section 5.3.1).

1 Checklist for data collection

There are many possible starting points in data collection for performance assessment. In addition, the processes of discovery and evolution of ideas are necessarily iterative and may not be all well defined at the start. However, some structure is necessary from the beginning as an aid to memory and reminder of what might be missed.

Checklists are among the most important basic tools used in the collection of information for irrigation performance assessment. Particularly for reconnaissance and rapid appraisal, many researchers find checklists useful, as guides to the data they wish to collect, often from key informants during informal guided interviews.

This study provides a checklist for data collection for performance assessment of medium scale irrigation schemes in Africa with joint management between farmers and irrigation agency. The emphasis is on the evaluation of technical, management and socio-economic issues (see Annexe A1). The data collected through the checklist could be used for documenting and describing the system background, and for analysing the chosen performance indicators.

The checklist presented is divided into four sections:
- Basic general information
- Technical assessment
- Management assessment, and
- Socio-economic assessment.

Section 1 of the checklist provides guidelines for collecting the basic information necessary for describing the background conditions of the irrigation scheme being assessed. These include scheme identity and location, physical environment, historical development, local farming systems, and the demographic and social characteristics of the irrigators.

Section 2 assesses the technical and design characteristics of the physical irrigation infrastructure. This covers the water sources, intake and diversion works, canals and drainage networks, structures, scheme access roads, field levels and extent of environmental problems.

In section 3, the checklist provides guidelines for assessing the organization and management of the irrigation scheme. It assesses the division of responsibilities and roles between the different groups involved in managing the scheme, their organizational structures, management capabilities and motivation of the management personnel and farmers. It also examines the O & M procedures as well as the financial resources available for carrying out these functions.

Finally, section 4 investigates the socio-economic conditions within the rural economy. It concentrates on the assessment of agricultural policy and economic environment, crop production practices, and the quality of agricultural support services. It concludes by giving guidelines for carrying out farm budgets to analyze farmers irrigation incomes and the relative profitability of the various irrigated crops.

2 Data processing and analysis

Data processing and analysis involve the operations of editing, exploratory analysis, coding, statistical analysis, tabulation, collating and interpretation. Editing is intended to detect and eliminate errors in the collected data. This preliminary process could partially be carried out during the field work by checking to expose made up information and removing obvious mistakes from completed forms and questionnaires. Information obtained from secondary sources particularly need scrutiny for accuracy and reliability to extract only the valid relevant portions.

Exploratory analysis seek to reveal the simple structure and patterns in data. This may involve graphical inspection, ordering of data, calculation of measures of location and dispersion, simple transformation of the data to facilitate further analysis, and assessment of the likelihood of linear relations. Tabulation is the process of transferring data from forms into tables in order to allow it to be manipulated. It is also a means for summarizing data and putting it together in a form that can undergo more detailed statistical and other analysis and interpretation.

Coding is necessary in order to put the results of analysis, especially for questionnaires, in quantitative form. During the process of analysis, answers to questions are classified into meaningful categories, so as to bring out their essential patterns. The results of the analysis are then collated and summarized into tables, figures, graphs, and maps, with interpretations provided where necessary.

The data collected from the field work in this study was analyzed using suitable computer techniques. The software used were **Quattro Pro** (Spreadsheet), **Paradox** (Database) and **Statgraphics** (Statistics). Correlation and regression techniques of statistical analysis were found to be very useful in investigating relationships and prioritizing factors limiting irrigation performance. This was particularly effective in revealing the factors that influence crop yields and quantifying the relationships.

The foregoing sections have outlined an approach for performance assessment of medium scale irrigation schemes. This methodology is applied in the following Chapters 5 to 9.

CHAPTER 5: FIELD WORK

This chapter highlights the considerations for scheme selection and provides a brief description of the project studied, and an outline of the work done during the field work. The aims of the field work were to:

- gain an understanding on the operation and performance of a medium scale irrigation scheme in Africa.
- apply and test the analytical approach and performance indicators proposed in this study, and
- provide experience and a basis for refining the proposed approach to performance assessment of irrigation schemes in Africa.

5.1 Scheme Selection

The following factors were considered in the selection of the project as a case study:

- a typical medium scale irrigation scheme (< 1000 ha) in Africa, preferably in the researcher's own country
- a compact scheme suitable for detailed study within the time and resources available
- a scheme with joint management between farmers and an irrigation agency, and
- accessibility to the scheme and availability of logistic support.

The Wurno Irrigation Scheme (WIS) in Nigeria satisfied all of the above criteria. In addition, it was planned for rehabilitation. Thus, it was considered that this study could serve as a baseline analysis for the rehabilitation project. The presence of some EEC experts who were carrying out the rehabilitation also provided logistic support, and an opportunity to share professional ideas. It was also hoped that the possibility of a follow-up study on the scheme could be undertaken to evaluate the impact of the rehabilitation.

5.2 Brief description of the Wurno Irrigation Scheme

5.2.1 Location

The Wurno Irrigation Scheme (WIS) is located in Sokoto State in the north west corner of Nigeria, West Africa. It is situated about 40 km north east of Sokoto, the capital city of the State (Figure 5.1). The scheme lies between latitudes 13° 15' and 13° 20' north of the Equator, and longitudes 5° 25' and 5° 30' east of the Greenwich. It is in the semi-arid region of Nigeria with a Sudan Savannah vegetation. The scheme area is drained by the Rima river to the north and west. It is bounded on the east by the Lugu reservoir, and the escarpment of the Wurno hills of 15 to 30 m height on the south.

5.2.2 Physical Conditions

The climate prevailing around the scheme is characterized by a dry season extending from October to May, and a short but intense rainy season from May/June to the end of September or October. The total mean annual rainfall is about 700 mm, with over 60% of the amount falling within July and August (see Figures 5.2 and 5.3). The annual potential evaporation is about 3000 mm while the altitude varies between 250 to 260 m above sea level. Annual mean temperature is about 30°C, with extreme variations from 10°C to over 40°C. The lowest temperatures occur in December and January, while maximum temperatures occur in April and May. In the dry season, maximum temperatures reach 25 - 35°C during the day, but may fall below 15°C at night. A harmattan wind blows from the north east, often with dust from the Sahara Desert. Relative humidity varies between a minimum of about 10% in February to a maximum of about 90% in August.

The fadama (flood plain) soils in the scheme are of alluvial and hydromorphic types formed on recent riverine deposits. These are generally fertile, deep, gravel free, and comprise mostly of clayey and clay loam textures. There are scattered portions of sandy loam and loam on higher elevations.

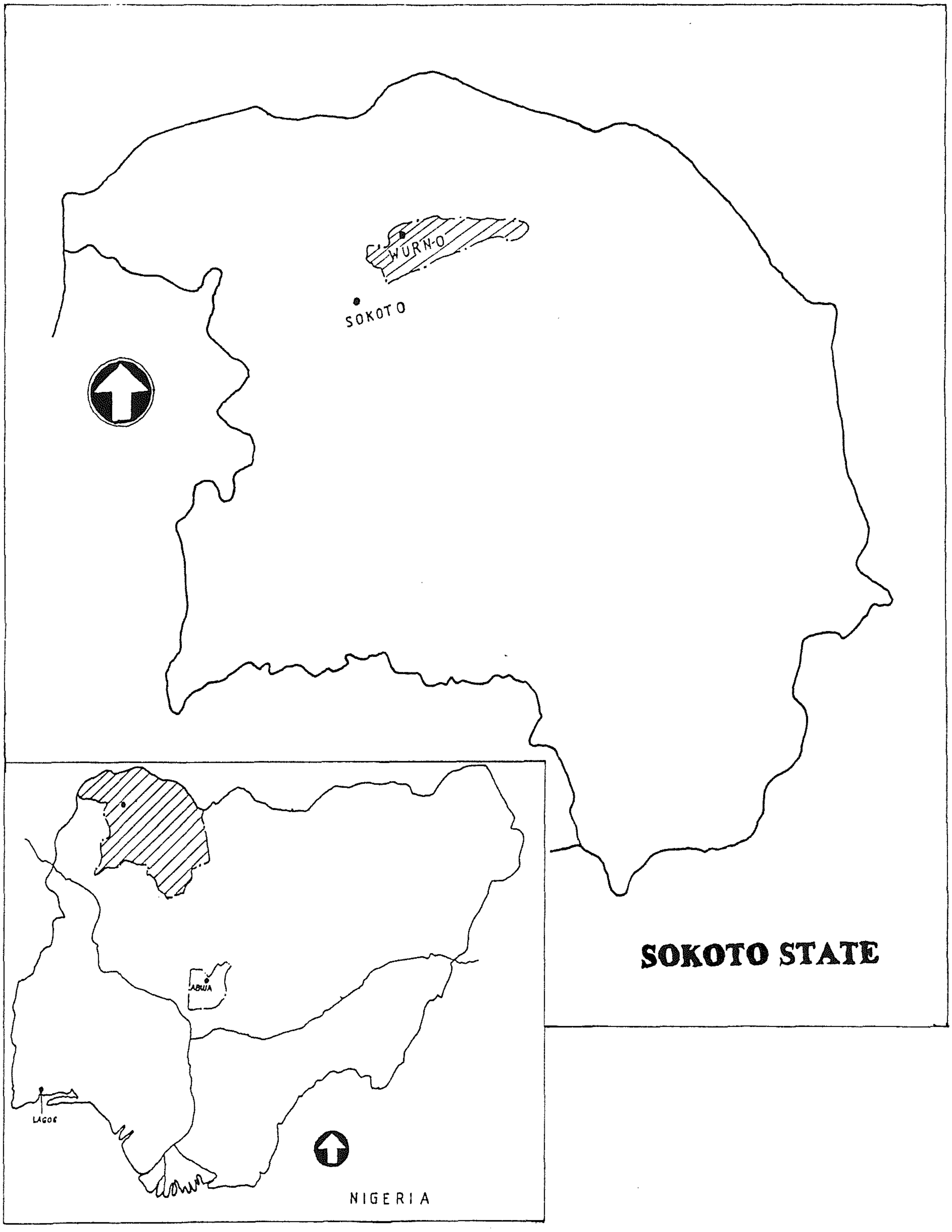

Figure5.1a Map of Sokoto State showing Wurno Local Government Area

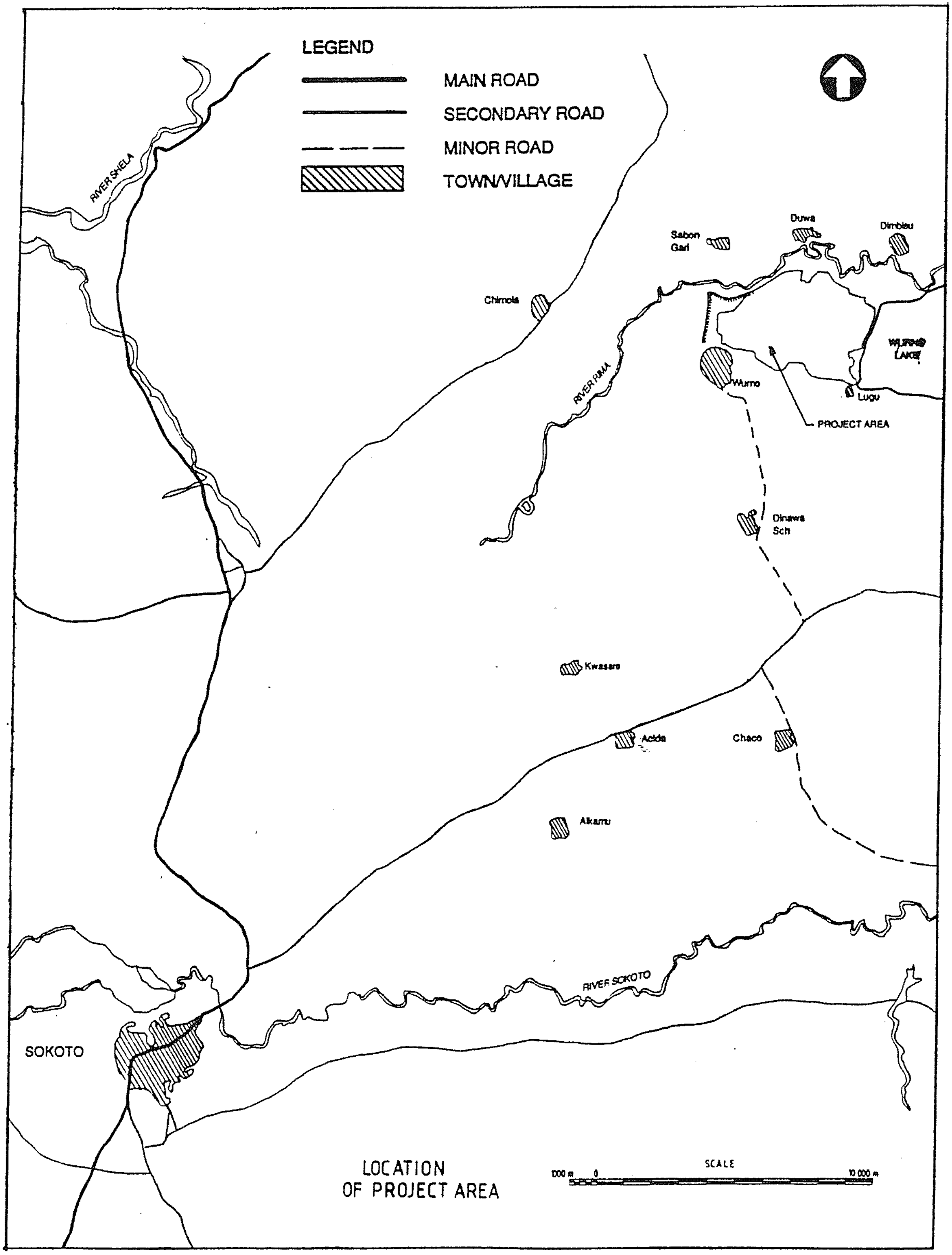

Figure5.1b Location of the Wurno Irrigation Scheme

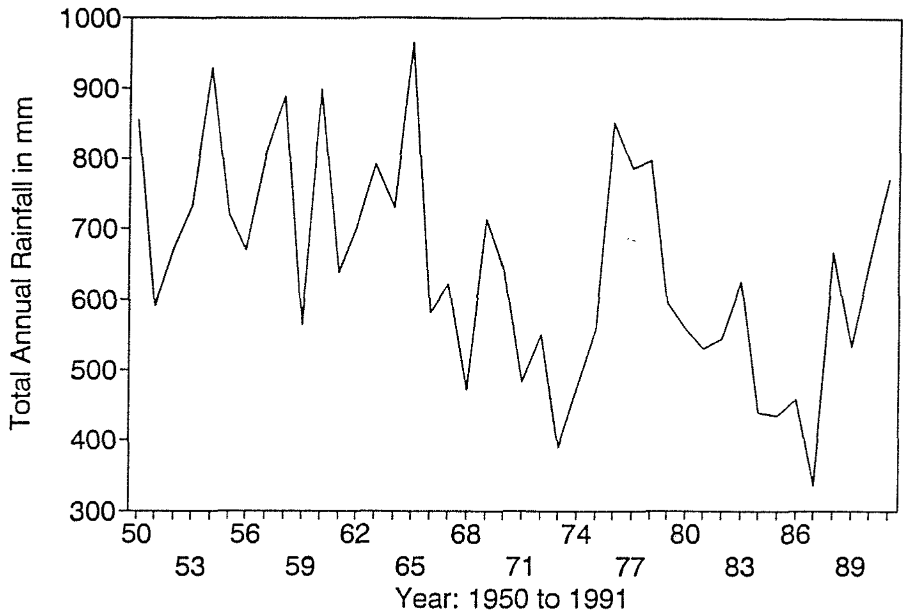

Figure 5.2 Long term total annual rainfall amount for Sokoto, Nigeria (1950 - 1991)

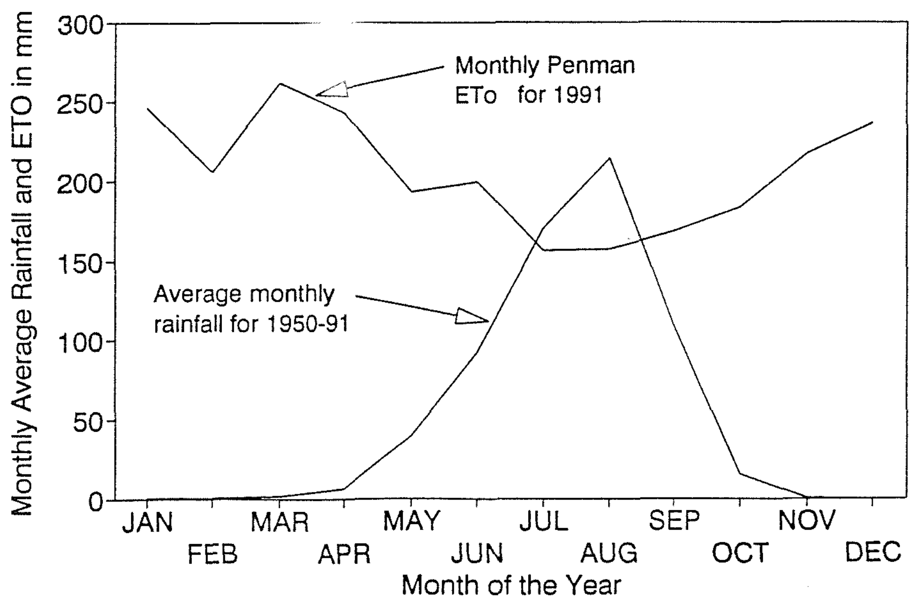

Figure 5.3 Average monthly rainfall amount and potential evapotranspiration for Sokoto, Nigeria

The soils are generally fairly well drained, especially in the dry season. However, the occurrences of cracking clay content have poor vertical drainage, mildly alkaline and thus liable to waterlogging and accumulation of salt deposits. The permeability of the soils is generally slow to moderate (5 - 25 mm/h). The water table in the driest parts of the year is within 1.5 - 4 m to the ground surface. This rises to the soil surface in the wet season when there is frequent rainfall and the water level in the Rima river is high.

The topography within the scheme is generally flat (< 0.2%), but locally slopes can be in excess of 1% or even 2%. The physical conditions make irrigation essential during the dry season if crops are to be grown.

5.3 Outline of work done and evolution of methodology

Before proceeding for the fieldwork, background preparations were made to identify the relevant data to be collected. This was in order to avoid the *'blinding insight syndrome'*- making a new discovery which then preoccupies the researcher resulting in the neglect of aspects of the subject under study **(Howell, 1979)**. However there was also a deliberate flexibility to investigate the real conditions as they were encountered.

Originally the purpose of the fieldwork was to evaluate the actual performance of the selected irrigation scheme using some pre-selected performance indicators and standards. The main focus was intended to be on water management, though various performance indicators were chosen under different sub-systems to reflect the whole system approach. These were:

- Technical
- Economic
- Social, and
- Environmental.

However, experience with the scheme studied proved that the initial approach and standards were not appropriate and too advanced for the selected irrigation scheme. Some of the proposed performance indicators were not applicable to the scheme, and some of the information intended for collection was not available. Generally the problems encountered were of a more basic nature. As a result the study was modified to suit the specific circumstances met. The focus changed to evaluation of the factors found to be most critical to the performance of the scheme as detailed in Chapters 7 to 9.

During reconnaissance field visits to the WIS, it was obvious that there were problems with the design-management interface. Canal capacities were observed to be limited, and blocked by weeds and sediments; breaches and leakages were common sight; structures were damaged or bypassed; embankments were low; etc. Little management or farmers effort was made to operate and maintain the system properly. Informal discussions with farmers and key informants also revealed some unfavourable socio-economic conditions. Thus, there was a need to investigate these issues and quantify their effects on the performance of the scheme, and to find out why things were the way they were. Thus some of the original plans and suppositions had to be modified to suit the actual circumstances.

The experience with application of the existing approaches to performance assessment based on professional bias and a pre-selected agenda of what to cover in an assessment brings into question their versatility. It also challenges our assumptions and priori choices of performance indicators and measurable variables before commencing an assessment. In particular, it is often assumed that water can be acquired, allocated, and distributed within the entire irrigation scheme, and that socio-economic conditions are conducive for farmers to be naturally attracted to applying water for crop production in the most efficient manner.

For instance, in pre-selecting to measure reliability of water supply, which is an indicator that reflects the degree of adherence to irrigation schedules, there is a built-in assumption that water delivery plans are made in advance. In choosing to measure equity and adequacy, it is assumed that structures exist within the scheme, or it is otherwise possible, to measure the distribution of water flows and the amounts of water supplied to various sections of the irrigation scheme, and so on. This study argues that these and such other assumptions are not always true!. There is therefore a need for flexibility in irrigation performance assessments to learn from the situations encountered. This is particularly important in rehabilitation studies where improvement strategies need to target the real issues.

5.3.1 Data collection materials and methods

Both direct and indirect approaches were used in collecting data during the field work. Indirect information was collected from secondary sources. Some of the data was obtained at the project field office and headquarters of the Ministry of Agriculture. Others were acquired from the State History Bureau, SARDA, and Ministry of Lands and Surveys. Finally, the EEC rehabilitation programme also provided very useful information.

Direct information was collected from the field to quantify observations and validate the secondary data. Observations were made during regular walks around the scheme. During these times, visual assessments were made of the conditions of physical structures (canals, drains, control structures, intake structures, weeds, etc.), farmers' operations and irrigation practices. Photographs and slides were taken during these walk-abouts. The direct measurements were done with standard equipment and procedures as outlined below:

1 <u>Discharge measurements.</u>
Attention was given to the measurement of discharges to determine water supply at the main system level. There were no existing network of flow measurement structures within the scheme. Due to the constraints of time, cost and other difficulties new flow measurement structures such as weirs and cut-throat flumes were not installed. A current meter **(Baby Ott type)** was used instead to estimate flow rate in the canal cross sections at various points (Plate 5.1).

Plate 5.1 Measuring discharge in the main canal by current metering

A close observation was also carried out to record the duration and timing of the operation of the main canals on a daily basis. Daily measurements from the current meter were combined with start and stop times of flow to estimate the total daily supply of water into the main system.

2 Crop monitoring and yields.

Information was collected on farming and irrigation practices from a cross section of the farmers in order to obtain an understanding of their farming operations. Crop areas were estimated by directly measuring the cultivated areas for various crops. Although special attention was given to the estimation of crop yields, the farmers practices which affect yield were also monitored including the following:

- Pre-season planning by farmers and irrigation agency
- Land preparation:- techniques, sequence of operations, span, uniformity of land levelling, and timing in relation to rains or irrigation
- Planting:- crop varieties, dates, staggering and timing of planting in relation to rain or irrigation schedule
- Weeding:- number of weedings, timing of each in relation to planting, and use of herbicides
- Fertilisation:- types, rates and timing of applications, availability and costs
- Pest control:- methods and timing of control
- Irrigation practice:- methods, frequency, amounts and timing, irrigation experience and irrigation at night
- Labour:- mechanisation and labour input, hired labour, family labour, animals, labour availability and cost
- Harvest:- timing, methods, and yields
- Transportation of farm produce and storage.

Crop cutting experiments were carried out on a sample of randomly selected farms for determination of wheat yields at harvest time. For each selected farm, its total area was measured and crop cuttings of one square metre were taken at five locations; one at the centre of the field, and one each by walking ten paces up the side of the field from each corner and then ten paces into the field **(Tanton, 1987).** Figure 5.4 shows a sketch of the locations for taking crop-cut samples. These were then threshed and weighed (Plate 5.2). Most farmers estimated their total production in number of bags harvested per unit area. As a result a of sample bagged produce were weighed to determine the average weight (Plate 5.3).

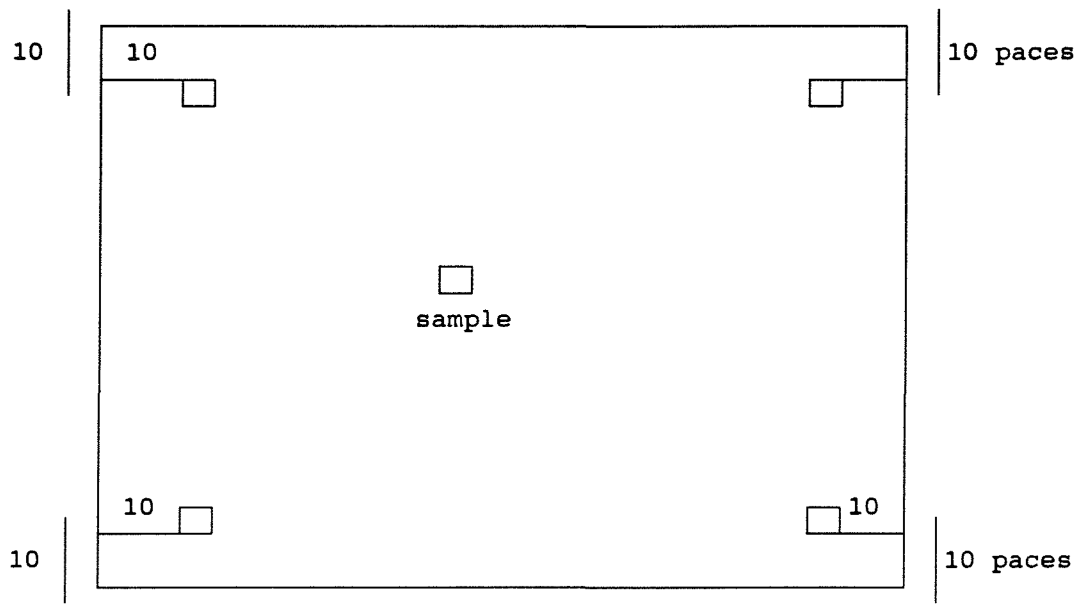

Figure 5.4: Locations for collecting 5 crop cut samples from a field **(After Tanton, 1987).**

3 <u>Soil measurements.</u>

Although it was not possible to carry out a comprehensive soil survey and analyses, reports of previous soil studies conducted in the irrigation scheme were reviewed. Furthermore, observations were done to determine the general nature of the soils; their spatial variability as well as physical problems of soil erosion and waterlogging. Through inspection and interactions with farmers, the problem of salinity was also identified. Salinity was very severe in places, and some areas had even gone out of production as a result.

Plate 5.2 Weighing crop cuts to determine yields

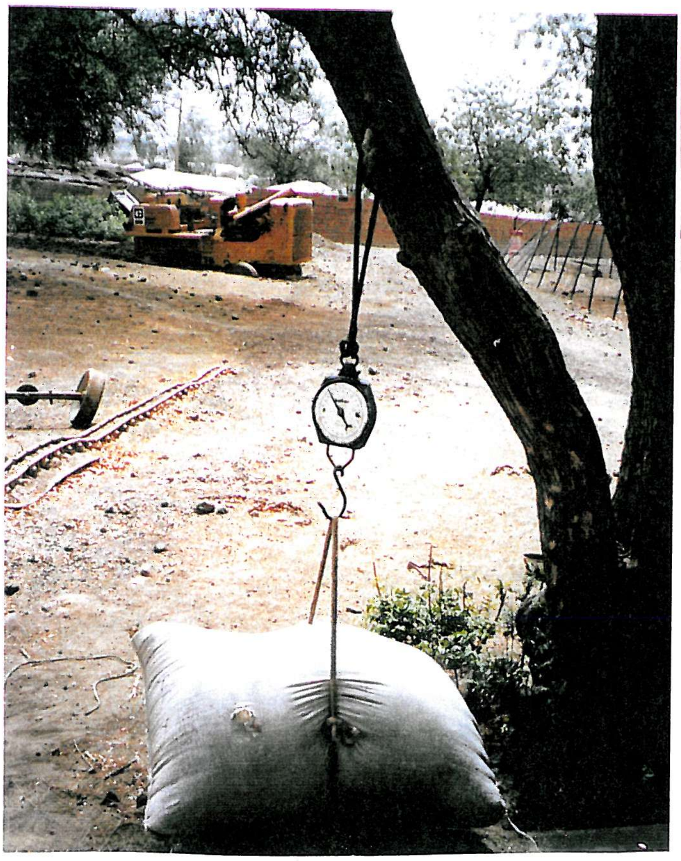

Plate 5.3 Weighing bagged produce

The total area within the scheme affected by salinity in various places was estimated. Random soil samples were then taken for laboratory analyses in three categories:

- severely affected areas
- moderately affected areas, and
- apparently unaffected areas.

A total of eighty (80) soil samples were collected all together from thirty five (35) sites. In the seemingly severely affected areas, three samples were taken at each site in the following horizons:

- surface scrap
- 0 - 15 cm, and
- 15 - 30 cm layers.

For all the other sites, only two samples each were collected in the 0 - 15 cm and 15 - 30 cm layers. These samples were analyzed in the University of Sokoto Soil Science Laboratory for pH, electrical conductivity (EC_s), and chemical exchangeable cations (CEC).

4 <u>Water quality</u>

Water quality was tested directly in the fields for pH and electrical conductivity (EC_w) using portable meters. The evaluation of these parameters was done by dipping the meters in the water at source (reservoir), and at various locations within the system canals and drains. The same procedure was carried out to test the quality of the water in the tube wells and shallow hand dug wells (see Plate 5.4).

5 <u>Ground water levels and water table</u>

Ground water levels were estimated for the dry season using the existing tubewells and hand dug wells. This was done by lowering a staff gauge into the wells to touch the water surface. The distance of the water level to the ground surface was then read on the gauge (see Plate 5.5).

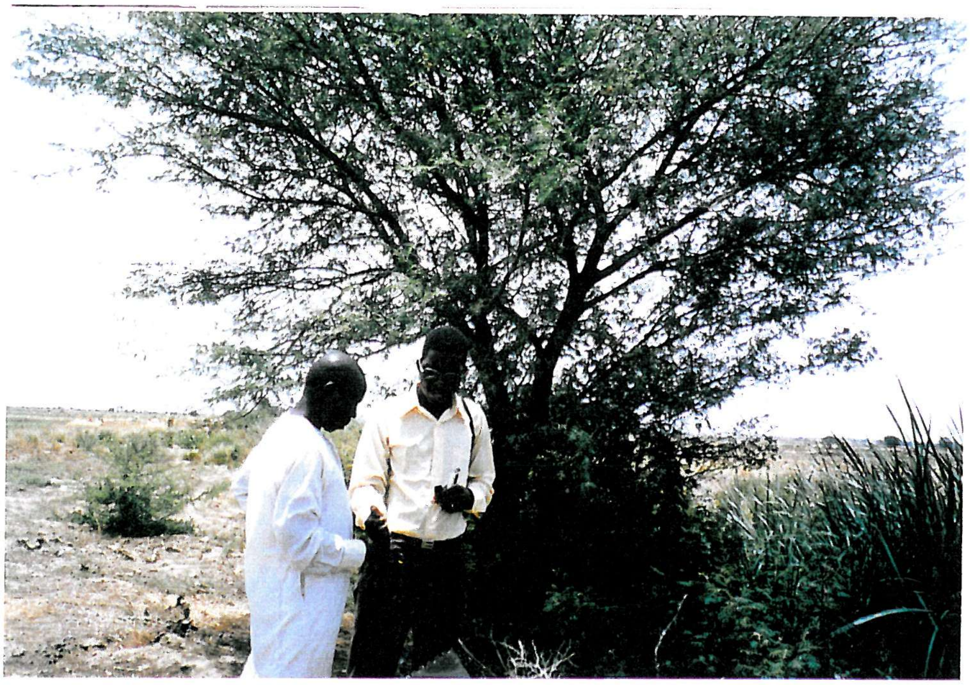

Plate 5.4 Measuring water quality in the field with portable meters

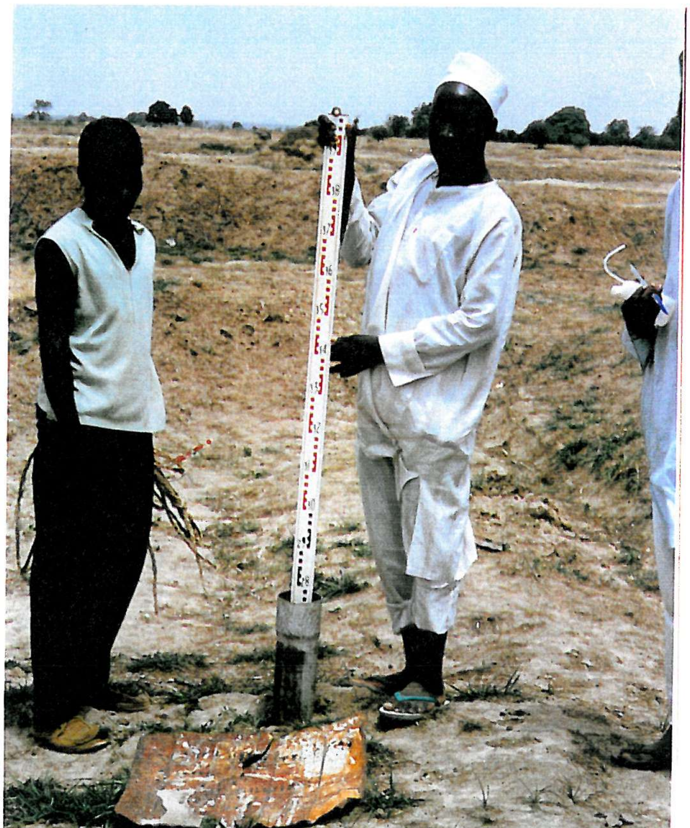

Plate 5.5 Estimating water table in wells

6 Lifting height from canals and drains to field level

Levelling procedures were used to estimate the lifting height from canals and drains to the fields in locations which were not commanded by gravity where farmers had to lift water to their fields. The lifting heights were measured with the use of an Abney hand level and levelling staff (see Plate 5.6).

7 Socio-economic data collection

Socio-economic information was collected from the farmers and other relevant people through structured questionnaires and informal talks. Informal interviews were conducted with irrigation staff at all levels, extension and support services staff, and farmers. The questionnaires were also administered to the same categories of people, but the one for staff was different from that of farmers (Annexes A2-A3).

The questionnaires were designed to obtain information on landholding sizes, cropped areas, planting dates, fertilizer applications, sources of power for farming operations, educational levels, irrigation experience, and other occupations. In addition, questions on farm expenditure, water-use, sources of irrigation water, and farmers' views about the problems and constraints in the performance of the irrigation scheme were included. The farmers interviews were scheduled to follow closely after the harvest of wheat. These were carried out by the author through an interpreter. Use was also made of two enumerators who were trained regarding the details of the questionnaires. However their survey was closely supervised (see Plate 5.7).

Key informants were identified among the farmers, including those who cultivate their plots only during the wet season. Since only a relatively small proportion of farmers actually cultivate their land during the dry season, attempts were made to interview all the dry season farmers. Only about 5% of them could not be interviewed. The random sample of the farmers who cultivate their plots only in the wet season was selected by using the farmers' official register as the sampling frame. Altogether, a total of 146 farmers were interviewed covering dry season activities on 102 ha.

Plate 5.6 Measuring levels in canals and field levels with Abney hand level

Plate 5.7 An enumerator administering questionnaires to farmers

CHAPTER 6: THE WURNO IRRIGATION SCHEME:- BACKGROUND DETAILS.

This Chapter includes brief background information to the Wurno Irrigation Scheme (WIS) which sets the scene for the performance assessment in Chapters 7, 8 and 9.

6.1 System Design Characteristics

1 The Water Supply System

The first phase of the WIS was completed in 1965 by building an earth-fill embankment at Lugu across the Balla creek which flows into the Rima river. The embankment protected the downstream scheme area and received overspills of the Rima river upstream in the wet season, creating a reservoir for dry season irrigation. The inflow during the rainy season into the reservoir was more than the combined irrigation requirements of the crops and maintenance of the maximum designed reservoir level. Thus an un-gated concrete spillway was provided to return excess water into the river. The initial storage reservoir had a total capacity of about 20 Mm^3 (16,000 Acre-Feet) with the embankment about 6 km long.

By 1980 the Rima river had adopted the Balla creek as its primary channel, and the river was then flowing through the Lugu reservoir (see Figure 6.1). The increased flows through the reservoir led to rapid siltation, and problems at the Daje creek, intake structures and canal system. The construction of the Goronyo dam, completed in 1984, about 50 km upstream of Wurno brought further changes in the water supply system. The Goronyo dam with a maximum reservoir volume of 970 million cubic meters (usable volume about 400 Mm^3) now regulates all flows in the Rima river. The dam is intended to supply water to downstream irrigation schemes, including Wurno, and drinking water supply for Sokoto and other towns (Figure 6.2). The total potential irrigable area downstream of the Goronyo dam in various locations is about 10,000 ha with Wurno as the biggest single scheme (1400 ha). The Goronyo dam releases sufficient water back into the river channel for the downstream uses , and all the released flow pass through the Lugu reservoir.

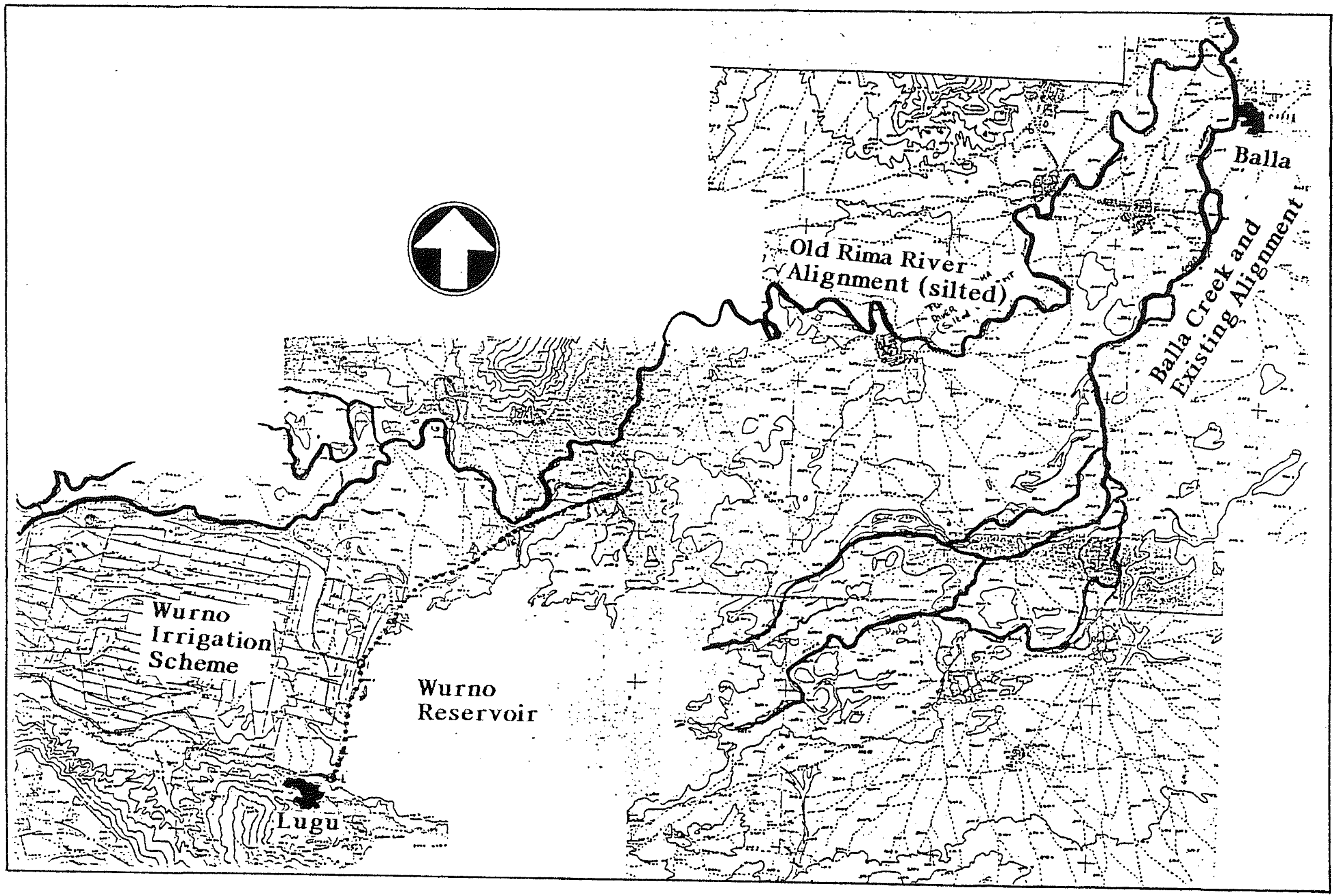

Figure 6.1 Position of the Wurno Irrigation Scheme and reservoir with respect to the Rima river alignment

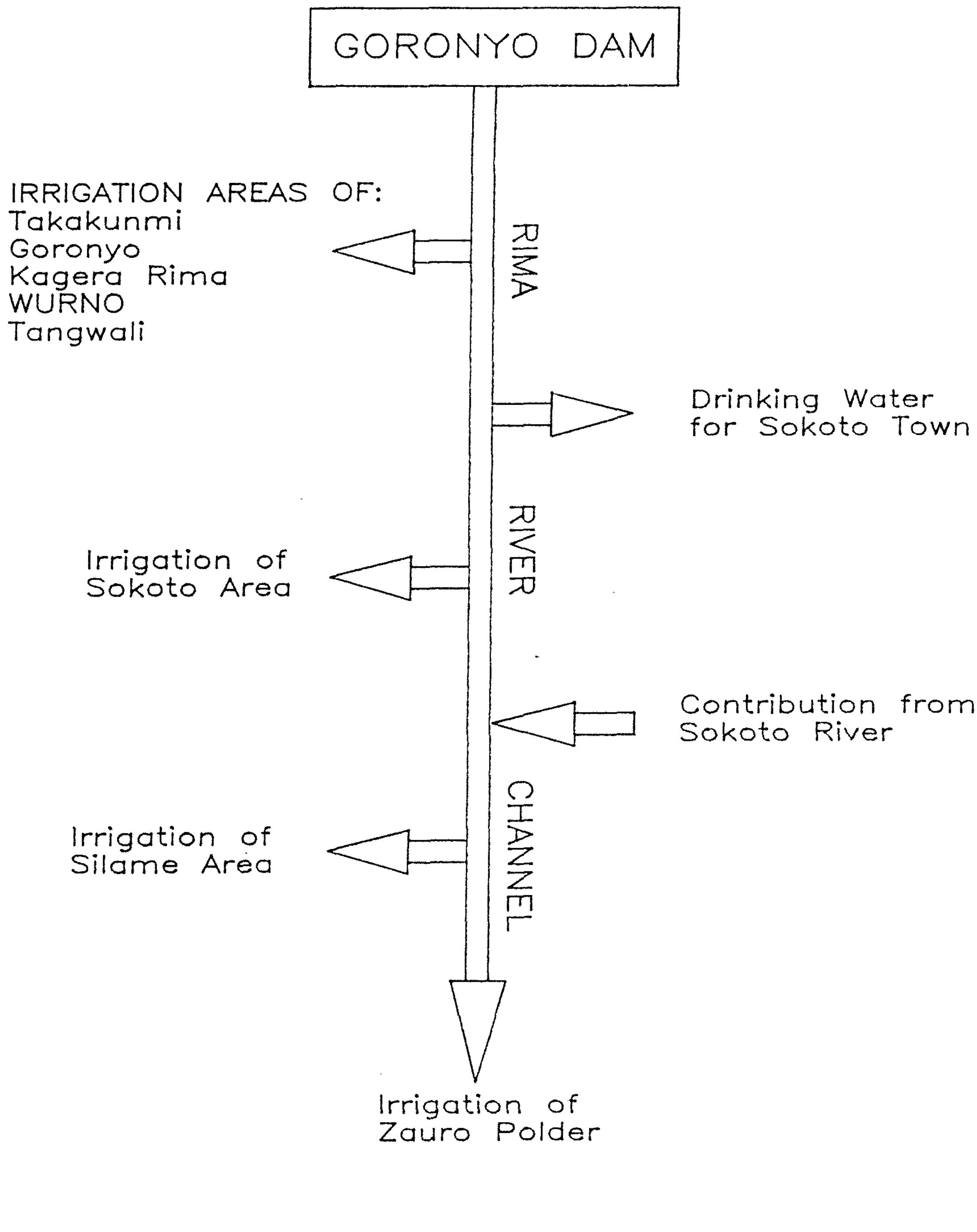

Figure 6.2 The Goronyo Dam Water Supply System

In 1987 a second un-gated gabion spillway was constructed on the Lugu embankment at Daje creek. The Goronyo dam operation plan has not yet been properly defined, but regular normal releases in the dry season for all downstream requirements vary from 10 m^3/s/day up to a maximum of about 250 m^3/s. The maximum discharge that can be spilled from the Goronyo dam is 1,500 m^3/s. This will occur only in the event of the maximum probable flood (1 in 100 years) reaching the completely full reservoir. The two un-gated spillways at Lugu reservoir are capable of passing a combined discharge of about 300 m^3/s.

The continued siltation of the Lugu reservoir (capacity now estimated at less than half original volume), combined with the creation of a year round regulation and supply of water from the Goronyo dam has resulted in the Wurno Irrigation Scheme becoming more or less a run-of-the-river system. The Lugu reservoir serves to maintain the water level, with a minimum supply level equivalent to the lowest crest level of the two spillways, which is about 258.5 m above sea level.

2 Scheme Lay-out and Networks

The Wurno Irrigation Scheme, as developed to date, has a command area of about 780 ha (1930 acres). The maximum potential net irrigable area protected within the scheme is about 1200 ha. The scheme is poldered and protected against floods from the Rima river by an 8.5 km embankment parallel to the alignment of the Rima river to the north and west.

Two unlined main canals: the Lugu and Tutudawa canals, convey water from the reservoir, from which a network of earthen secondary and tertiary canals supply the irrigation blocks and fields (Figure 6.3). The two main canals have a combined length of about 11 km while the secondary canals altogether have a total length of about 15 km. Drainage is accomplished by a network of main and subsidiary drains. A cut-off drain to the south of the scheme collects rainfall run-off from the adjoining upland and escarpment of the Wurno hills. The network of drains, all connected to the main drain, dispose their discharge directly into the river to the west. The main and cut-off drains have a length of about 6.5 km each.

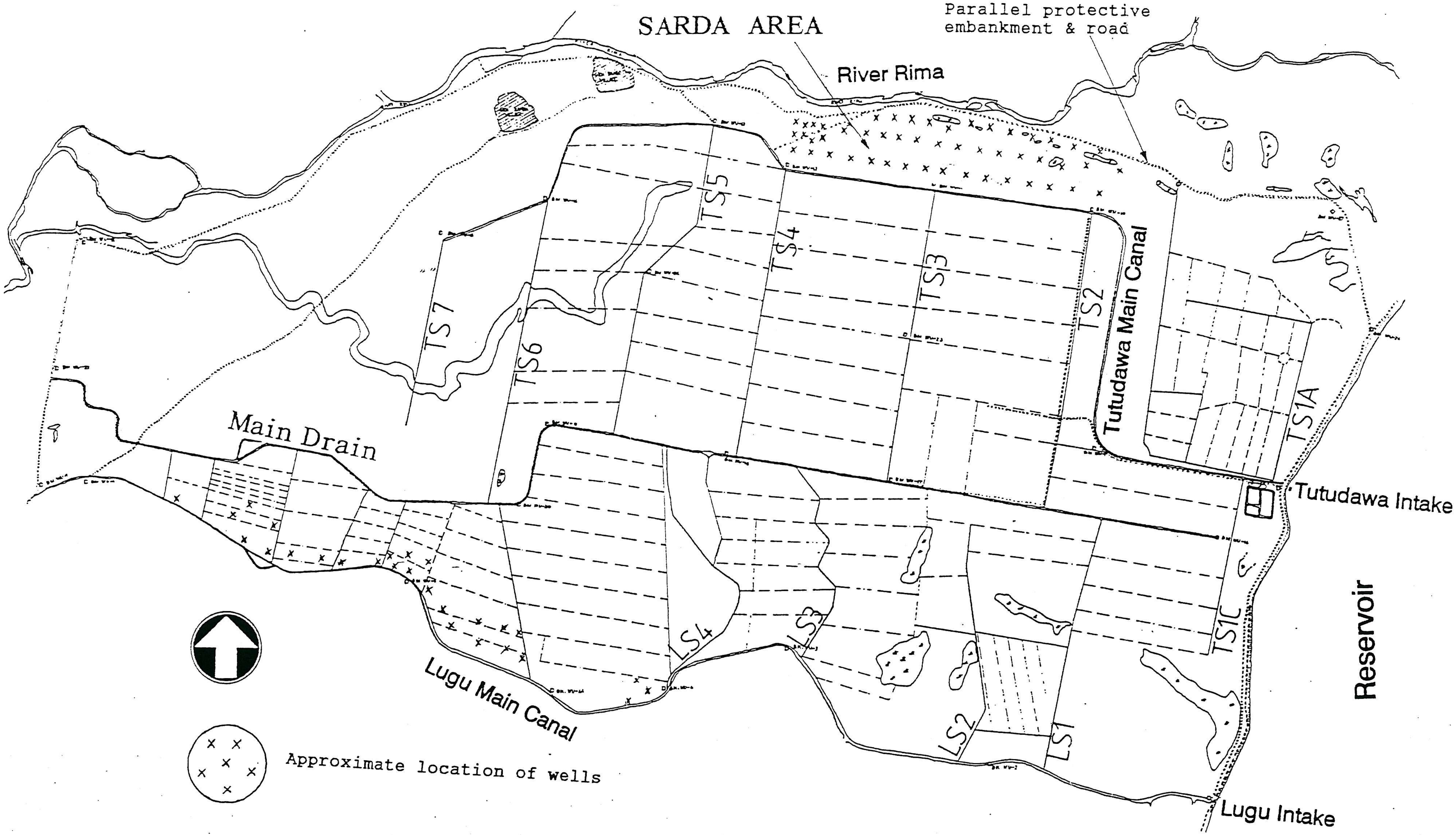

Figure 6.3 Lay-out map of the Wurno irrigation scheme showing the main system and blocks.

There are laterite based perimeter roads around the entire scheme which are used not only by scheme traffic, but also by public traffic. The perimeter road to the south of the scheme runs parallel to and between the Lugu main canal and cut-off drain. In addition, there are access and maintenance roads adjacent to the Tutudawa main canal for most of its length, and between secondary canals and drains. The total length of road works in the scheme amounts to about 30 km.

The two main canals each have two gated culvert intake structures connected to the reservoir. Other control structures in the scheme are mostly canal intakes and culverts. The main drain also has a concrete outlet structure with a slide gate to prevent water entering the scheme from the Rima river during floods. In all, the scheme has about 180 canal and drain structures. The WIS area has been laid out in blocks of various sizes ranging from 2 - 50 acres. Each block is served by a secondary canal and field channels from which farmers take water to their plots. Figure 6.4 presents the schematic lay-out of the scheme showing the main and secondary canals together with the demarcated blocks and areas served. There are a total of 18 secondary canals and 122 blocks serving the developed area.

Although the WIS was intended as a gravity supply system, design, construction and maintenance defects have resulted in some areas being out of command. Consequently, a number of farmers take water direct from the main and secondary canals, or by lifting from canals and drains in order to irrigate their fields. The lifting height in these locations varies from 0.2 - 1.2 m. Pumping also takes place from shallow hand dug and tube wells in locations where canals no longer exist.

6.2 Management and Administration

1 Organizational Structure and Responsibilities

Administratively, all formal small and medium scale schemes in Sokoto State are controlled by the Ministry of Agriculture and Natural Resources **(MANR)**. Thus, the State government is responsible for the development, operation and upkeep of the WIS through the Irrigation Services Department (Figure 6.5).

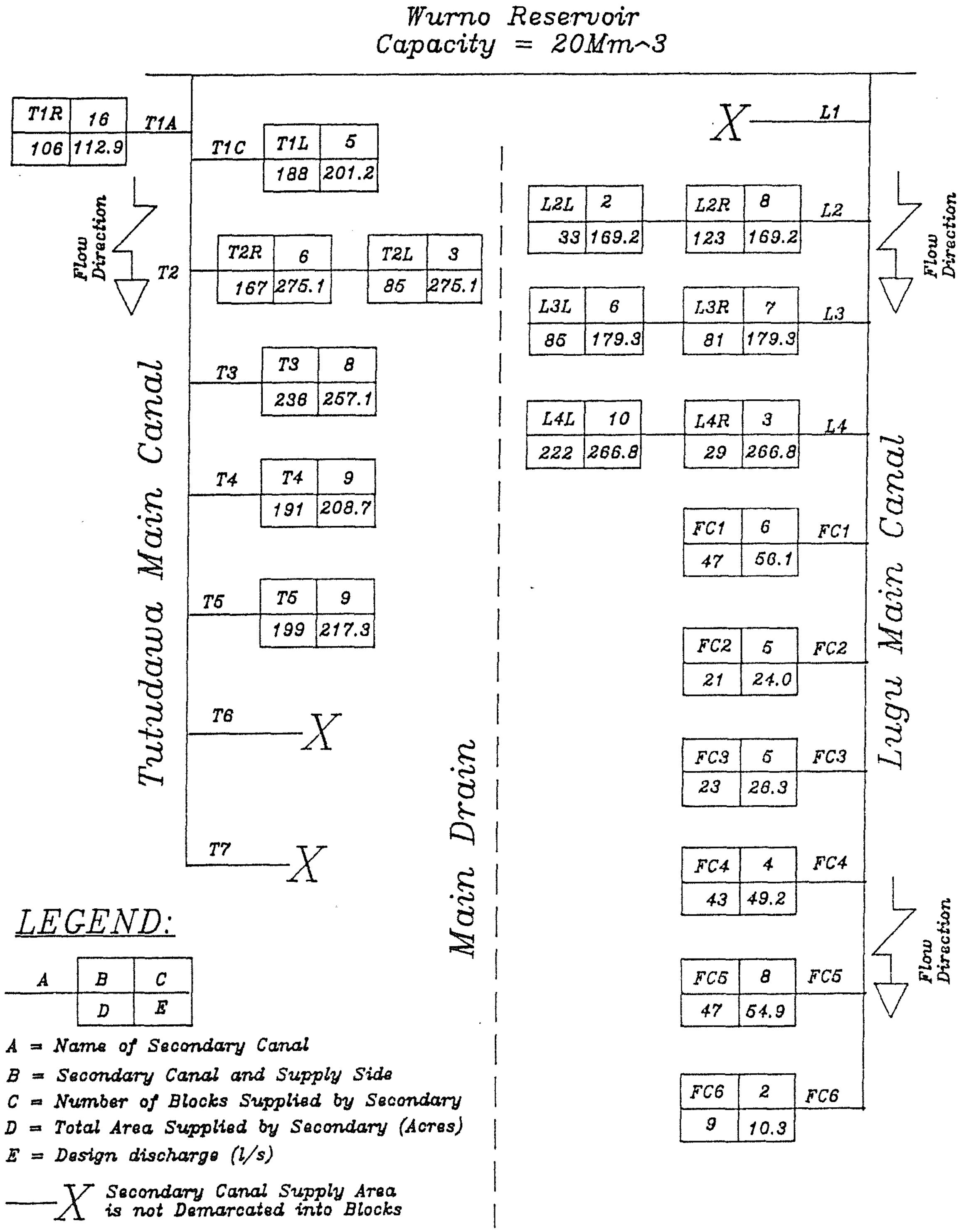

Figure 6.4 Schematic Lay-out of the Wurno Irrigation Scheme

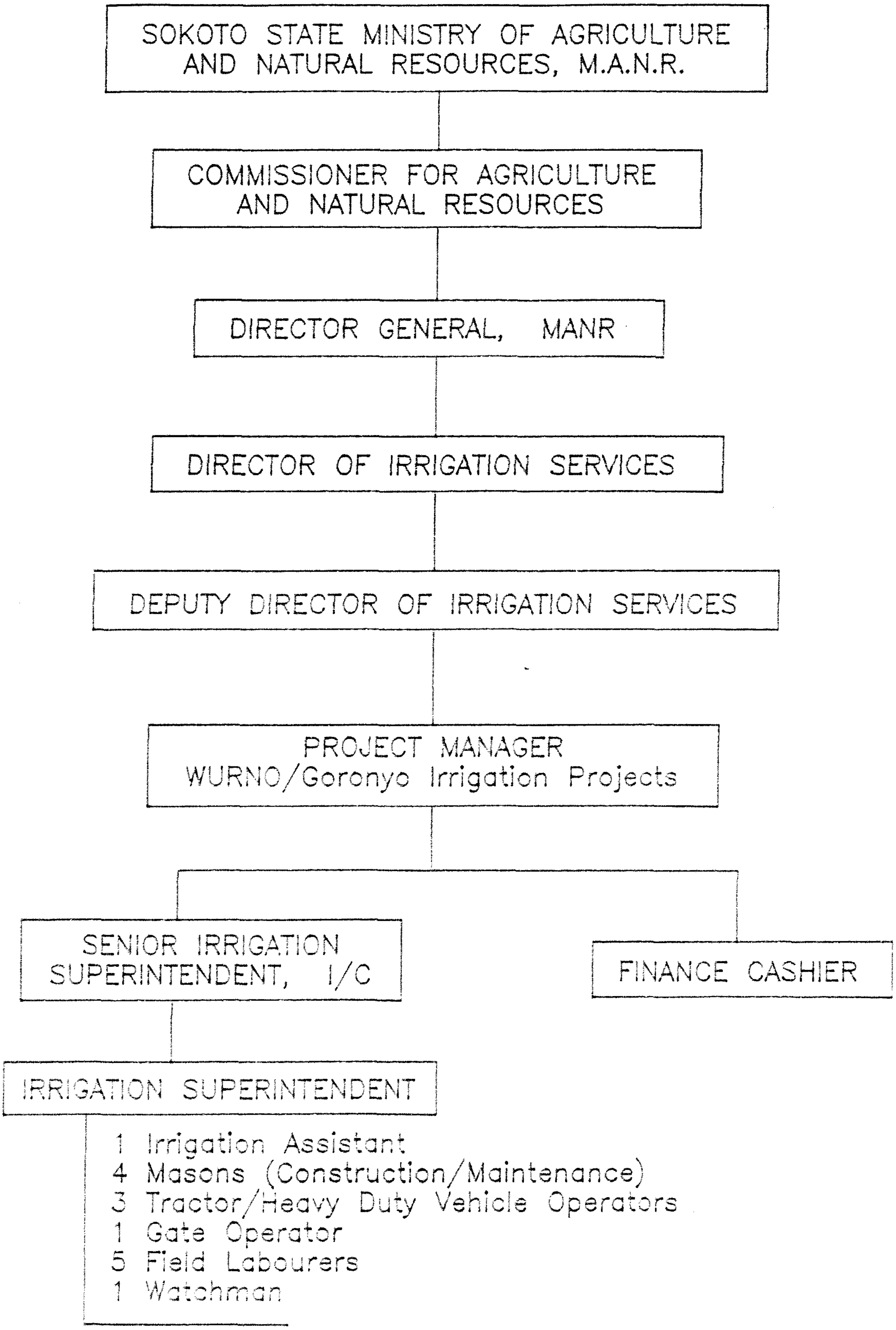

Figure 6.5 Organizational chart for the Operation and Management of the Wurno Irrigation Scheme

Responsibility for the direct management and day to day operations and maintenance of the scheme rests with the Project Manager and his Senior Irrigation Superintendent (i/c) who are the only management staff. The Project Manager, however, also has responsibility for another irrigation scheme, thus making him part-time at Wurno. Only the deputy (i/c) and other staff live full-time at Wurno.

Releasing water into the main canals, minor construction, repairs and routine maintenance of the irrigation facilities are supposedly carried out by the field labourers. However, major works are awarded to local or outside contractors through negotiations with the Headquarters of the Irrigation Division at Sokoto. Altogether the WIS has about 20 staff.

In the late 1970s, a State para-statal extension agency, the Sokoto Agricultural an Rural Development Authority **(SARDA),** was established with responsibility for agricultural advice and supply of farm inputs at subsidized rates for both irrigated and rain-fed crops. The extension agency operates a State-wide network, with a field zonal office at Wurno, and a seed multiplication and demonstration farm within the WIS.

2 Farmers Participation

There are no water users' associations **(WUAs)** in the WIS. Farmers have no land security or water rights, and no official responsibilities. They passively participate in the management and maintenance of the scheme as tenants. The influence of farmers is limited to their allocated plots and the adjoining canals that supply their fields. They work on an individual basis, making their own decisions about cropping patterns, irrigation intervals, and other cultural practices. In the past many informal farmers' groups were said to be quite active in the WIS. The informal groups then, and the few that still remain, are based on hydrological units. Their main function is joint maintenance of the tertiary system that supply their fields. There are no established communication channels between farmers and agency staff. Individual farmers deal direct with scheme officials in making their requests or complaints, and in payment of their water charges.

6.3 Socio-economic Conditions

1 <u>Composition of scheme farmers.</u>

The majority of the farmers in the WIS live in the villages around the scheme, such as Wurno and Lugu. However, use of the scheme is not restricted to local inhabitants as people from distant cities such as Sokoto and other towns also own plots in the scheme. The official farmers' register shows that there are some 600 to 700 plot holders in the scheme.

All absentee plot holders have other forms of employment. There are also civil servants among the farmers who live locally. The local farmers are also engaged in wet season farming and some in other non-irrigated occupations such as petty trading, fishing, crafts, and animal rearing. On the whole, only about 22% of the scheme farming population do not have any other occupations beside farming (Figure 6.6). This must have, at least, an indirect effect on the levels of farmers' commitment and investment in the scheme.

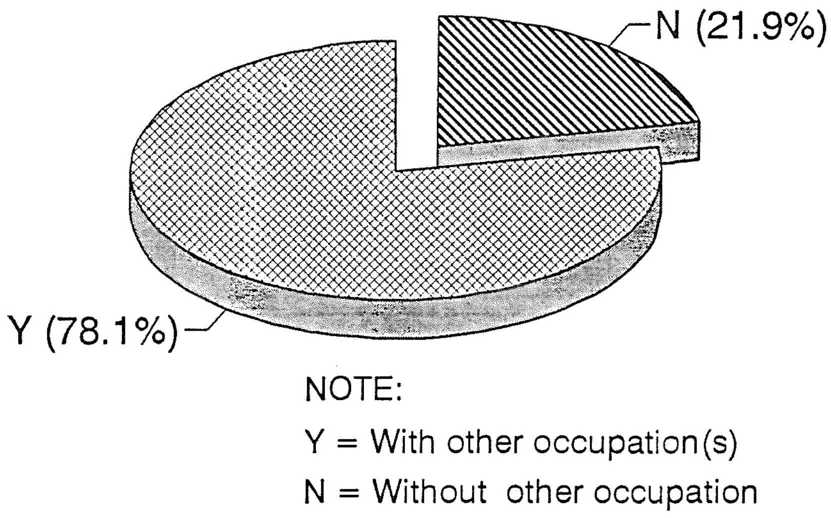

Figure 6.6: Distribution of farmers with and without other occupations.

2 Personal Characteristics

Nearly 100% of the scheme farmers are male. This is because the majority of the inhabitants are Moslems and Islamic laws prohibit women from going out during the day time for any reasons, including work. A few women who were observed in the scheme were widows, working as hired labourers for other men in order to obtain food for their household.

The age distribution of the sample is shown in Figure 6.7. Over 50% of the farmers were over 40 years of age, with the majority within the 41 - 50 years range. This indicates that the younger generations have been keen on taking to irrigated farming. Nearly 70% of the farmers are illiterate (Figure 6.8). Hence the farmers do not keep records.

The farmers irrigation experience and involvement in the scheme varies from 1 to 35 years, with an average of about 14 years (Figure 6.9). The Wurno Irrigation Scheme itself is about 35 years old (as at 1991), indicating that since its inception, new farmers have been joining continuously.

3 Access to the Scheme

There is a tarmac road connecting Sokoto town and the WIS. The road terminates at Wurno and is in the main of poor quality surface, especially the last 10 km which branch off from the main Sokoto - Sabon Birni road. Public transport is infrequent, and vehicle ownership among the farmers is rare.

4 Agricultural Markets

Wurno has a market centre and some farmers sell their surplus produce locally. The Wurno market is particularly noted for rice. Produce merchants and consumers come from Sokoto and even further distances to purchase rice at Wurno. The market for wheat, onions and garlics is not as readily available as that for rice partly because these crops have different consumer characteristics. Wheat, for instance, is not processed and consumed locally, it has to be sold and processed into bread or other forms elsewhere. The production of onion exceeds the local market, and garlic is grown mainly for export from Nigeria as it is not consumed locally.

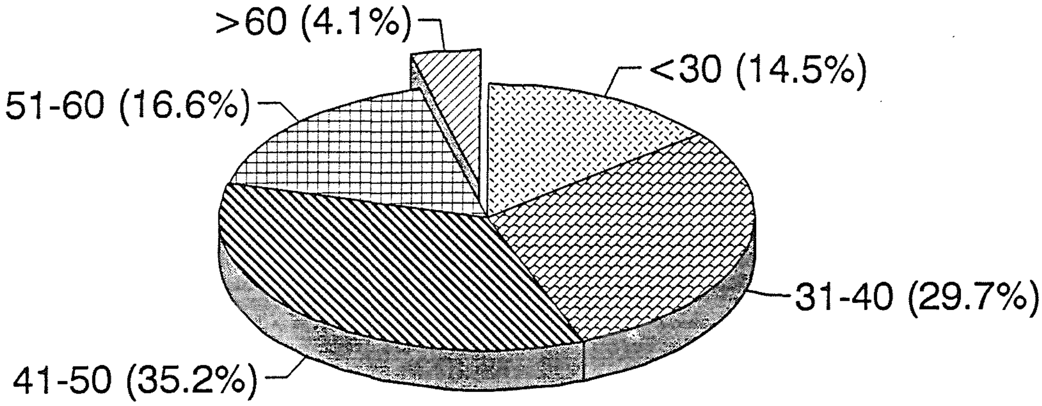

Figure 6.7 Farmers age distribution in years

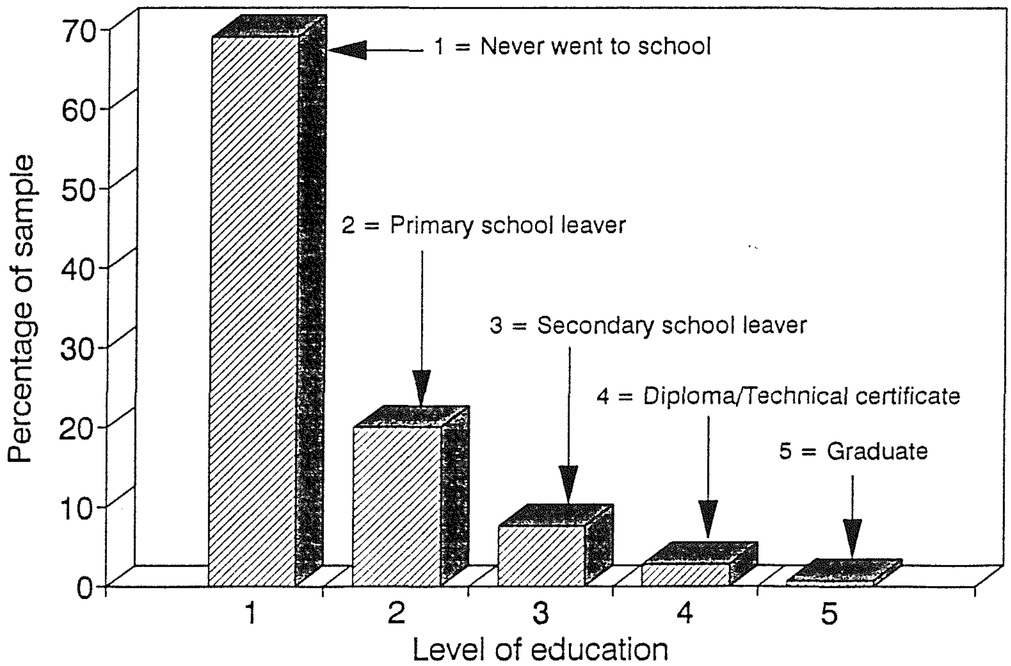

Figure 6.8 Farmers educational level distribution

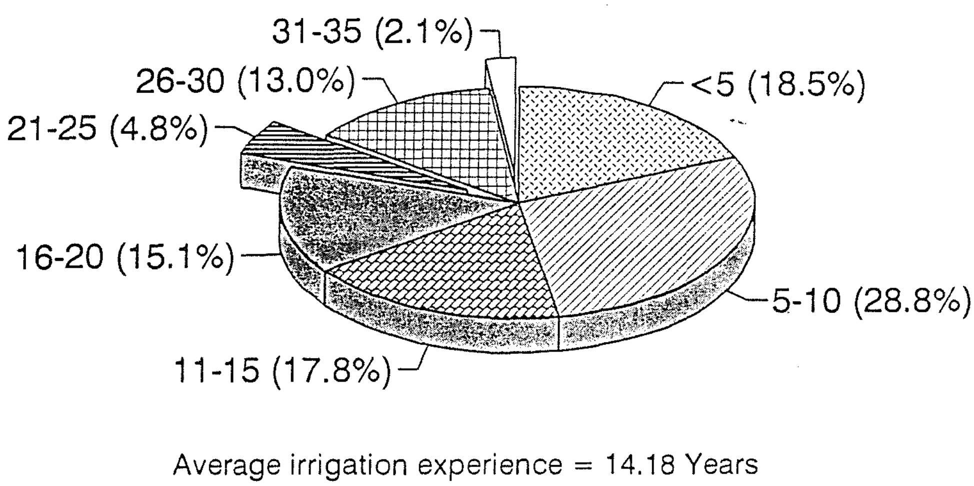

Figure 6.9: Farmers irrigation experience in years

Reports indicate that in the past there were government price, market and other incentives to encourage farmers to grow wheat. These measures were stopped in 1988. Nowadays farmers sell their wheat through a small number of private wheat merchants. As a result of diminishing incentives for growing wheat, farmers are turning to other crops, although wheat is the approved main irrigated crop.

Onion and garlic are also marketed through private channels. Farm-gate prices at harvest were very low at about ₦2,000/t ($100/t) for onion and ₦6,000/t ($300/t) for garlic. The prices skyrocket as high as 2 - 6 times later in the wet season when the crops are not commonly grown. Some farmers were observed attempting storage under local conditions, but they reported storage losses of up to 50%.

5 Cropping Patterns and Cropping Intensity

Rice, which is grown for subsistence and cash, is the main wet season crop in the WIS with a cropping intensity of 70 - 90% of scheme area. The actual total area cultivated to rice in the wet season of any year is more than the scheme developed area. This is because some locations on the periphery of the scheme area are also cultivated.

The actual measured crop areas in the dry season studied and the results from survey suggest that wheat, onion, and garlic were grown in the ratio of 40%, 40%, and 20%, respectively out of the total dry season cultivated area of 120 ha. This represent a cropping intensity of about 15% for the dry season. On the whole, the maximum cropping intensity in the scheme each year is about 100%.

6 Land Tenancy System

Prior to the establishment of the irrigation scheme at Wurno in 1958, the land was owned by the local inhabitants under customary rights. The scheme brought along a change in policy as the land was taken over when it was declared a settlement area in 1959. The customary rights were expropriated and compensated (in reality the compensation has not been paid!). All the land within the scheme now belongs to the government, and is settled under enforceable tenancies. The scheme officials, on behalf of the Land Allocation Committee, have the right to reallocate the plots every season. In practice some influential farmers maintain their plots for many years.

It is not clear what proportion of local inhabitants and outsiders own land in the scheme because the official farmers' register does not contain details of all the plot holders. Some influential absentee plot holders do not appear on the scheme register at all. Reports indicate that many members of the state civil service, military government, and traditional rulers own plots in the scheme, mostly in strategic locations. The majority of the powerful plot-holders cultivate their plots to rice only in the wet season and sublet them to other farmers interested in irrigated cultivation at other times.

In the past there was a policy of allocating a fixed ratio of the scheme developed area to outsiders. In 1975, the quota was 60% of the land for local inhabitants and 40% for residents of Sokoto and other people. **(Minutes of the Wurno Scheme Land Allocation Committee Meeting held in Wurno on the 2nd July, 1975).** By 1981 the land tenure policy in all schemes under the Sokoto State Government was that:

> "90% of the scheme area whether new or old, be allocated to natives and the remaining 10% be acquired by Government on payment of compensation for seed multiplication, demonstration farms, or for allocation to deserving non-natives" **(Sokoto State Government of Nigeria, 'The White Paper on the Report of the Committee on Irrigation Schemes in Sokoto State', 1981).**

This change in policy was as a result of complaints and protests from local farmers about not having enough allocation of land within the scheme. There are reports that previously most of the land at the WIS was allocated to outsiders, especially members of the Sokoto elite. Local farmers protesting about influential outsiders monopolizing land in the scheme were told they could continue as they were, or receive compensation in return for loss of all rights. In addition, they were told that since the Sokoto people had been 'owners' of the main part of the scheme land, they would not obtain many benefits!. It appears that in those days many of the farmers allocated plots on the scheme area were 'fronts' for local rich men, members of the government staff, or Sokoto people **(Palmer-Jones, 1980).** The relationship between local inhabitants and outsiders, and their relative proportions have obvious consequences on scheme performance, as will be discussed later in Chapter 10.

The developed part of the WIS has been laid out in 1 acre (0.4 ha.) units as the basic unit of land allocation. Farmers holdings are in multiples of 1 acre, ranging from 1 to over 10 acres. The largest holding recorded was 30 acres (12 ha.). The majority of the farmers, however, hold less than 5 acres (2 ha.). Figure 6.10 shows the allocation of land holdings with the average of about 4 acres (1.6 ha.).

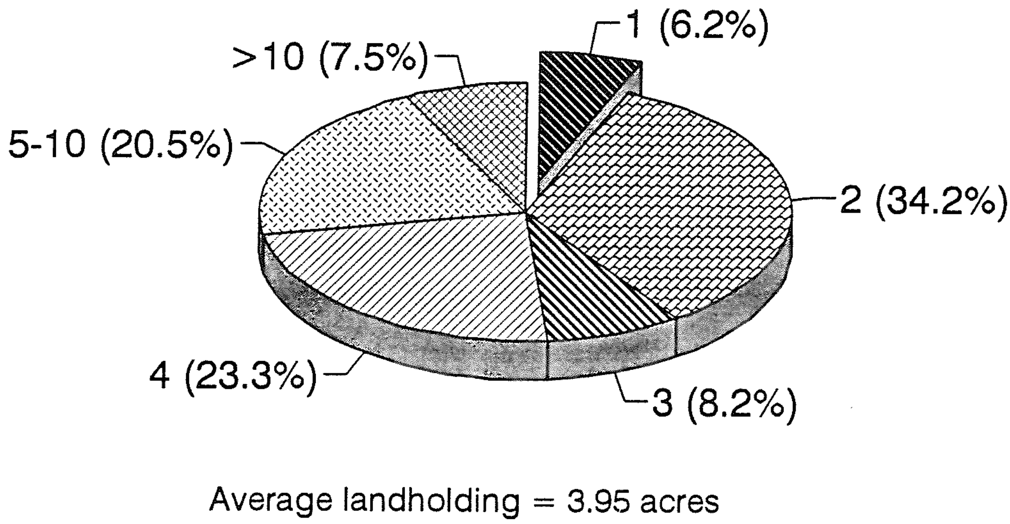

Figure 6.10: Distribution of farmers total landholding size in acres.

7 <u>Labour and Power Sources for Farming Operations</u>

Only a few farmers cited labour as a constraint to production in the scheme. This of course does not imply that labour is in abundant supply. There is potential for competing demands for labour from rain-fed crops, and other vocations. During the irrigation (dry) season farmers often have difficulty in finding sufficient labour for the relatively labour intensive tasks such as weeding, harvesting and threshing. The constraint of labour availability may become even more severe if the dry season cropped area is increased.

It is only the absentee plot holders and those in full-time occupations who depend entirely on hired labour. The majority of local farmers utilize family labour. They use hired labour only as a supplement to family labour for the labour intensive tasks mentioned above. Labour use and power for the major farming operations is presented in Table 6.1. Besides human labour, the only other sources of power were animals and tractors. Animals (camels and donkeys) were used only for transporting materials to the fields, and produce from the farm to the local market or home.

Table 5.1 Percentage use of labour and power sources for principal activities.

ACTIVITIES:	POWER SOURCES: Animals	Family Labour	Hired Labour	Tractor	Family &Hired Labour	Family Labour& Tractor	Hired Labour& Tractor
Plough/Harrow	-	1.4%	10.3%	84.1%	1.4%	2.1%	0.7%
Basins/Ditches	-	29.5%	54.7%	-	15.8%	-	-
Planting	-	19.4%	42.4%	21.5%	12.5%	4.2%	-
Fert. Appln.	-	46.9%	35.2%	-	17.9%	-	-
Irrigation	-	44.4%	46.6%	-	9.0%	-	-
Weeding	-	9.0%	66.2%	-	24.8%	-	-
Harvesting	-	6.9%	75.9%	-	17.2%	-	-
Threshing	-	4.2%	64.8%	12.7%	14.1%	-	4.2%
Transport	58.3%	-	11.8%	14.6%	15.3%	-	-

Tractors are in acute short supply. Ownership of tractors and agricultural equipment among individual farmers is non-existent. The scheme agency has no tractors of their own. As a result farmers depend on tractors from other government agencies and private sources. Some farmers even cultivate with hand implements. This problem is a major constraint to early land preparation, especially for ordinary farmers who find it most difficult to access the few available tractors. The farm activities which require the most use of tractors are ploughing and harrowing.

8 Irrigation Practices

The proportion of farmers obtaining water by the different methods is illustrated in Figure 6.11. About 40% of the scheme has no access to gravity water and has to be irrigated by some form of lifting. Farmers without tertiary canals obtain water from the main canals and secondary canals. There are also a number of wells at the downstream areas of the scheme where the canals are no longer flowing. About 83% of the wells in the scheme are tube wells while the remaining 17% are hand dug wells.

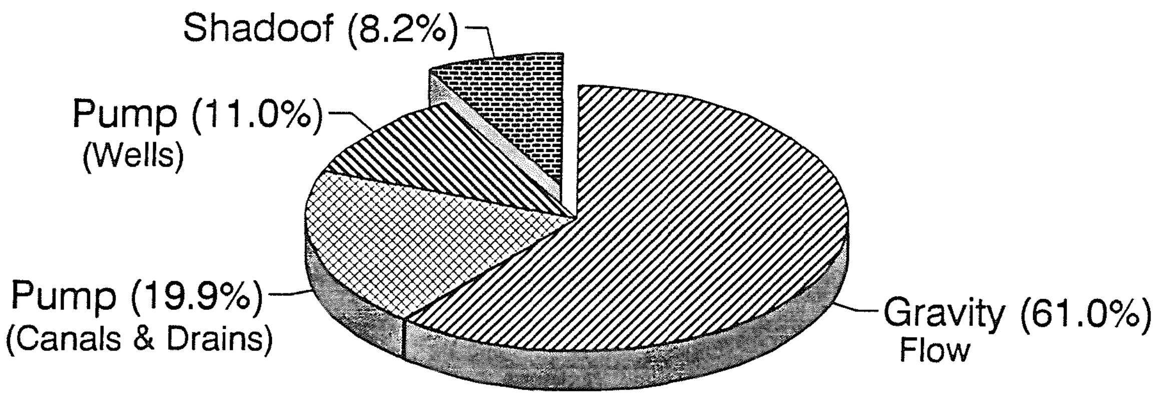

Figure 6.11 Distribution of sources and methods of irrigation water.

The irrigation of rice is not carried out in the normal way. Planting of rice is done by hand, either transplanted, broadcasted, or drilled. The farmers who plant rice early start irrigating by controlled flooding. However, after all the fields are planted and the crops grown to a certain stage, the main drain outlet is closed while the main canals opened almost continuously. This results in the whole scheme being flooded as water backs-up from the main drain outlet to the intakes. Water supply from the main canals is shut off when the crops are matured, and the main drain outlet is then opened to drain the fields for harvest.

Irrigation practices during the dry season are different. The main crops during these season are grown on small basins of about 3 m by 5 m. The crops are then irrigated in the basins in a normal way. It was found that no fixed irrigation schedules exist so farmers irrigate as they wish. On the whole, wheat is generally irrigated once a week, while onion and garlic are irrigated every 2 or 3 days.

CHAPTER 7: ENGINEERING ASSESSMENT

This chapter assesses the potential capability of the WIS main system (primary and secondary canals), and supports the field observations made during the field work. In particular, it seeks to answer the following questions:

- can we get adequate water down the canals to irrigate the proposed command areas at existing conditions?
- are the existing canal water levels at the right command required by the fields they are intended to irrigate?.

7.1 Design and analysis of existing conditions

From preliminary surveys and observation of the existing situation it was obvious that the operation and performance of the WIS was constrained by deficiencies in system capacity and command levels. Since the original designs of the system were not available design calculations had to be done in order to compare the existing conditions with ideal conditions. The following sections describe the procedures used in determining the main system canal capacities and required canal command water levels.

7.1.1 Irrigation and crop water requirements

Irrigation water requirements and canal design capacities were determined from crop water requirements. The sizing of the canals was based on the critical period of peak crop water requirement. It was assumed that if the canals were designed to have adequate capacity to supply the period of peak crop water requirement for the selected cropping pattern, then they would be able to conveniently supply adequate water for all other periods. The determination of crop water requirements was carried out in accordance with standard procedures for the selected cropping pattern.

The cropping pattern used was based on the rehabilitation designs of 1991. That design adopted a cropping pattern of

75% wheat, 15% onions and 10% tomatoes for the dry season, with a total cropping intensity of 90%. A cropping intensity of 100% was assumed for the wet season with the entire scheme cropped to rice and continuous watering for 24 hours per day. The overall cropping intensity for a year was 190% with the critical period for design occurring during the dry season when there is no rainfall.

Crop water requirements were calculated with the use of the FAO agro-climatological tables as the source of potential evapotranspiration **(ETo)** and crop coefficients **(Kc)** for the Penman formula **(Doorenbos & Pruitt, 1977)**. Long term climatological records from Sokoto area were used for the calculation of the Penman potential evapotranspiration, ETo.

It was assumed that within each tertiary unit and throughout the scheme, planting dates for each of the dry season crops would be staggered throughout a 30-day period. This results in the water requirement being the same at all levels of the system network. It also allows farmers to reduce peak labour demands and schedule their activities most economically.

Table 7.1 shows a typical format for crop water requirement calculations of wheat. The full calculations are given in Annexes B1 to B3. Table 7.2 shows the combined crop water requirements for the chosen cropping pattern with overall cropping intensity of 90% in the dry season. The resulting net peak irrigation requirement occurs in the first decade of February with a peak module of **0.801 l/s.ha.**

The net peak water requirement for the dry season was applied to each tertiary unit in a period of 14 hours per day since night irrigation was not practised on the scheme, and 6 days of irrigation per week. The gross peak irrigation demand including losses (gross module) was used for the design of the canal flows and capacities, taking into account water losses in the canals (canal efficiencies).

Table 7.1 Typical format for crop water requirement calculations.

IRRIGATION SEASON	STAGGER DECADE	ETO	ETO	Kc	ETc	PRE-IRRIGATION	RAIN	TOTAL REQUIREMENT	DECADE MODULE	MEAN REQUIREMENT	AVERAGE MODULE
months		mm/d	mm/ decade		mm/ decade	mm/ decade	mm/ decade	mm/ decade	l/s.ha	mm/ decade	l/s.ha
November	i	5.9	59.0		0.0	100		100	1.16		
1 - 10	ii	5.9	59.0		0.0			0	0.00	33.3	0.39
	iii	5.9	59.0		0.0			0	0.00		
11 - 20	i	5.9	59.0	0.43	25.4			25	0.29		
	ii	5.9	59.0		0.0	100		100	1.16	41.8	0.48
	iii	5.9	59.0		0.0			0	0.00		
21 - 30	i	5.9	59.0	0.49	28.9			29	0.34		
	ii	5.9	59.0	0.43	25.4			25	0.29	51.4	0.60
	iii	5.9	59.0		0.0	100		100	1.16		
December	i	5.5	55.0	0.68	37.4			37	0.43		
1 - 10	ii	5.5	55.0	0.49	27.0			27	0.31	29.3	0.34
	iii	5.5	55.0	0.43	23.7			24	0.27		
11 - 20	i	5.5	55.0	0.98	53.9			54	0.63		
	ii	5.5	55.0	0.68	37.4			37	0.43	39.4	0.46
	iii	5.5	55.0	0.49	27.0			27	0.31		
21 - 30	i	5.5	55.0	1.15	63.2			63	0.73		
	ii	5.5	55.0	0.98	53.9			54	0.63	51.5	0.60
	iii	5.5	55.0	0.68	37.4			37	0.43		
January	i	6.2	62.0	1.15	71.3			71	0.83		
1 - 10	ii	6.2	62.0	1.15	71.3			71	0.83	67.8	0.79
	iii	6.2	62.0	0.98	60.8			61	0.70		
11 - 20	i	6.2	62.0	1.15	71.3			71	0.83		
	ii	6.2	62.0	1.15	71.3			71	0.83	71.3	0.83
	iii	6.2	62.0	1.15	71.3			71	0.83		
21 - 30	i	6.2	62.0	1.15	71.3			71	0.83		
	ii	6.2	62.0	1.15	71.3			71	0.83	71.3	0.83
	iii	6.2	62.0	1.15	71.3			71	0.83		
February	i	6.9	69.0	1.05	72.5			72	0.84		
1 - 10	ii	6.9	69.0	1.15	79.4			79	0.92	77.1	0.89
	iii	6.9	69.0	1.15	79.4			79	0.92		
11 - 20	i	6.9	69.0	0.83	57.3			57	0.66		
	ii	6.9	69.0	1.05	72.5			72	0.84	69.7	0.81
	iii	6.9	69.0	1.15	79.4			79	0.92		
21 - 30	i	6.9	69.0	0.59	40.7			41	0.47		
	ii	6.9	69.0	0.83	57.3			57	0.66	56.8	0.66
	iii	6.9	69.0	1.05	72.5			72	0.84		
March	i	7.5	75.0	0.34	25.5			26	0.30		
1 - 10	ii	7.5	75.0	0.59	44.3			44	0.51	44.0	0.51
	iii	7.5	75.0	0.83	62.3			62	0.72		
11 - 20	i	7.5	75.0	0.00	0.0			0	0.00		
	ii	7.5	75.0	0.34	25.5			26	0.30	23.3	0.27
	iii	7.5	75.0	0.59	44.3			44	0.51		
21 - 30	i	7.5	75.0		0.0			0	0.00		
	ii	7.5	75.0	0.00	0.0			0	0.00	8.5	0.10
	iii	7.5	75.0	0.34	25.5			26	0.30		
April	i	7.6	76.0		0.0			0	0.00		
1 - 10	ii	7.6	76.0		0.0			0	0.00	0.0	0.00
	iii	7.6	76.0	0.00	0.0			0	0.00		
11 - 20	i	7.6	76.0		0.0			0	0.00		
	ii	7.6	76.0		0.0			0	0.00	0.0	0.00
	iii	7.6	76.0		0.0			0	0.00		
21 - 30	i	7.6	76.0		0.0			0	0.00		
	ii	7.6	76.0		0.0			0	0.00	0.0	0.00
	iii	7.6	76.0		0.0			0	0.00		

Table 7.2 Combined crop water requirements for a cropping pattern of 75% wheat, 15% onion, and 10% tomato

ROW No.	MONTHS / CROPS	DECADE	CALCULATIONS	NOVEMBER 1	NOVEMBER 2	NOVEMBER 3	DECEMBER 1	DECEMBER 2	DECEMBER 3	JANUARY 1	JANUARY 2	JANUARY 3	FEBRUARY 1	FEBRUARY 2	FEBRUARY 3	MARCH 1	MARCH 2	MARCH 3	APRIL 1	APRIL 2	APRIL 3
	Unit Irrigation Crop Water Requirements (last column from Tables B1 - B3, ANNEX B)																				
	Average Module: (l/s.ha):																				
1	WHEAT			0.39	0.48	0.60	0.34	0.46	0.60	0.79	0.83	0.83	0.89	0.81	0.66	0.51	0.27	0.10	0.00	0.00	0.00
2	ONIONS			0.39	0.48	0.57	0.28	0.34	0.45	0.64	0.72	0.76	0.84	0.82	0.80	0.83	0.77	0.49	0.24	0.00	0.00
3	TOMATO			0.39	0.49	0.59	0.29	0.31	0.37	0.54	0.67	0.78	0.94	0.96	0.96	0.99	0.87	0.72	0.43	0.19	0.00
	Crop Pattern (%):																				
4	WHEAT	75	1*.75	0.29	0.36	0.45	0.26	0.34	0.45	0.59	0.62	0.62	0.67	0.61	0.49	0.38	0.20	0.07	0.00	0.00	0.00
5	ONIONS	15	2*.15	0.06	0.07	0.09	0.04	0.05	0.07	0.10	0.11	0.11	0.13	0.12	0.12	0.12	0.12	0.07	0.04	0.00	0.00
6	TOMATO	10	3*.10	0.04	0.05	0.06	0.03	0.03	0.04	0.05	0.07	0.08	0.09	0.10	0.10	0.10	0.09	0.07	0.04	0.02	0.00
	Total Average Requirement (l/s.ha):																				
7	Sum (l/s.ha)		4+5+6	0.39	0.48	0.59	0.33	0.42	0.55	0.74	0.80	0.81	0.89	0.83	0.71	0.61	0.40	0.22	0.08	0.02	0.00
	Total Requirement for Cropping Intensity of 90%:										90.00										
8	(l/s.ha)		7*.9	0.35	0.44	0.53	0.29	0.38	0.50	0.66	0.72	0.73	0.80	0.74	0.64	0.55	0.36	0.20	0.07	0.02	0.00

9 Net PEAK Requirement (Max. value in Row 8), l/s.ha = 0.801 Occuring in the first decade of February.

7.1.2 Design canal capacities

Main and secondary canal discharges were calculated by summing up the discharges of the tertiary canals which were calculated from the net peak irrigation module itself. Gross tertiary unit irrigation water requirements were calculated as the product of net crop water requirement (l/s.ha) and tertiary unit areas (ha), modified by application and distribution efficiencies, irrigation hours per day and number of irrigation days per week. Application efficiency of 70% and distribution efficiency within the tertiary of 90% were assumed for the scheme. The assumed efficiencies are typical figures used in conventional irrigation design **(Bos & Nugteren, 1974)**, the distribution efficiency being high as a result of relatively short tertiary and quaternary canals.

Main and secondary canal conveyance losses were included in the calculation of gross design canal flows at various levels of the main system. The losses in the secondary canals were estimated at 4% of initial discharge per kilometre canal length, and 5% of initial discharge per kilometre for main canals. The length of secondary canals were quite small, the longest being about 1.4 kilometres. As a result secondary canals were designed with uniform sections to carry their full discharge throughout their entire lengths. Such an arrangement would permit the canals to flow continuously during the irrigation period to supply all downstream tertiary canals at the same time. Alternatively, all of the flow could be given to one or two tertiary canal off-takes on rotation for a share of the time. This design principle also provides adequate capacity for the canals to cope with improper operation upstream, and the discharge of excess storm run-off to the drainage system.

Tertiary canals were similarly assumed to have uniform sections throughout their lengths to permit rotation of all the tertiary flows to one or more farmers for a share of the time. Indeed, observations and recent surveys of the existing system confirm that the original designs also provided secondary and tertiary canals of uniform sections. The primary canals were designed in reaches, with each reach having a uniform section. The downstream discharge in the primary canals was reduced at each secondary canal off-take by the discharge of the off-taking canal.

Discharge at head of tertiary canals was calculated from:

$$Q=\frac{s\times 24\times 7\times A}{h\times d\times E_a\times E_d}$$

where:

s = peak net irrigation water requirement, l/s.ha

A = net area in tertiary unit, ha

E_a = application efficiency, %

E_d = distribution efficiency, %

h = hour of irrigation per day, hrs

d = days of irrigation per week

Discharge at the beginning of a secondary canal was calculated from:

$$Q'=\frac{\Sigma Q_t}{1-e_s\times L}$$

where:

Q' = discharge at head of secondary canal, l/s

Q_t = tertiary unit head flows, l/s

e_s = fraction of secondary canal losses of initial discharge per km of canal length.

L = length of secondary canal

The main canals were designed in sections, with the discharge at the beginning of a stretch calculated from:

$$Q'=\frac{Q}{1-e_m\times L}$$

where:

Q' = discharge at beginning of the canal section, l/s

Q = required discharge at the end of canal section, l/s

L = length of main canal section, km

e_m= fraction of main canal losses of initial discharge per km.

The values used in the calculations were as follows:

Peak net module, s = 0.801 l/s.ha

Application efficiency, $E_a = 70\%$
Distribution efficiency, $E_d = 90\%$
Irrigation hours per day, $h = 14$
Irrigation days per week, $d = 6$
Secondary canal loses per km, $e_s = 4\%$
Main canal losses per km, $e_m = 5\%$

Table 7.3 gives a summary of the design gross capacities for the different reaches of the primary canals and their respective secondary canals. The complete schedule for computation of the canal design discharges is given in Annexe C1. These calculations result in scheme overall efficiency of 50% at the main canal intakes. Again this is reasonable figure for such a scheme.

7.1.3 Command and design water levels

"Command" is defined as the difference in elevation between canal water surface and the adjacent ground level which the canal is intended to irrigate. For all gravity irrigation systems the command must be positive and adequate to ensure the desired flow of water from the canal onto the land. Inadequate command would prevent or severely curtail the transfer of water from the canal system onto the land.

Design command requirements for the WIS were determined using 1991 contour maps superimposed on the scheme canal layout. The calculations were done from the field ground level, back through the system to all secondary and primary canal off-take points, up to the reservoir intakes. The resultant command levels on the main system canals were plotted and lines fitted to form the design water levels (DWL).

On inspection of the tertiary units it was found that if the head fields were commanded it would be possible to command all downstream fields supplied by that tertiary. This was due to the alignment of the canals relative to the contours. Hence the command levels on the secondary canals at the tertiary off-take points were determined from the head fields to be irrigated.

Table 7.3: Summary of main system canal design discharges

Canal Name	Canal Section	Canal/Section Length	Cumulative Downstream Area	Design Gross Head Flow
		m	ha	l/s
LUGU	Intake - LS1	436	359.1	1207.8
PRIMARY	LS1 - LS2	814	309.1	1040.2
CANAL	LS2 - LS3	958	245.5	828.6
	LS3 - LS4	692	177.3	584.8
LUGU SECONDARY CANALS:				
LS1	Whole length	-	50	141.3
LS2	Whole length	1122	63.6	169.2
LS3	Whole length	825	68.2	179.3
LS4	Whole length	1362	99.2	266.8
FC1	Whole length	-	19.8	56.1
FC2	Whole length	-	8.5	24
FC3	Whole length	-	9.3	26.3
FC4	Whole length	-	17.4	49.2
FC5	Whole length	-	19.4	54.9
FC6	Whole length	-	3.6	10.3
TUTUDAWA	Intake - TS1A	66	568.7	1820.5
PRIMARY	TS1A - TS1C	136	526.2	1701.6
CANAL	TS1C - TS2	1873	449.7	1488.8
	TS2 - TS3	733	346	1074.2
	TS3 - TS4	684	268.3	777.8
	TS4 - TS5	418	190.6	542.5
	TS5 - TS6	1285	110	313.9
	TS6 - TS7	525	50	134.5
TUTUDAWA SECONDARY CANALS:				
TS1A	Whole length	1072	42.5	112.9
TS1C	Whole length	829	76.5	201.2
TS2	Whole length	1050	103.6	275.1
TS3	Whole length	1375	95.5	257.1
TS4	Whole length	1319	77.7	208.7
TS5	Whole length	1425	80.6	217.3
TS6	Whole length	1050	60	159.3
TS7	Whole length	729	50	130.9

NOTE: LS* = Lugu secondary canal number *
TS* = Tutudawa secondary canal number *

The following typical command requirements and representative head losses were used, assuming free flow conditions:

Required depth of ponded water in fields:	0.15m
Surface water slope in field canals:	1 in 5000 (20 cm/km)
Head loss, field canal to field:	0.10m
Head loss, tertiary canal to field outlet:	0.15m
Head loss, secondary canal to tertiary outlet:	0.15m
Head loss, primary to secondary outlet:	0.25m

The estimated command levels at the off-take points on the main system canals were not always compatible. In some cases adjustments were made, within acceptable levels of command tolerance, by either accepting a slightly higher or lower command level at the field itself, and/or by varying the water surface slope in the canals to permit the desired command level to be achieved. In cases where drops were required they were made to occur at locations of off-takes. The typical design command water levels on a longitudinal canal section are shown in Figure 7.1 together with the actual possible water levels.

7.2 Existing canal capacities and actual water levels.

The 1991 survey data of the existing primary and secondary canals was used to plot cross and longitudinal sections in order to determine the existing canal capacities by a theoretical procedure. A practical approach for determining the maximum capacity of an existing canal could be to pass an increasing amount of water down the canal. The discharge at which overtopping of the canal banks starts to occur could then be measured as the maximum the canal can carry. Unfortunately it was not possible to use this procedure in the WIS during the field work due to logistical problems, lack of control, and potential damage to crops. Theoretical numeric procedures as described below were therefore used.

The longitudinal profiles for all the surveyed main and secondary canals were drawn comprising of actual bed levels **(ABL)**, minimum bank top levels **(MBTL)**, and adjacent natural ground levels **(ANGL)** as shown in Annexe C2.

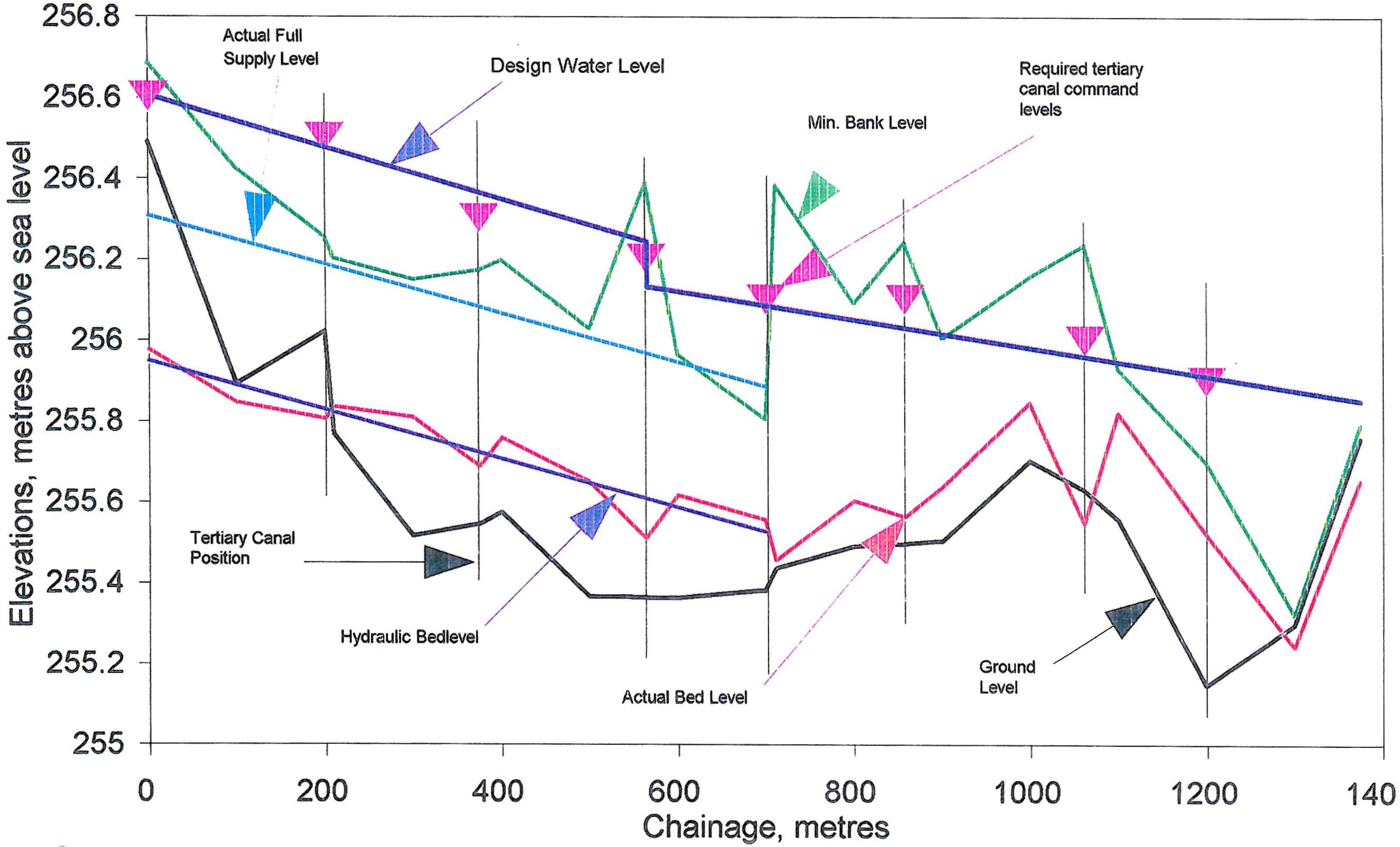

Figure 7.1 Typical design and existing canal water levels in the Wurno Irrigation Scheme (Tutudawa Secondary Canal TS3)

No empirical data was available to define the hydraulic grade lines of the flow water surface in the canals. Consequently regression analysis was used to determine the general slopes of the canal actual bed levels and adjacent natural ground levels by evaluating the lines-of-best-fit. This enabled a comparison to be made between the canal bed slope and the natural ground slope for each canal. Regression analysis was used to define the slopes in order to standardize and obtain the best slope, instead of estimating the grade lines by eye.

The regression lines for the natural ground levels were drawn for the entire length of each canal. However for the actual canal bed levels, the lines were drawn only within the limits of the initial stretches to which water could still flow by gravity. These limits were set from inspection during the field work by the extent to which water was seen to reach. For the secondary canals where actual water flow limits were not observed, the limits were determined from the shapes of the lines of the actual canal bed levels. The gravity flow of water was assumed to stop at points where a sudden rise in bed level occurred on the longitudinal section. The regression lines through the actual bed levels were assumed to represent approximately the hydraulic gradient of the canals, and the slopes taken as equivalent to the canal flow water surface slope **(S)**. Hence these lines were termed the 'hydraulic bed level' lines **(HBL)**.

Table 7.4 shows the total length for each of the main system canals and the limits to which gravity water could still flow. It also shows the proportion of non-irrigable areas behind each canal as a result of flow restrictions in the canal lengths. It can be observed that only the secondary canal **LS2** could still flow for its entire length. But this secondary canal was not in use because its command area was completely waterlogged. It should be noted that the non-irrigable areas shown in Table 7.4 do not reveal the whole picture as even within the lengths of primary and secondary canals where water was still flowing, some areas within the tertiary units could not be irrigated by gravity due to the absence of tertiary canals and low command.

Table 7.4 Flow possibilities of existing main system canals, Wurno Irrigation Scheme, March 1992

CANAL NAME	LENGTHS			AREAS		
	Design Flow Length	Actual Flow Length	Actual/ Design Length	Original Designed Irrigable Area	Current Irrigable Area	Current/ Original Irrigable Area
	km	km	%	ha	ha	%
L-PC	4.725	3.4	72.0	359.1	281.0	78.2
LS1	Was never constructed			50.0	-	-
LS2	1.122	1.0	89.1	63.6	63.6	100.0
LS3	0.825	0.6	72.7	68.2	56.6	82.9
LS4	1.362	1.0	73.4	99.2	64.0	64.5
TT-PC	5.720	3.8	66.4	568.7	378.1	66.5
TS1A	1.072	0.7	65.3	42.5	17.3	40.7
TS1C	0.829	0.3	37.4	76.5	25.1	32.8
TS2	1.050	0.6	57.1	103.6	45.6	44.0
TS3	1.375	0.7	50.9	95.5	36.3	38.0
TS4	1.319	0.3	22.7	77.7	8.9	11.5
TS5	1.425	0.0	0.0	80.6	0.0	0.0
TS6	1.050	0.0	0.0	60.0	0.0	0.0
TS7	0.725	0.0	0.0	50.0	0.0	0.0
TOTALS =	22.599	12.4	54.9	867.4	317.4	36.6

NOTE: L-PC = Lugu primary canal
TT-PC = Tutudawa primary canal
LS* = Lugu secondary canal number *
TS* = Tutudawa secondary canal number *
Gross area downstream a primary canal = Sum of its secondary canal areas.

The extent of canals in which water can flow are also shown in Figure 10.1

For simplicity, steady uniform flow conditions were assumed within all the canals. The normal depth of flow, water area, velocity, and discharge at every section of the channel reach were assumed to be constant within each main canal reach, and throughout secondary canals. Hence the water surface and energy line were assumed to be parallel to the 'hydraulic bed level' and their slopes considered as equal.

In practice the channel cross sections were not uniform, the bed levels were particularly irregular along the canal length (see Figures 7.2 - 7.3 and Plates 7.1 - 7.2). However, it was assumed that such canal irregularities would only result in some 'dead water' at some points while the flow water area, hydraulic bed slope and average flow velocity would remain constant. It was further assumed that channel obstructions and actual bed levels higher than 'hydraulic bed level' would only result in 'local phenomena' and increased velocities at such points without 'tail water effects.'

These assumptions were deemed valid because no structures existed within the scheme canal network apart from simple off-take structures and culverts. Moreover most of the existing structures were not functional. Hence there were no back water effect as a result of canal structures. The flow of water throughout the scheme canal network was free, and controlled only by the force of gravity.

Canal bed widths were selected based on the existing cross sections and canal side slopes (z) taken as 1.5 : 1. The Manning's roughness coefficient (n) was chosen to be 0.035 in accordance with the existing canal vegetation conditions (see Plate 7.2). From these parameters the maximum possible canal flow capacities, normal depth, and water surface levels of the existing canals were determined using the Manning's equation through an iterative procedure such that the full supply level (FSL) would not overspill the canal banks. The full supply levels were calculated at each point as the sum of the hydraulic bed level and normal flow depth.

Plate 7.1 Typical conditions of canal banks

Plate 7.2 Typical vegetation condition in main canals

The Newton-Raphson method was used to solve the Manning's equation for normal depth employing a spreadsheet programme **(D.C. Clarke, 1992)**. The programme accepts flow rate, canal slope, Manning's coefficient, canal side slopes, bed width and freeboard as input data, and calculates the normal depth and flow velocity after ten iterations (see Annexe D).

For every canal, an initial guess was made of the maximum possible discharge. The corresponding normal depth and full supply levels were then computed using the spreadsheet. If the guessed discharge resulted in the full supply level being above minimum bank top level at any point within the reach in consideration, the discharge was reduced and the procedure repeated until it resulted in the full supply level being at or below the minimum bank top level throughout the canal reach. That discharge was then considered as the maximum possible discharge for the canal reach. Along the main canals, the maximum discharge in any reach was reduced at the points of secondary canal off-takes by the maximum possible discharge of the off-taking secondary canals. This resulted in a drop in the downstream discharge and the corresponding normal flow depth and full supply levels. The computation schedule for the full supply levels from the maximum possible and design canal flows under the existing canal conditions are shown in the Tables of Annexe C3.

7.3 Comparison of design and existing conditions

Table 7.5 gives a summary of the design and possible flow conditions under the existing main system canals as at March 1992. Although some canal sections were still capable of carrying the design flows, this was only for a limited length only since most of the canals could not flow for their entire lengths (see Table 7.4). Figures 7.2 and 7.3 present a comparison between design water levels and those obtainable at current canal conditions in the two main canals. It can be seen that the actual command and water levels are well below the design command levels. The reduction in canal capacities and command water levels were due mainly to siltation and low bank top levels resulting from poor maintenance.

This analysis confirms the observed situation. It helps to quantify the extent to which the system capacity is restricted and reduced, and hence the limitations imposed on downstream cultivable area. The issues raised above are further discussed in Chapter 9.

Table 7.5 Comparison of actual and design canal capacities for the primary and secondary canals, Wurno Irrigation Scheme, March 1992.

Canal Name	Canal Section	FLOW Design Gross Head Flow l/s	FLOW Possible Max. Flow l/s	FLOW Possible/ Design Flow %	DEPTH Design Flow Depth m	DEPTH Possible Flow Depth m	DEPTH Possible/ Design Depth %
LUGU	Intake - LS1	1207.8	1000.0	82.8	0.93	0.84	90.3
PRIMARY	LS1 - LS2	1040.2	880.0	84.6	0.86	0.73	84.9
CANAL	LS2 - LS3	828.6	700.7	84.6	0.77	0.65	84.4
	LS3 - LS4	584.8	433.9	74.2	0.64	0.58	90.6
LS1	Whole length	141.3	N/A	N/A	N/A	N/A	N/A
LS2	Whole length	169.2	120.0	70.9	0.49	0.35	71.4
LS3	Whole length	179.3	179.3	100.0	0.31	0.31	100.0
LS4	Whole length	266.8	266.8	100.0	0.39	0.39	100.0
FC1	Whole length	56.1	0.0	0.0	?	0.00	-
FC2	Whole length	24	0.0	0.0	?	0.00	-
FC3	Whole length	26.3	0.0	0.0	?	0.00	-
FC4	Whole length	49.2	0.0	0.0	?	0.00	-
FC5	Whole length	54.9	0.0	0.0	?	0.00	-
FC6	Whole length	10.3	0.0	0.0	?	0.00	-
TUTUDAWA	Intake - TS1A	1820.5	1400.0	76.9	0.98	0.85	86.7
PRIMARY	TS1A - TS1C	1701.6	1287.1	75.6	0.95	0.81	85.3
CANAL	TS1C - TS2	1488.8	1085.9	72.9	0.88	0.74	84.1
	TS2 - TS3	1074.2	910.9	84.8	0.73	0.67	91.8
	TS3 - TS4	777.8	760.9	97.8	0.61	0.60	98.4
	TS4 - TS5	542.5	542.5	100.0	0.50	0.50	100.0
	TS5 - TS6	313.9	0.0	0.0	?	0.00	-
	TS6 - TS7	134.5	0.0	0.0	?	0.00	-
TS1A	Whole length	112.9	112.9	100.0	0.21	0.21	100.0
TS1C	Whole length	201.2	201.2	100.0	0.37	0.37	100.0
TS2	Whole length	275.1	175.0	63.6	0.47	0.37	78.7
TS3	Whole length	257.1	150.0	58.3	0.48	0.36	75.0
TS4	Whole length	208.7	208.7	100.0	0.31	0.31	100.0
TS5	Whole length	217.3	0.0	0.0	?	0.00	-
TS6	Whole length	159.3	0.0	0.0	?	0.00	-
TS7	Whole length	130.9	0.0	0.0	?	0.00	-
	TOTALS =	14055.1	10415.8	74.1	10.88	9.64	88.6

NOTE: LS* = Lugu secondary canal number *
TS* = Tutudawa secondary canal number *

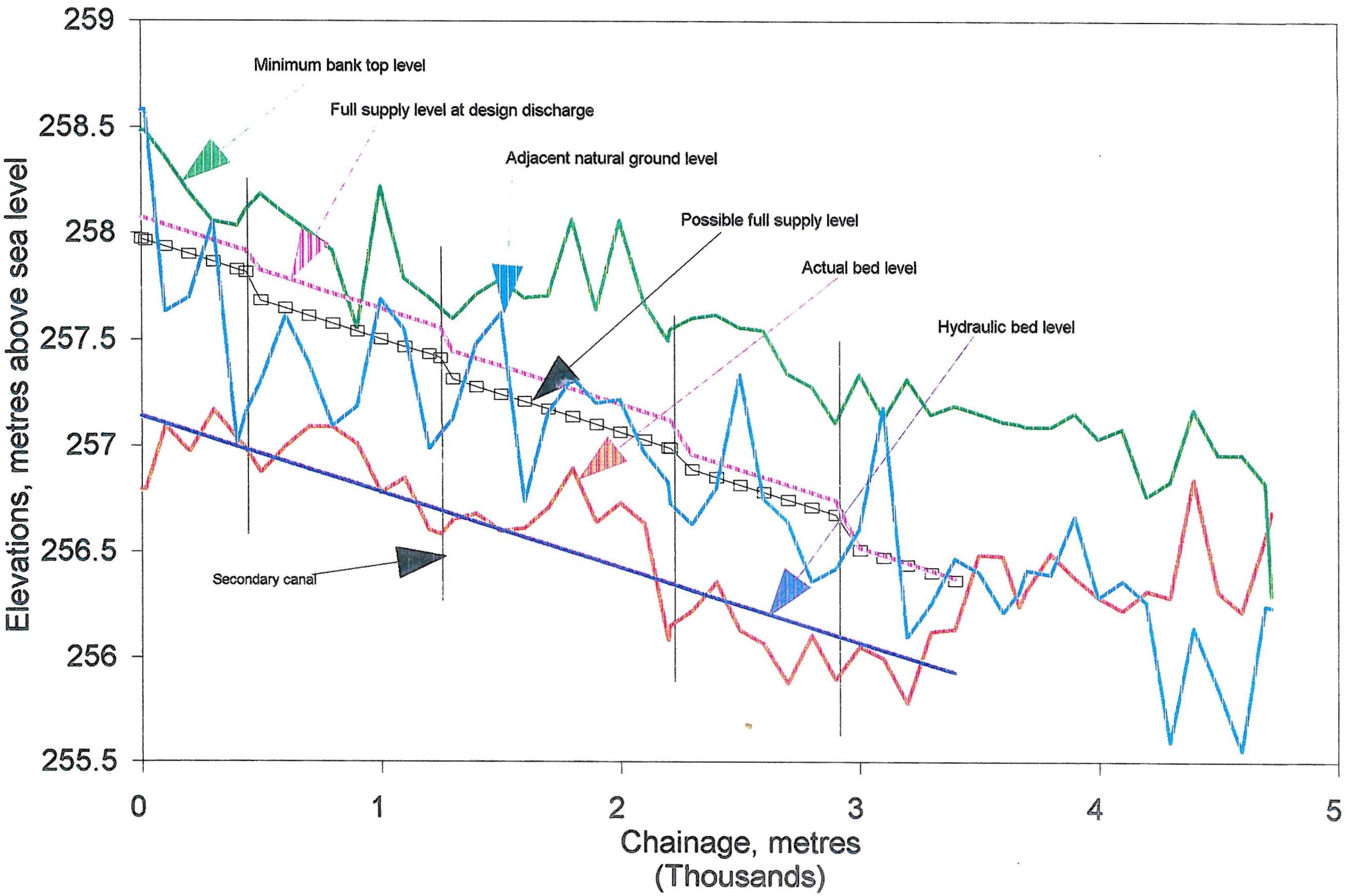

Figure 7.2 Longitudinal section of the Lugu main canal showing the design and possible water levels

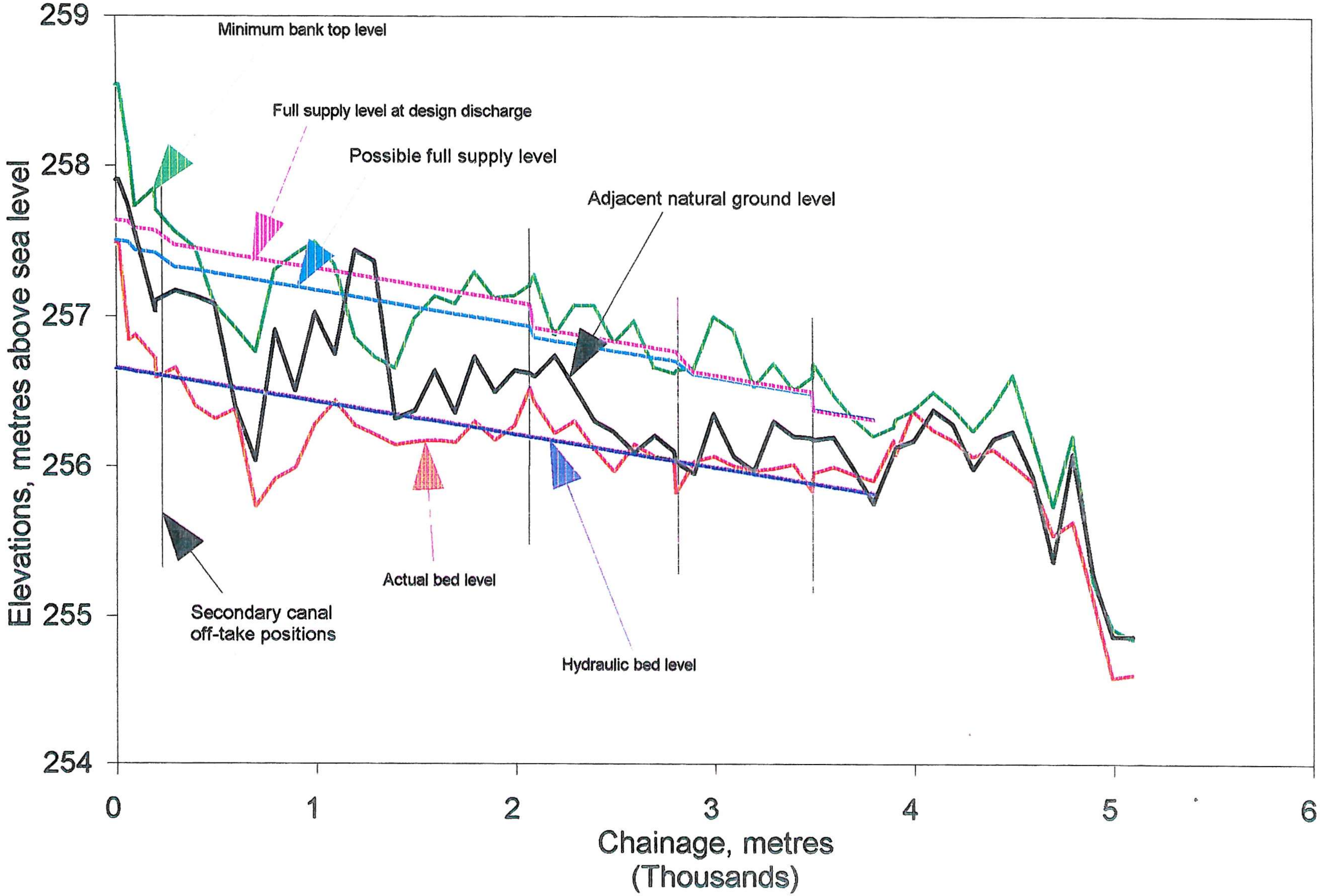

Figure 7.3 Longitudinal section of the Tutudawa main canal showing the design and possible water levels

CHAPTER 8: MANAGEMENT ASSESSMENT

This Chapter looks at the management component of the design-management complex. It is short, reflecting the inadequate attention paid by the scheme to management at the system. The issues studied include:

- Manpower
- Water control, maintenance and management
- Operation and maintenance budgets, and
- Cost recovery.

8.1 Manpower

One of the important factors that affect the performance of irrigation schemes is the manpower that is responsible for management, operation and maintenance. Three major issues identified in this regard are manpower numbers, quality of personnel, and institutional aspects **(Carter *et al*, 1986)**. At the Wurno Irrigation Scheme, the performance of the manpower on all these counts was judged to be deficient.

8.1.1 Manpower numbers

Manpower numbers is probably the least important while being the one to which most attention is often paid. However, to date there has been no consensus on staffing levels for operation and maintenance (O & M) of irrigation schemes. Various figures from 25 to over 600 staff per 100,000 ha have been reported for various countries worldwide **(Carter *et al*, 1986; Bos and Storsbergen, 1978; Sagardoy *et al*, 1982; Haissman, 1971; and Wright *et al*, 1982)**.

Table 8.1 shows the actual staffing levels in the Wurno Irrigation Scheme as at June 1992, compared with recommended levels for operation and maintenance of formal irrigation schemes in Nigeria **(Carter *et al*, 1986)**. The recommended manpower levels are not ideal for every irrigation scheme, neither were they designed for performance assessment. A recent detailed study by **Ragodon (1992)** failed to find any correlation between O & M staffing levels and scheme area, lengths of canals and control structures for irrigation schemes in Kenya, Nepal, Philippines, Somalia, and Sudan, and highlighted the difficulties of such comparisons.

Nevertheless the figures for Wurno indicate that the scheme under-scored in numbers of qualified staff (see Section 8.1.2: Quality of personnel) while being overstaffed with unskilled manpower.

Table 8.1 Staffing levels for operation and maintenance in the Wurno Irrigation Scheme, June 1992

Staff Category	Actual Numbers	Recommended Numbers
Professionals: (Graduates with relevant experience)	0 (0)[3]	1 (40)[4]
Middle Level: (HND and OND)	3 (375)	2 (120)
Artisans: (Technical certificate or relevant experience)	5 (625)	5 (480)
Unskilled Manpower	11 (1375)	n.a (n.a)
TOTAL	19 (2375)	8 (640)

8.1.2 Quality of personnel

The quality of manpower is linked with qualifications, appropriate training, experience, skills and motivation.

Again it was observed that the situation at the Wurno Irrigation Scheme was not satisfactory (Table 8.1). The scheme had no engineer, no training of staff in O & M, and staff had no experience of working on a 'good' project. In general the scheme was overstaffed with poorly trained, ill-motivated, inexperienced, and poorly equipped manpower.

[3]( ) Projected from actual numbers in the Wurno irrigation scheme (700 ha) to 100,000 ha.

[4]( ) Recommended figures per 100,000 ha for formal irrigation schemes in Nigeria (**Carter et al., 1986**).

8.1.3 Institutional aspects

The institutional aspects concern the organizations within which the trained manpower has to operate, such as objective setting, incentives, external constraints beyond the immediate control of the management, government pricing policies, availability of input resources (funds, spares, machineries, etc), and inadequate coordination between organizations with overlapping responsibilities.

The objectives for the Wurno Irrigation Scheme are not well defined. The staff of the irrigation agency are not accountable to the farmers as their salaries are paid from the government civil service without regards to their performance in the scheme. Salaries are poor and there are no incentives or status for staff. The scheme is a long way from city centre without some basic amenities. There is no monitoring of performance and inadequate funds for O & M.

On the whole, the potential of the management in the scheme is very low. The deficiency in quality of the agency personnel, combined with the operational and institutional issues place considerable constraint on the overall performance of the scheme. In addition, there are no incentives for staff to commit themselves to managing the scheme well. Thus their main preoccupation is on what they can get out of the system!.

8.2 Water control, maintenance and management

No operation and maintenance procedures exist for irrigation water management in the Wurno Irrigation Scheme, neither is there any system for monitoring and evaluation. Operation procedures normally comprise of collecting irrigation water requirements from farmers and compiling schedules for given periods of time. This is usually followed by water allocation according to the agreed plans, and control and monitoring to ensure equitable distribution. In Nigeria, as in many other developing countries, there is generally a poor maintenance culture which inhibits good operation. This was obvious in the Wurno Irrigation Scheme by the low priority given to operation and maintenance activities.

At Wurno once water is released into the main canals, farmers freely extract it to their fields according to their perceived needs. This practice is exacerbated by the constraints of poor water control imposed by the deficiencies in the physical system. Water management at field level is the exclusive concern of the farmers. The farmers plan irrigation intervals to suit their convenience. They also determine for themselves how much water to apply based on their experience and condition of the soil.

Scheme staff are not involved in regular inspection of canals and structures for maintenance. Furthermore, no schedules are made for predetermined closures to allow for more detailed inspection and repair of normally submerged areas. Even emergency conditions like canal breaches and unusual gate leakages are taken lightly by management. Field staff and labourers only loiter around the scheme office, or go about working on their private farms and businesses.

8.3 Operation and maintenance budgets

Operation costs comprise of staff salaries and allowances, while maintenance includes civil works on the irrigation infrastructure and equipment running costs. The budgets for operation and maintenance in the Wurno Irrigation Scheme are normally prepared by the headquarters of the State Ministry of Agriculture. Operation and maintenance funds are provided by the Sokoto State government. Salaries and operation costs for the scheme are fairly fixed at about one hundred and twenty thousand Nigerian Naira per year (₦120,000/year)[5], about US$6,000/year.

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[5]The exchange rate of the Nigerian Naira to the US Dollar is highly variable. At the time of this study (1991) the official exchange rate was fluctuating around twenty Naira to the Dollar **(₦20.00/$)**. The parallel black market and Bureaux De Change rates were even higher.

Official records (1981-91) indicate that maintenance budgets vary from year to year, and funds are always inadequate. The actual amount of funds released for maintenance are even more variable, and always fall short of the proposed budget. It was difficult to obtain the full details of the long term records in order to compare the budgetary allocations and actual releases for maintenance of the scheme. However, an example in 1991 showed that only 50% of the total budgetary allocation was actually released that year to the EEC/SEP rehabilitation programme for emergency maintenance. This confirms the reports that in general, the actual total annual release of funds to the irrigation agency for maintenance is normally less than 40% of the required budget.

Figure 8.1 illustrates the operation and maintenance expenditure for the WIS from 1984 - 91. The maintenance expenditure average about ₦22,124/year (US$1,110/year), representing only 16% of the total O & M expenditures per year. These average figures indicate that the maintenance expenditure per year is only ₦32/ha (US$1.60/ha). The total O & M expenditure is equivalent to ₦203/ha (US$10.15). O & M costs in Asian countries vary from a minimum of $10/ha in Nepal to $211/ha in Korea **(ADB, 1986)**.

It can be observed from Figure 8.1 that operation costs take the giant share of 84% of the total O & M budgets. Although there may be some doubts regarding the accuracy of these figures, they, nonetheless, reflect the imbalance in the expenditure in favour of operation, and the neglect of maintenance. This situation is characteristic of under-funding for O & M whereby salaries are paid but no money remains for maintenance of the system **(Burton, 1992)**.

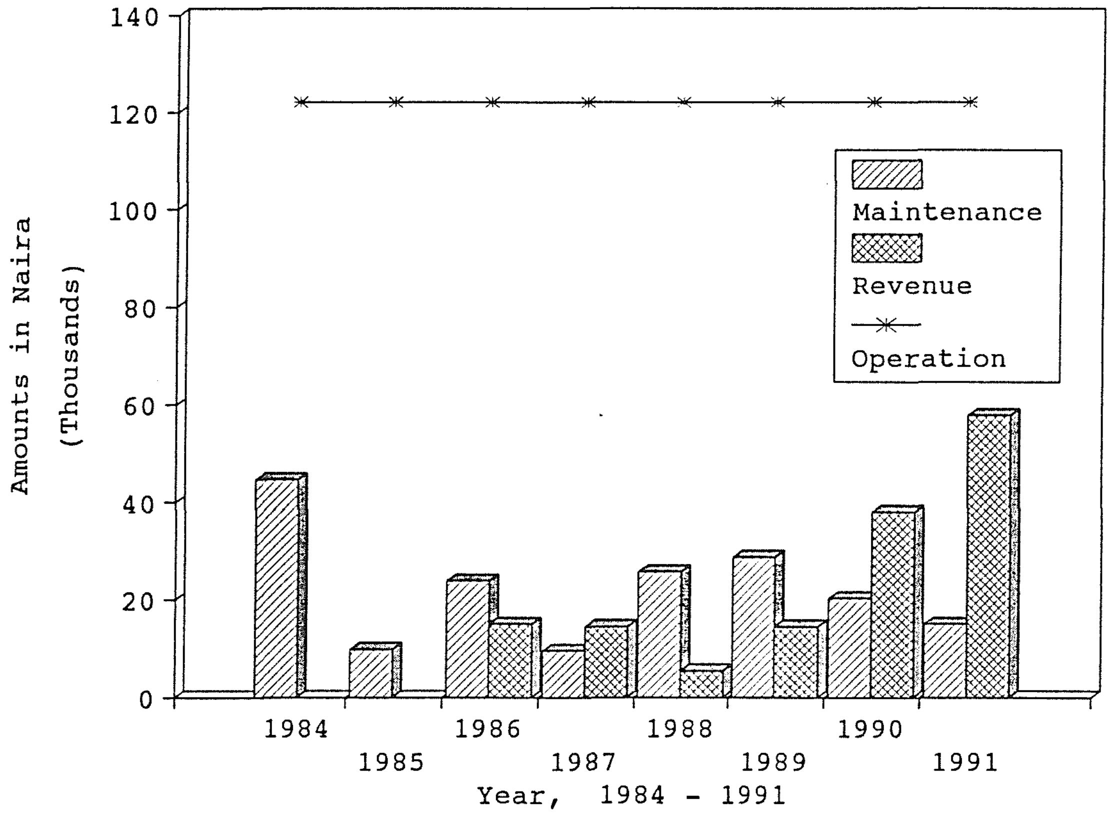


Figure 8.1 Operation and maintenance expenditure for Wurno Irrigation Scheme, 1984 - 1991

8.4 Cost recovery

The only source of revenue in the WIS is water charges levied by the State government to be collected by the scheme agency each season. Prior to September 1990 the water charge was set at a subsidized rate of ₦50/ha (US$2.50/ha), but since then it has been raised to ₦250/ha (US$12.50/ha). Apart from a few exemptions, every farmer that uses water from the irrigation system is required to pay the water charges. The total receipts are transferred to the State Treasury. The total annual amount of revenue is low compared to total O & M costs (see Figure 8.1), the main causes being low water rate and the exemption of some farmers.

The recovery rate of the assessed fees is relatively high at over 80% of total dues per year. This is so because the rate is affordable and farmers are scared of losing their land tenure if they do not pay the water charges. The amount collected in 1988 was unusually low due to excessive floods in the wet season which destroyed the wet season crops. Before the increase in the water rates in 1990, the average amount of revenues collected each year represented only about 10% of the annual O & M expenditure. Following the increase, the amount collected in 1991 represented about 40% of the O & M expenditure. These figures indicate that the scheme is not financially self-sufficient. With the present low rates of water charges, the capital and yearly O & M costs can be considered as an additional subsidy to the farmers. The low cost recovery and low maintenance budget allocation go part way to explaining the poor state of the Wurno scheme.

However, any proposal for additional increase in the water rate has to consider the farmers' incomes. The farm budget analysis in Chapter 9 indicate that for a one hectare farm, a five-fold increase in the rate could conveniently be afforded by a typical garlic or onion farmer, which will represent only about 5% of his net income. But rice and wheat farmers cannot easily cope with such an increase as the net income for these crops are relatively lower. Some wheat farmers even find it difficult to cope with the present level of water rate due to low crop yields and smaller margins.

CHAPTER 9: SOCIO-ECONOMIC AND CROP PRODUCTION ASSESSMENT

The aim of this chapter is to provide details of the social and economic factors that were observed to influence farmers' decision making, crop production, management, and overall performance in the Wurno Irrigation Scheme. These include:

- the level of income from irrigated crops and the relative profitability between different crop options
- availability of farm inputs and farmers' view of them
- farmers' cultural practices and their effect on crop yields and income
- marketing possibilities and problems, prices and their variability with time
- farmers' commitment to irrigated enterprise with respect to other farm and other non-farm occupations
- the problems of storage facilities
- political influence.

9.1 Agricultural crop production

9.1.1 Crop Areas and Cropping Calendar

During the wet season almost all farmers in the scheme grow rice. The only exceptions are the scattered high spots which cannot be flooded, the waterlogged areas where cultivation is impossible, and areas otherwise unsuitable for farming. Overall, 70 - 90% of the existing developed scheme area is normally planted to rice during the wet season.

The planting of rice begins in May and may go on through June and into July. Delays in planting are caused by lack of machinery for land preparation, and non-availability of other inputs, especially fertilizer. The delays in planting of rice causes problems for the dry season crops which followed immediately after rice harvest.

The main irrigated dry season crops are wheat, onion and garlic. In the dry season during which survey work was carried out the actual total cropped areas were measured to be 120 ha. The measured crop areas showed wheat, onion, and garlic respectively in the ratio of 39%, 41%, and 20%. Of this 120 ha, a detailed survey covering 102 ha (85%) was carried out. Figure 9.1 shows the cropping calendar.

Farmers do not always cultivate their total land holdings, particularly during the dry season. Rice has higher farm sizes with the average farm size being 4 acres. The average dry season crop areas are 2 acres for wheat and 1.5 acres for onion and garlic. For the dry season crops, about 80% of the farms are 2 acres or less (see Table 9.1). The smaller farm sizes for the dry season crops is due to higher labour requirements during the dry season for these crops.

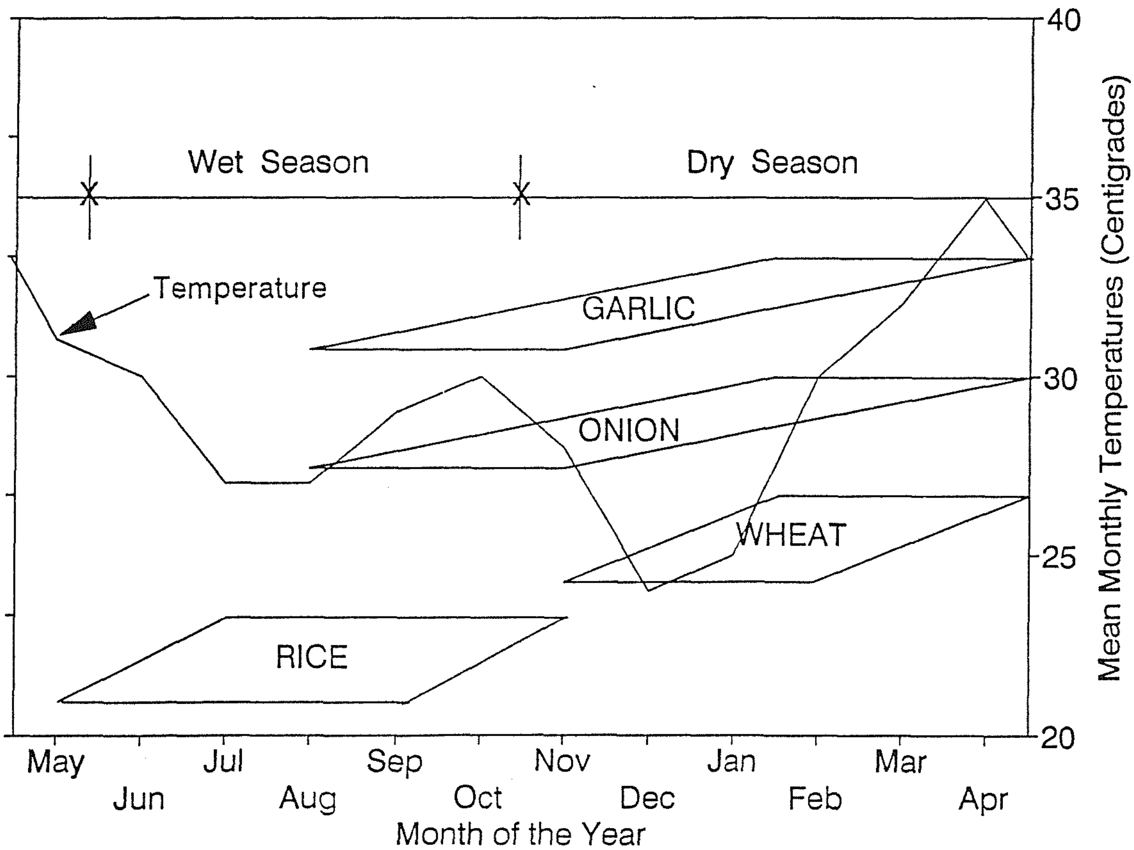


Figure 9.1 Cropping calendar diagram, Wurno Irrigation Scheme

Table 9.1 Distribution of cropped areas by farm sizes (%).

FARM SIZE (Acres)	RICE	WHEAT	ONIONS	GARLICS
1	9.2%	26.4%	58.2%	62.5%
2	42.3%	50.9%	30.9%	30.0%
3	8.5%	7.5%	9.1%	5.0%
4	16.9%	11.3%	1.8%	-
5	5.6%	3.8%	-	-
>5	17.6%	-	-	2.5%
Total	100%	100%	100%	100%
Mean Size (acres)	3.86	2.13	1.45	1.43

The total cropped area in the dry season represent only about 15% of existing developed scheme area, and was reportedly decreasing over time. The reasons for this are numerous, but some of the main factors were found to be the following:

i. Most farmers have subsistence as their primary objective and so many do not bother with dry season (irrigated) farming when mainly cash crops are grown. They derive enough food from the wet season rice grown in the scheme and other staple rain-fed crops grown outside the scheme such as guinea-corn (sorghum), millet and maize.

ii. There are problems with obtaining inputs on time. The input availability problem is particularly bad for under-privileged farmers who do not have enough sway to guarantee them easy access to inputs which are supplied through government channels at subsidized rates.

iii. The scheme is in a poor state of repair due to lack of maintenance. This has led to water availability problems in some areas due to siltation and weeds in canals.

iv. Environmental problems of waterlogging, salinity and soil erosion are on the increase. A few parcels of land have been abandoned due to these problems.

The combination of the aforementioned factors discouraged a number of farmers from continuing with irrigated farming as they had done in the past. That these factors are influential is witnessed by the fact that many farmers with relatively easy access to water did not bother to crop their land in the dry season. Discussions with farmers confirmed that their decisions were not based on availability of water alone.

Research conducted by the Institute for Agricultural Research **(IAR)** Zaria, recommends that wheat should be planted in mid-November to early December **(Andrews, 1968)**. However, data collected during the survey and field observations revealed that wheat planting date spread to as late as February. The reasons farmers gave for this late planting included late harvest of wet season rice, inadequacy of tractors for early land preparation, and availability of seeds and fertilizer. The survey indicated that planting of onion and garlic had even a wider span, from July to March, but this was due more to continuous cropping than to the factors mentioned above.

9.1.2 Factors Affecting Crop Yields

The interrelationship between crop yields and other factors is very complex, especially in irrigated agriculture. Some of the factors which could affect the yields of irrigated crops include the following:

- location in the scheme (head, middle, or tail)
- fertilizer inputs
- farmers' cultural practices
- soil types and fertility
- planting dates
- planting density
- water availability to crops
- size of farms
- farmers' irrigation experience, and so on.

The data collected from the survey was analyzed to reveal the influence of some of these variables using techniques of correlation and regression analyses. The sample average yields were 2.6 t/ha for rice, 1.16 t/ha for wheat, 8.94 t/ha for onion and 8.55 t/ha for garlic. However, there were wide variations within the yields with rice ranging from 0.4 t/ha to 5 t/ha, wheat from 0.25 t/ha to 3.2 t/ha, onion from 2 t/ha to 30 t/ha, and garlic from 1.7 t/ha to 25 t/ha (see Table 9.2 and Figures 9.2 - 9.5).

About 61% of rice farmers' sample achieved less than average yields; 50% of wheat farmers' sample achieved less than average yields; 65% of onion farmers' sample achieved less than average yields; and 55% of garlic farmers' sample achieved less than average yields. Wheat yields seem particularly low considering that research experimental yields of up to 5 t/ha have been recorded in Nigeria **(Andrews, 1968)**. Yet farmers hardly ever achieve wheat yields over 2 t/ha.

It can be observed from Table 9.2 and Figures 9.2 - 9.5 that apart from rice yields which are almost symmetrical around the average, the yields for the dry season crops are skewed towards the low side. There is also a high degree of variation, signifying that the majority of farmers' yields need to be improved. Only a small proportion of farmers seem to be achieving adequate yields, with a few achieving the exceptionally high crop yields. This is particularly true for onion and garlic where a few farmers reported yields in excess of 20 t/ha.

Table 9.2 Summary statistics of crop yields, WIS, 1991/92 (t/ha).

CROP STATISTIC	Rice	Wheat	Onion	Garlic
Sample Size	142	53	55	140
Average	2.60	1.16	8.94	8.55
Geometric Mean	2.47	0.99	7.74	7.44
Variance	1.06	0.44	26.91	19.40
Standard Deviation	1.03	0.66	5.18	4.40
Minimum	0.37	0.25	1.98	1.73
Maximum	4.94	3.21	29.64	24.7
Lower Quartile	1.85	0.74	5.43	5.93
Upper Quartile	3.09	1.36	10.37	11.24
Skewness	0.40	1.23	1.88	1.22
Kurtosis	0.03	1.87	4.97	3.27
Coeff. of Variation	39.52	57.11	58.02	51.54

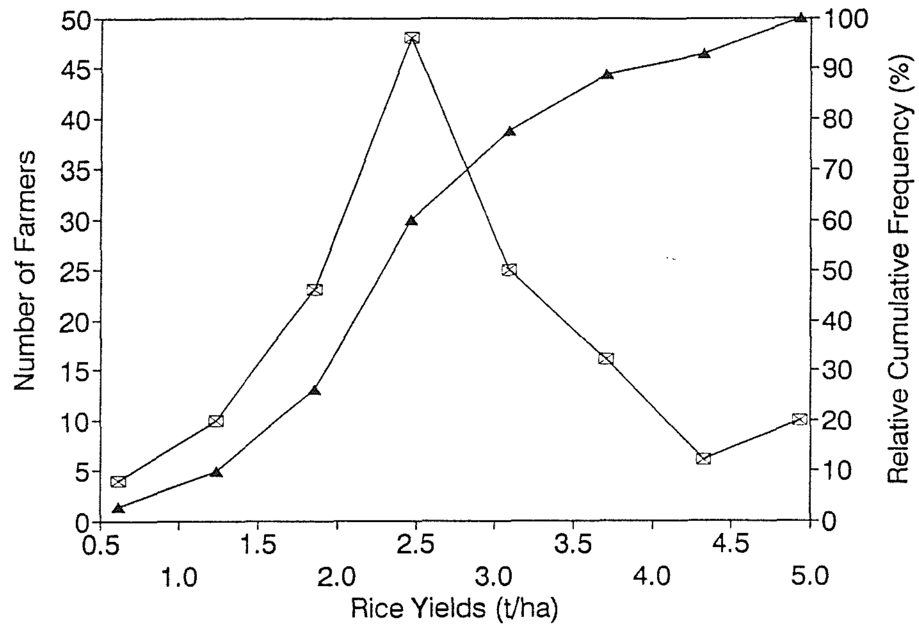


Figure 9.2 Distribution of rice yields, Wurno Irrigation Scheme, 1991/92

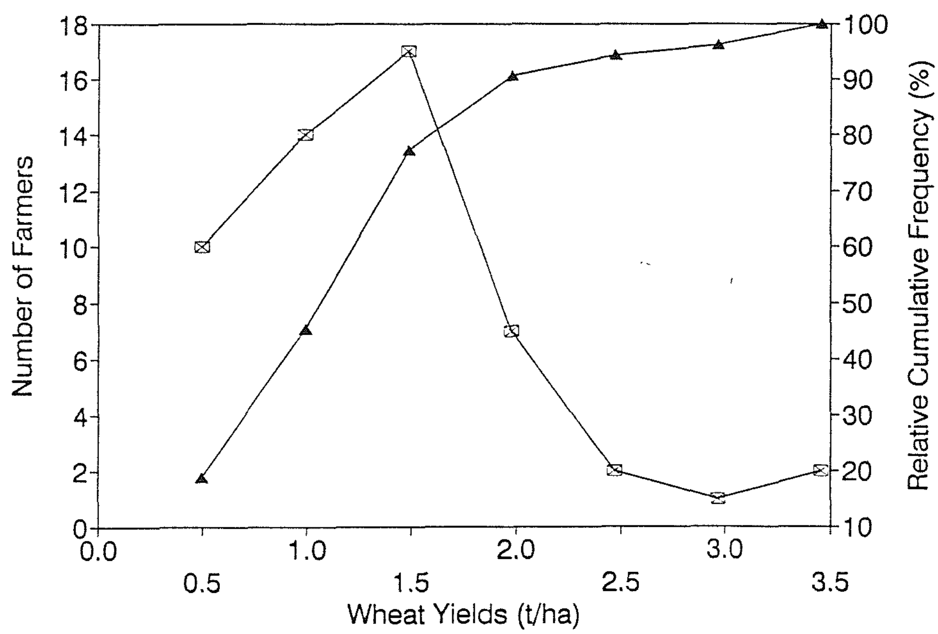


Figure 9.3 Distribution of wheat yields, Wurno Irrigation Scheme, 1991/92

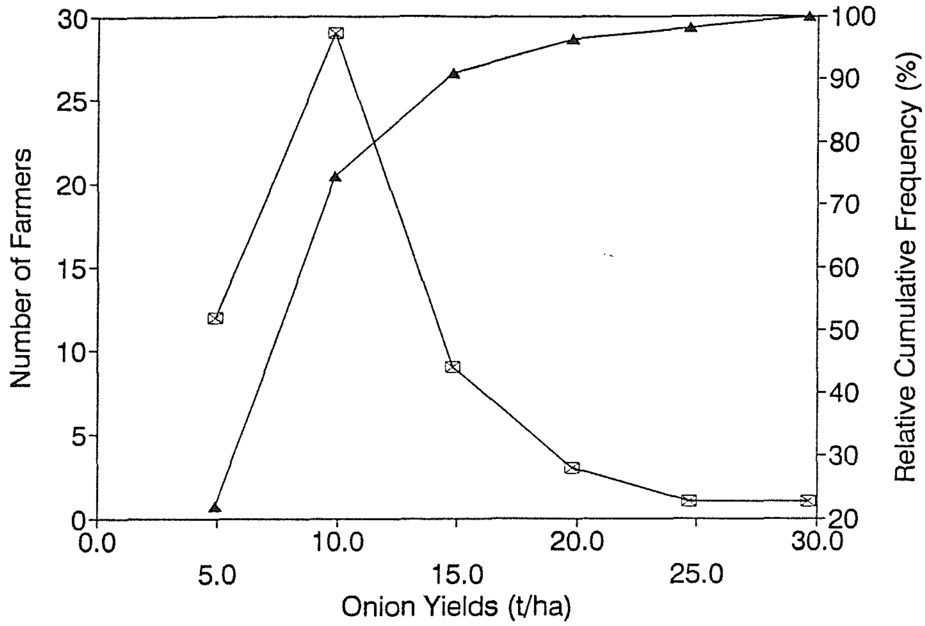


Figure 9.4 Distribution of onion yields, Wurno Irrigation Scheme, 1991/92

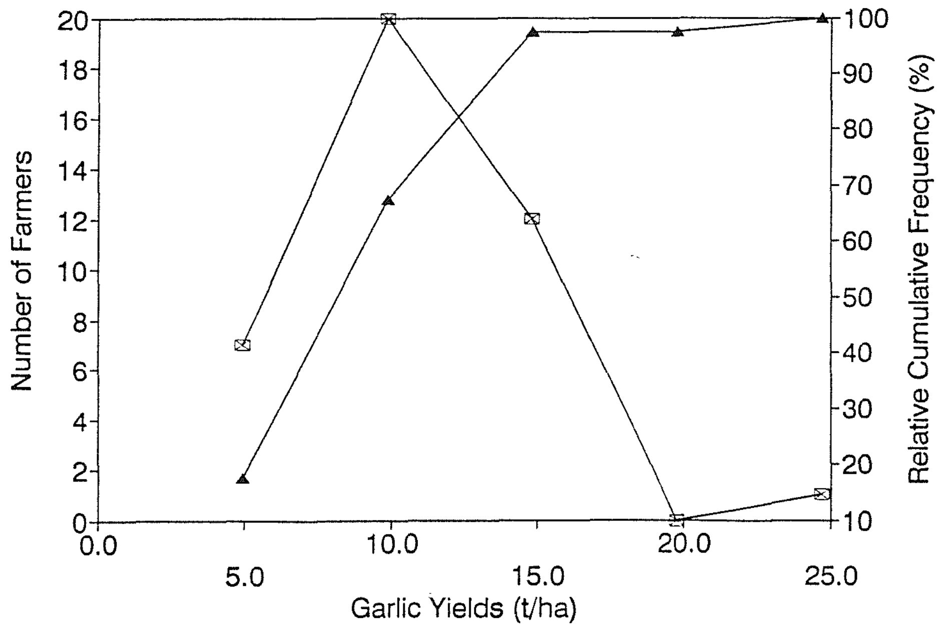


Figure 9.5 Distribution of garlic yields, Wurno Irrigation Scheme, 1991/92

1 Planting Date

The effect of planting date on crop yields is shown in Table 9.3. There is clearly an adverse effect on wheat yields from crops planted outside the recommended planting date of mid-November (Figure 9.6). Unfortunately over 50% of farmers planted late. The recommendation of wheat planting date is based on temperatures to which it is sensitive, particularly during its tillering and grain filling stages. The optimum time to plant at Wurno therefore is early in the dry season (November) so that the crop matures in the coolest months (December/January). Temperatures start to rise in February, reaching the average monthly peak in April/May of about 35°C. However, the daily maximum temperatures during these months could be as high as 45°C.

Wheat planted in November has its grain filling stage in January/February thus avoiding the high temperatures. If planted later, this critical stage occurs during the high temperatures in April or May resulting in poor yields. The crop calendar at WIS seems very tight and farmers find it difficult to comply with the recommended schedule. Many of them were observed harvesting their wet season rice in November when they should have been planting wheat. Besides, they also needed a waiting time in order to drain off their fields before cultivating for the dry season crops.

The yields of onion and garlic crops do not indicate any consistent pattern as an effect of planting date. This may be as a result of the wide time period within which they are planted, more or less on a continuous basis.

2 Fertilizer use and farm size

The farmers' reported total use of fertilizer for the different crops varied widely from one 50 kg bag per acre (0.124 t/ha) to 15 bags per acre (1.853 t/ha, see Table 9.4). Various types of fertilizer are used, but Urea and NPK are most common. Only few farmers reported use of CAN (Calcium Ammonium Nitrate), Superphosphate, DAP (Di-Ammonium Phosphate) and farmyard manures.

Table 9.3 Crop yields:- Effect of planting date, Wurno Irrigation Scheme, 1991/92

RICE

Planting Period	% of Farmers who planted in this period	Average Yields (t/ha)
May '91	8.39	2.18
Jun. '91	59.44	2.70
Jul. '91	32.17	2.53
Sample = 143		

WHEAT

Planting Period	% of Farmers who planted in this period	Average Yields (t/ha)
Oct. '91	1.85	0.74
Nov. '91	42.59	1.52
Dec. '91	22.22	1.45
Jan. '92	29.63	0.95
Feb. '92	3.70	1.05
Sample = 54		

ONION

Planting Period	% of Farmers who planted in this period	Average Yields (t/ha)
Aug. '91	3.64	12.97
Sep. '91	7.27	14.00
Oct. '91	14.55	12.57
Nov. '91	14.55	9.06
Dec. '91	12.73	5.05
Jan. '92	34.55	8.34
Feb. '92	7.27	5.28
Mar. '92	5.45	7.33
Sample = 55		

GARLIC

Planting Period	% of Farmers who planted in this period	Average Yields (t/ha)
Jul. '91	2.50	12.35
Aug. '91	2.50	2.47
Sep. '91	2.50	24.70
Oct. '91	7.50	9.10
Nov. '91	57.50	7.79
Dec. '91	10.00	7.72
Jan. '92	2.50	14.82
Feb. '92	10.00	8.63
Mar. '92	5.00	7.78
Sample = 40		

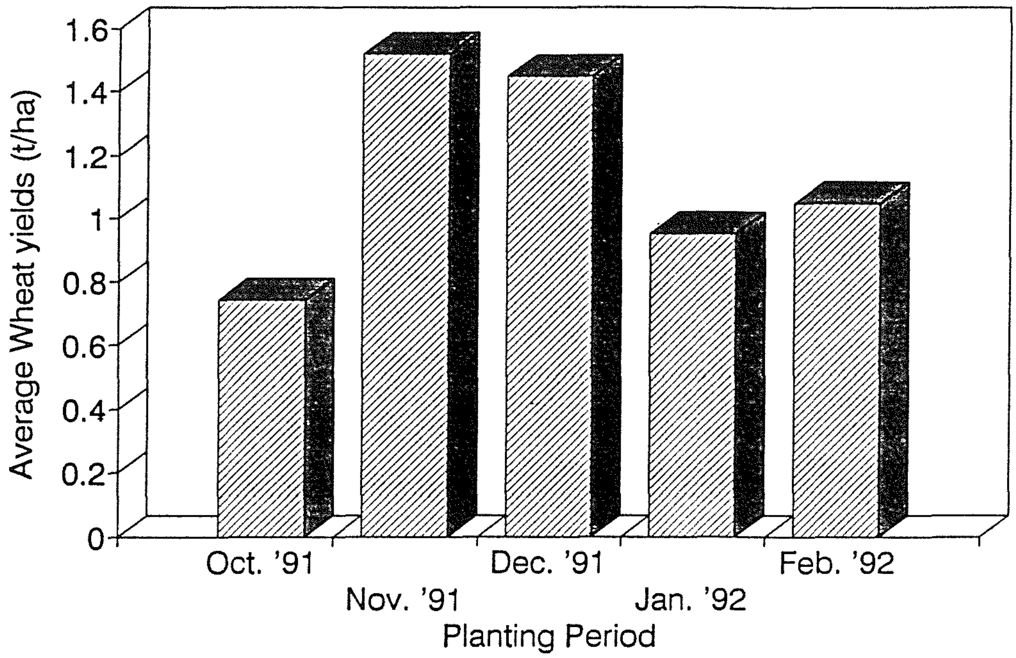


Figure 9.6 Effect of planting date on wheat yields

Table 9.4 Variation of crop yields by fertilizer application

FERTILIZER APPLICATION		RICE	WHEAT	ONION	GARLIC
Bags/Acre	T/Ha	Yields t/ha	Yields t/ha	Yields t/ha	Yields t/ha
1	0.124	2.33	0.74	7.00	-
2	0.247	2.38	1.11	8.32	-
3	0.371	2.40	1.34	7.49	5.56
4	0.494	2.73	1.38	9.88	9.39
5	0.618	2.78	0.58	12.90	13.59
6	0.741	3.17	1.27	9.23	8.01
7	0.865	-	-	7.14	9.39
8	0.988	-	1.65	9.76	8.94
9	1.112	-	-	7.79	9.11
10	1.235	-	-	1.98	-
15	1.853	-	-	7.41	2.47

Farmers use and dosage of fertilizers depend on availability. Although fertilizers are supposed to be available to farmers at subsidized prices, often, it is private merchants who acquire them at the subsidized rates. Farmers who are unable to obtain fertilizer at the government subsidized rates are forced to spend 2 to 5 times more to buy from the private fertilizer merchants on the black market!.

Onion and garlic receive higher doses of fertilizer than wheat or rice. Nevertheless, only rice confirms a positive response to the amount of fertilizer application. Correlation and regression analysis illustrates that nearly 10% of the rice yield variation can be explained by variation in fertilizer application (Tables 9.5 and 9.6 and Figure 9.7). The other possible sources of variation in rice yields such as farm size, farmers' irrigation experience, planting date, and number of weedings or fertilizer applications, did not show any significant correlation.

The variation of fertilizer use with farm size for the various crops did not show consistent trends. Similarly rice and wheat yields did not show any significant variation as a consequence of farm size. However, onion and garlic yields are negatively influenced by farm size (Table 9.7).

The decreasing yields of onion and garlic with increasing farm size is partially as a result of the high labour requirements for these crops. Farmers reported weeding onion and garlic on an average of 4 times during the season, as compared to 2 or at most 3 times for rice and wheat. In addition, onion and garlic are irrigated more frequently; 2 to 3 times a week compared to once per week for wheat. As a result farmers with larger onions or garlic farms had problems coping with the labour demands, and hence the effect on yields.

Table 9.5 Simple regression results of rice yields (t/ha) against total fertilizer application (t/ha)

Regression Analysis - Linear Model: Y = a + bX

Dependent Var.: Rice Yields; Independent var.: Total Fert. Applied

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	1.957	0.198	9.908	0.00000
Slope	1.543	0.410	3.762	0.00025

Analysis of variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	13.705	1	13.704	14.152	0.00025
Residual	130.735	135	0.968		
Lack-of-Fit	1.687	5	0.337	0.3399	0.8879
Pure Error	129.047	130	0.993		
Total Correlation	144.439	136			

Correlation Coefficient = 0.308 R-Squared = 9.49 percent
Stnd. Error of Estimate = 0.984

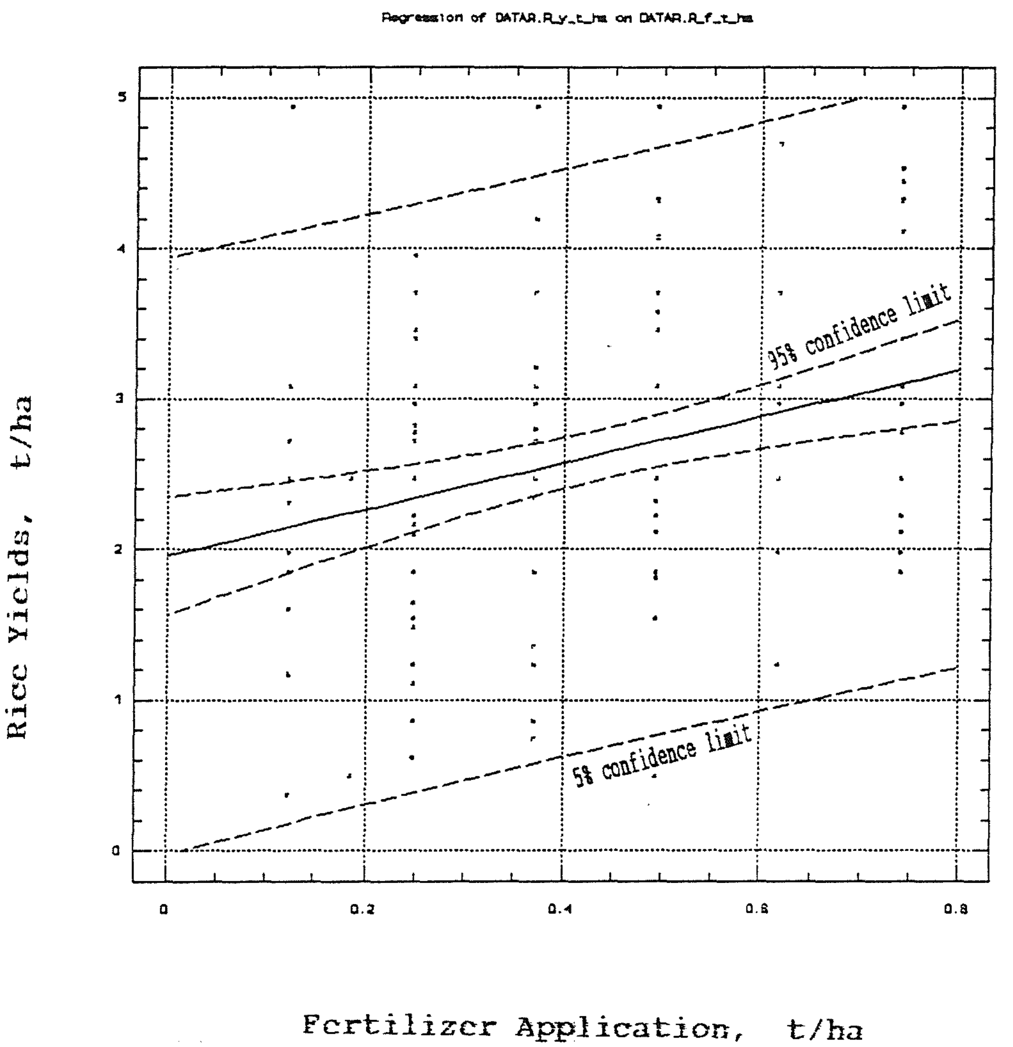


Figure 9.7 Regression of rice yield on fertilizer application

Table 9.6 Multiple regression results *(Stepwise Selection)* of rice yield (t/ha) against several other factors

Table 9.6A: Stepwise Selection for Rice Yields

Selection: Forward   Maximum Steps: 500   F-to-enter: 4.00
Control: Automatic   Step: 1   F-to-remove: 4.00

R-Squared: 0.09277   Adjusted: 0.0857   MSE: 0.9911   d.f.: 129

Variables in Model	Coeff.	F-Remove	Variables Not in Model	P.Corr.	F-Enter
7. Fert. Applied	1.5610	13.191	1. Total Holding	0.136	2.411
			2. Irrig. Experience	0.109	1.554
			3. Rice Cropped Area	0.062	0.049
			4. Rice Planting Date	0.034	0.149
			5. Water Type	0.067	0.584
			6. No. of Weeding	0.049	0.312
			8. No. of Fert. Applns.	0.046	0.272

Table 9.6B: Model Fitting Results for Rice Yields

Independent Variable	Coeff.	Std. Error	t-Value	Sig. Level
CONSTANT	1.9448	0.2073	9.3796	0.0000
Rice Yields	1.5610	0.4298	3.6319	0.0004

R-SQ. (ADJ.) = 0.0857   SE = 0.9955   MAE = 0.7877   DurbWat = 1.847
131 observations fitted, forecast(s) computed for 0 missing values of dependent variable

Table 9.6C: Analysis of Variance for the Full Regression

Source	Sum of Squares	DF	Mean Square	F-Ratio	P-Value
Model	13.0726	1	13.0726	13.1905	0.0004
Error	127.848	129	0.9911		
Total (Corr.)	140.920	130			

R-Squared = 0.09277   Standard error of estimate = 0.9955
R-Squared (Adj. for d.f.) = 0.0857   Durbin-Watson Statistic = 1.8474

Table 9.7 Crop production and fertilizer application by farm size

	RICE		WHEAT		ONION		GARLIC	
Farm Size	Ave Fert. Appln	Ave. Crop Yield	Ave. Fert. Appln	Ave. Crop Yield	Ave. Fert. Appln	Ave. Crop Yield	Ave. Fert. Appln	Ave. Crop Yield
acres	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha
1	0.44	2.53	0.36	1.02	0.59	8.85	0.74	8.77
2	0.39	2.48	0.49	1.09	0.70	8.28	0.74	9.19
3	0.35	2.89	0.62	1.56	0.62	7.41	0.74	3.29
4	0.43	2.69	0.49	1.14	0.74	6.18	-	-
5	0.62	2.45	0.49	2.05	-	-	-	-
>5	0.56	2.70	-	-	-	-	1.85	2.47

3 <u>Source of irrigation water</u>

Table 9.8 presents the variation of yields for the dry season irrigated crops according to the method of obtaining irrigation water. For all crops the yields from farmers pumping from wells are highest. The data also indicates that farmers with wells cultivated relatively large areas and applied higher doses of fertilizer. *These results demonstrate the farmers' disposition and willingness to invest more resources to irrigated farming if there would be a reliable source of water. The results also confirm that these higher investments pay off in higher yields.*

In all cases the farmers lifting by hand with buckets or calabash (shadoof) cultivate the smallest areas, which depicts their difficulties with large crop areas with using this method. It was also noticed that the majority (over 60%) of the farmers who use pumps choose to grow high value onion or garlic instead of wheat. According to them, wheat is not worthwhile irrigating with pumps since returns from it are low. This assertion is confirmed in the farm budgets analysis presented in section 9.2.

Although planting date seem to be the single most important factor affecting wheat yields, application of multiple regression techniques revealed that over 70% of the variance in the yields of wheat could also be explained by the

Table 9.8: Variation of irrigated crop yields by method of obtaining irrigation water

			WHEAT	
Water Type	1	2	3	4
% of Users in Sample	64	8	13	15
Ave. Farm Size, acres	1.89	1.75	2.64	2.88
Ave. Fert. Appln., t/ha	0.39	0.40	0.51	0.60
Ave. Yield, t/ha	1.09	0.93	1.07	1.68
			ONION	
Water Type	1	2	3	4
% of Users in Sample	20	14	46	20
Ave. Farm Size, acres	1.55	1.06	1.59	1.32
Ave. Fert. Appln., t/ha	0.69	0.65	0.59	0.65
Ave. Yield, t/ha	8.23	10.13	7.02	13.16
			GARLIC	
Water Type	1	2	3	4
% of Users in Sample	20	20	33	27
Ave. Farm Size, acres	1.25	0.94	1.81	1.46
Ave. Fert. Appln., t/ha	0.74	0.68	0.79	0.66
Ave. Yield, t/ha	8.07	8.74	7.25	10.27

KEY to Water Types:

1 = Gravity flow from canals or drains
2 = Shadoof from canals or drains
3 = Pumping from canals or drains
4 = Pumping from wells

combination in the variations of three factors:

- farmers' irrigation experience
- source of irrigation water
- number of weedings during the crop season (proxy for general care of the crops).

The results of the multiple regression analysis are presented in Table 9.9 and Figure 9.8. These results are important, particularly as some of the farmers hold the belief that wheat does not require any weeding. Of all the wheat farmers interviewed, only 30% of them reported weeding the crop from 1 to 3 times throughout the crop season. *The results confirm that the more experienced wheat farmers, who irrigated using pumps, and also weeded their crops achieved higher yields.*

Table 9.9 Multiple regression results *(Stepwise Selection)* of wheat yields against several other factors

Table 9.9A: Stepwise Selection for Wheat Yields

Selection: Forward	Maximum Steps: 500	F-to-enter: 5.00	
Control: Automatic	Step: 1	F-to-remove: 5.00	
R-Squared: 0.7714	Adjusted: 0.7091	MSE: 0.1678	d.f.: 11

Variables in Model	Coeff.	F-Remove	Variables Not in Model	P.Corr.	F-Enter
2. Irrig. Experience	0.044	11.652	1. Total Holding	0.080	0.065
5. Water Type	0.322	13.090	3. Wheat Cropped Area	0.551	4.367
7. No. of Weeding	0.485	8.615	4. Planting Date	0.156	0.250
			6. No. of Irrigations	0.436	2.348
			8. Total Fert. Applied	0.315	1.102
			9. No. of Fert. Applns.	0.070	0.049

Table 9.9B: Model Fitting Results for Wheat Yields

Independent Variable	Coeff.	Std. Error	t-Value	Sig. Level
CONSTANT	-0.6765	0.3621	-1.8683	0.0886
Irrig. Experience	0.0436	0.0128	3.4136	0.0058
Water Type	0.3219	0.0889	3.6180	0.0040
No. of Weeding	0.4849	0.1652	2.9352	0.0136

R-SQ. (ADJ.) = 0.7091 SE = 0.4096 MAE = 0.2858 DurbWat = 1.979
15 observations fitted, forecast(s) computed for 0 missing values of dependent variable

Table 9.9C: Analysis of Variance for the Full Regression

Source	Sum of Squares	DF	Mean Square	F-Ratio	P-Value
Model	6.2289	3	2.0763	12.3760	0.0008
Error	1.8455	11	0.1678		
Total (Corr.)	8.0734	14			

R-Squared = 0.7714 Standard error of estimate = 0.4096
R-Squared (Adj. for d.f.) = 0.7091 Durbin-Watson Statistic = 1.9791

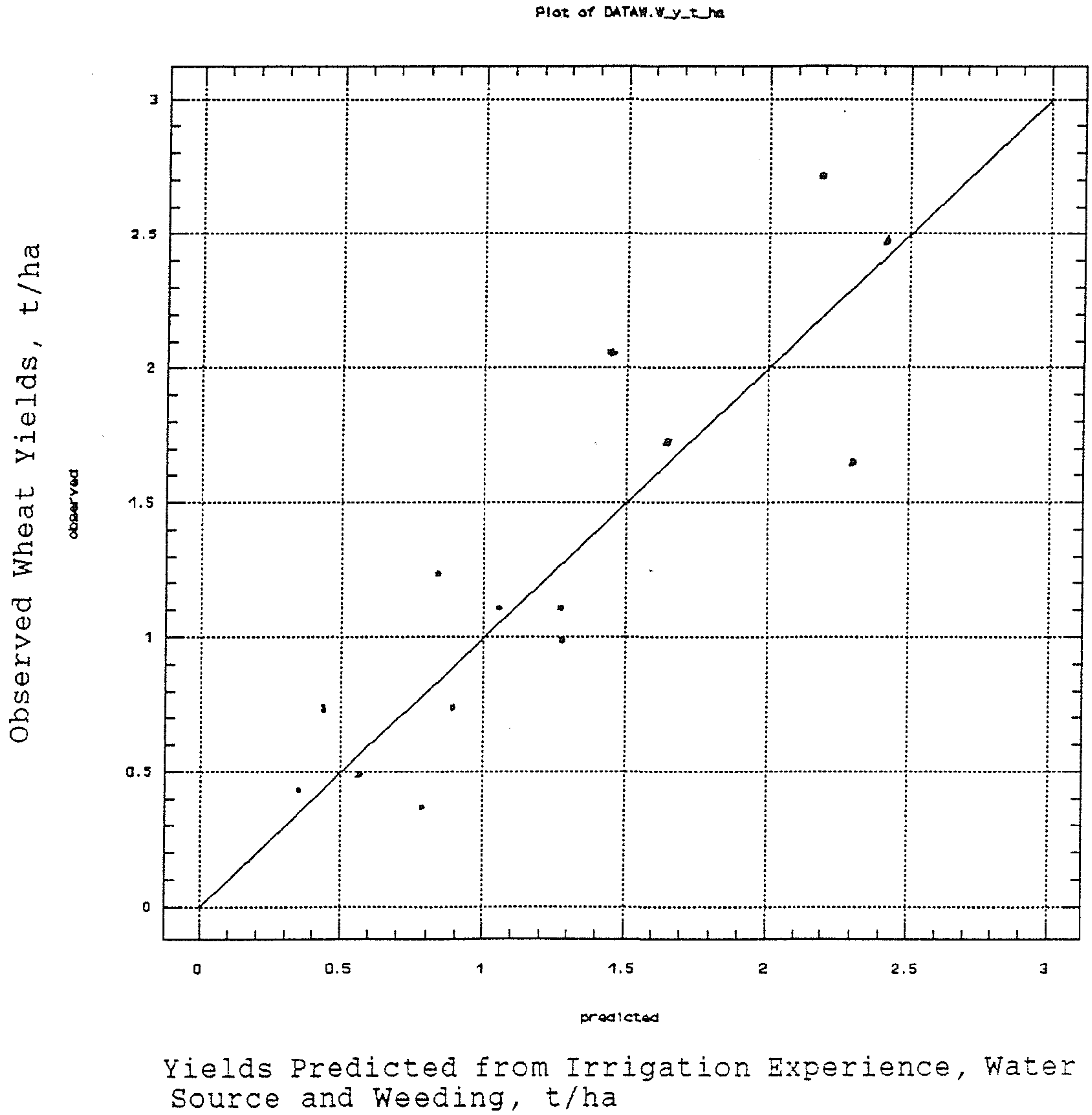


Figure 9.8 Graph of observed wheat yields against yields predicted from combination of irrigation experience, irrigation water source and weeding

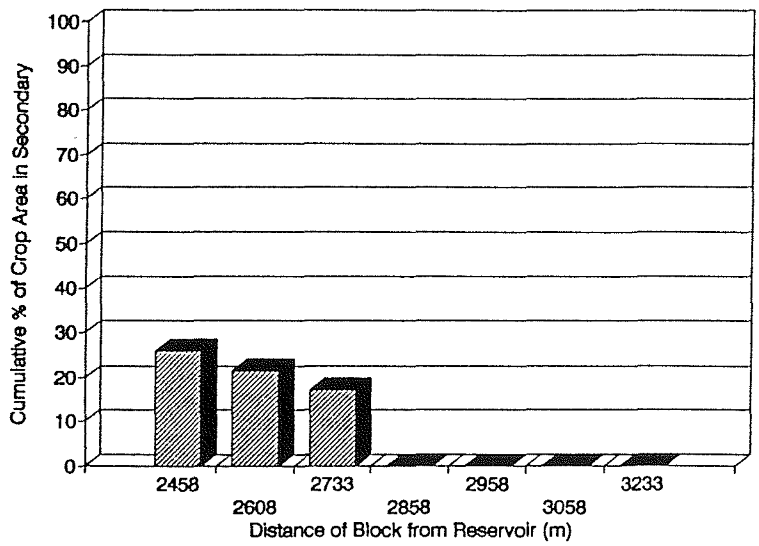
4 Geographical variation of crop yields

It is difficult to analyze the geographical distribution of crop yields within the scheme in detail. This is because during the survey some farmers were not able to accurately describe the exact location of their plots. Another factor is that crop areas were not continuous along the lengths of canals. On some canals only the areas next to the head reaches were cropped, while on others it was the area towards canal tail that was cropped using water from the main drain (see Figure 9.9).

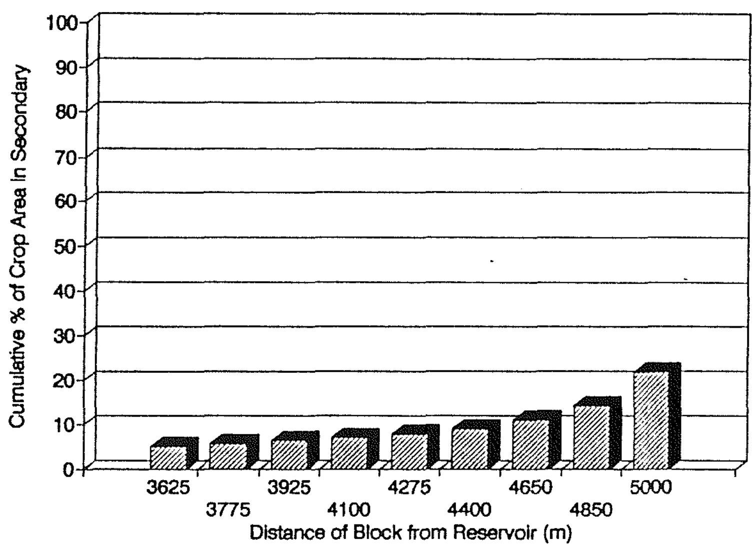
Figures 9.10 to 9.13 show the variation of crop yields by the location of secondary canals along the two main canals, from head to bottom. The yields are averages for the crops grown within the command of the various secondary canals from all sources of water: gravity, shadoof, and pumping from canals, drains and wells.

The results do not show much significant trends in yield variation between the head and tail of the main canals. The yields of rice in particular seem uniformly distributed from top to bottom for both Lugu and Tutudawa main canals. This is because water supply for rice is relatively easily available in almost all locations in the scheme as the whole scheme was deliberately flooded during the wet season by closing the main drain outlet.

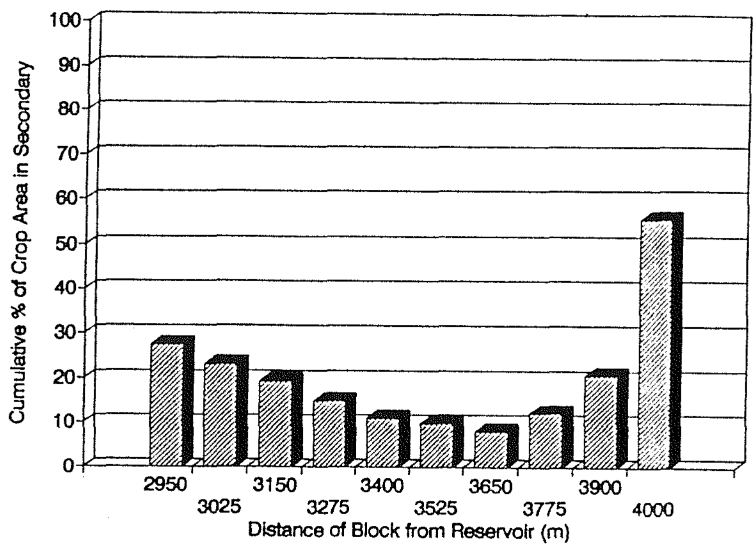
On the whole, the yields of rice and wheat were slightly higher along Tutudawa main canal while onions and garlic yields were higher along Lugu main canal. These variations may have been as a result of differences in soil types and soil conditions between these canals, and differences in farmers' practices other than water availability.



A: Lugu secondary canal LS3 cropped at head only



B: Tutudawa secondary canal TS5 cropped at tail only



C: Lugu secondary LS4 cropped at head and tail

Figure 9.9 Cumulative crop areas along some secondary canals cropped at different positions

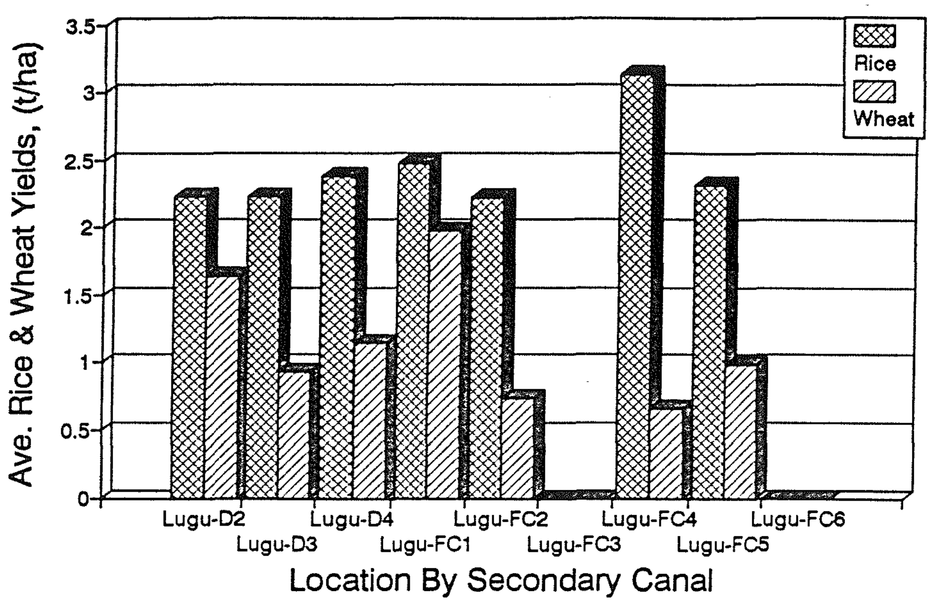


Figure9.10 Variation of rice and wheat yields along Lugu main canal

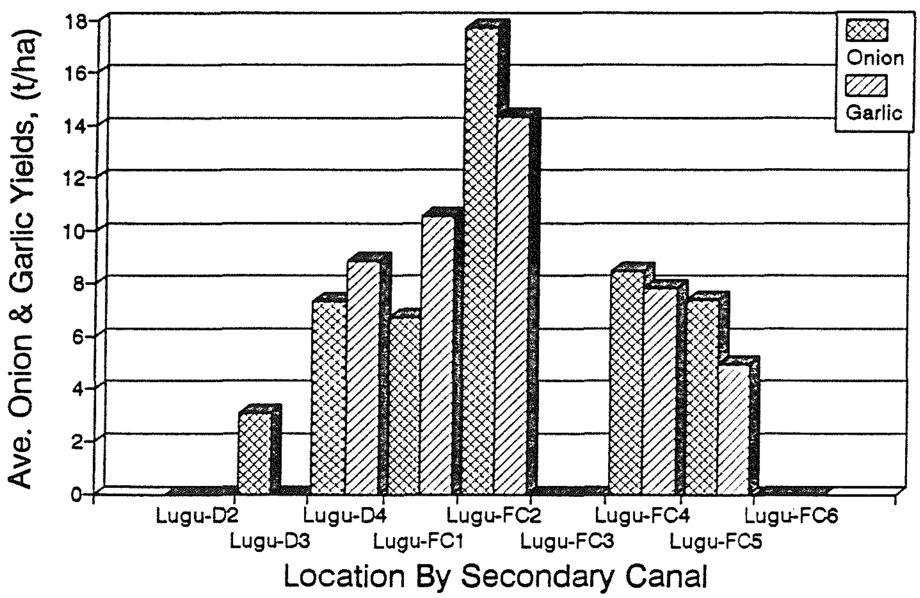


Figure9.11 Variation of onion and garlic yields along Lugu main canal

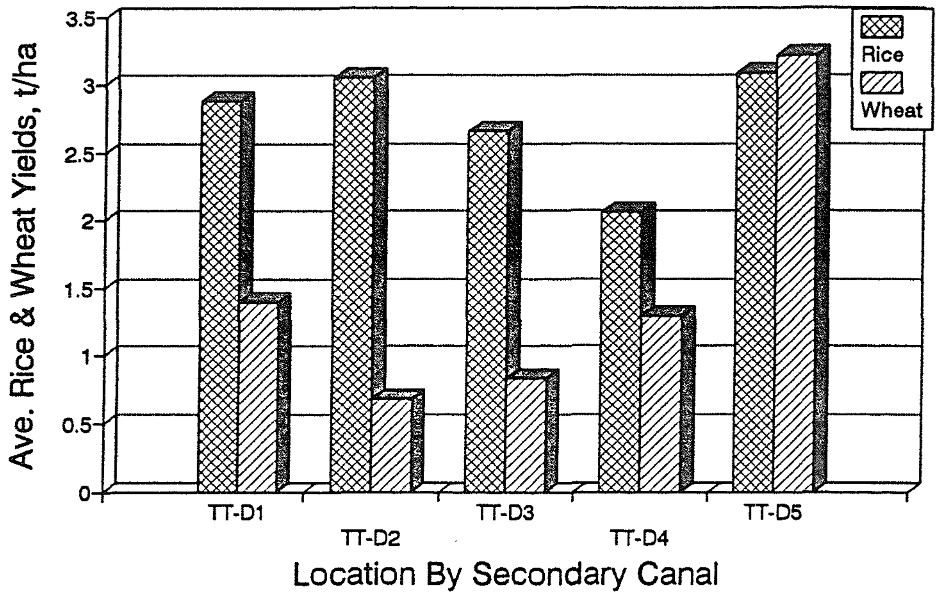


Figure9.12 Variation of rice and wheat yields along Tutudawa main canal

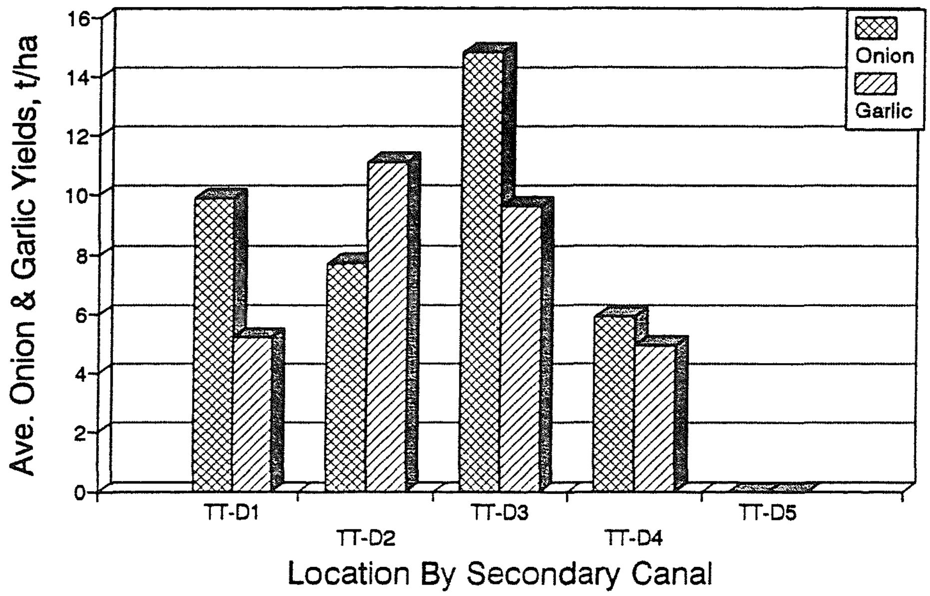


Figure9.13 Variation of onion and garlic yields along Tutudawa main canal

9.2 Farm budgets and incomes from irrigated crops

The farmers' ability to sustain irrigated farming, and to increase their investment in it is largely dependent on the level of income they generate from it, and the profitability of the irrigated crops. Their choice of which crops to grow is influenced by their perception of the relative profitability between the various crop options.

Farm budgets for individual crops were calculated to determine the relative profitability of the various crops, and to understand the priority that farmers give to them in their allocation of farm resources. The budgets are based on farmers' reported use of inputs, and crop yields for the 1991/92 cropping season. Some of the information on inputs and produce prices are also based on discussions with scheme officials, SARDA (extension) staff, and produce merchants.

The average production costs and income for the principal crops are presented in Table 9.10. The production costs include family labour and subsidized inputs from farmers practices. Apart from the cost of hiring tractors, fertilizer and water charges which are fixed, the production costs used are the averages of the values reported by farmers.

Production costs were computed for different scenarios to give an indication of returns to the various farm resources which may limit crop production. The cost of wells and pumps were taken as the annual depreciation figures of the average cost prices over a period of ten years, using the straight line method of depreciation. The average production costs were used to calculate the various margins by deducting the costs from gross income. The different scenarios of costs calculated also act as a built-in sensitivity analysis.

Two price figures were used in calculating the incomes of onion and garlic to show the effect of price variations. The yields and prices of rice and wheat were computed averages of the farmers' reports.

Table 9.10 Crop budgets for principal crops, Wurno Irrigation Scheme, 1991/92

		CROPS PER HECTARE:			
		RICE	WHEAT	ONIONS	GARLIC
LAND PREPARATION:	Ploughing	247	247	247	247
	Harrowing	148	148	148	148
	Seedbeds/Farm Ditches	618	618	618	618
PLANTING/SOWING:	Seeds	790	790	7410	7410
	Planting Labour	74	74	74	74
FERTILIZER COSTS:	# of Bags	10	10	12	15
	Price/Bag	40	40	40	40
	Total Cost	395	395	494	593
FERT. APPLICATION:	Applications	3	3	3	4
	Cost/Application	74	74	74	74
	Total Cost	222	222	222	296
PESTICIDES:		-	-	-	-
WEEDING:	# of Weedings	3	0	4	4
	Cost/Weeding	1853	0	1853	1853
	Total Cost	5558	0	7410	7410
IRRIGATION:	Irrigations	7	14	25	30
	Cost/Irrigation	99	99	99	99
	Total Cost	692	1383	2470	2964
	Water Charges	247	247	247	247
BIRD SCARING:		1976			
HARVESTING:		642	642	642	642
THRESHING:		618	618	618	618
WINNOWING:		148	148	148	148
TRANSPORTATION:		247	124	371	371
Sum of All Labour Costs Only:		10547	3705	12202	12770
	Proportion of Labour costs to Total Production Costs Without Pump (%):	84	66	58	59
EXTRA COSTS FOR USING PUMP IRRIGATION					
	Cost of Well	272	272	272	272
	Pump Cost	568	568	568	568
	Pump Repair	2347	2347	2347	2347
	Fuel & Lubrication	2223	2223	2223	2223
	Pumping Costs Without Well	5138	5138	5138	5138
	Pumping Costs With Well	5409	5409	5409	5409

Table 9.10: Continued

PRODUCTION COST CATEGORIES:	CROPS PER HECTARE: RICE	WHEAT	ONIONS	GARLIC
1 = Non-Labour Costs Without Pump:	2075	1951	8917	9016
2 = Costs at 50% Hired Labour Without Pump:	7348	3804	15018	15400
3 = TOTAL PRODUCTION COSTS WITHOUT PUMP:	12622	5656	21119	21785
4 = Costs Using Pump Without Well and Excluding Labour Costs:	7212	7089	14054	14153
5 = Costs Using Pump With Well and Excluding Labour Costs:	7484	7361	14326	14425
6 = Costs Using Pump Without Well and Employing 50% Hired Labour:	12486	8941	20155	20538
7 = Costs Using Pump With Well and Employing 50% Hired Labour:	12758	9213	20427	20810
8 = Total Costs Using Pump Without Well:	17759	10794	26256	26923
9 = TOTAL COSTS USING PUMP WITH WELL:	18031	11066	26528	27195

	RICE	WHEAT	ONIONS		GARLICS	
		Yields in Tonnes/Hectare				
AVERAGE YIELDS:	2.59	1.16	8.94		8.55	
	Price	Price	Price 1	Price 2	Price 1	Price 2
GROSS PRICES: (for onion & garlic, price 1 = at harvest, price 2 = other times)	5000	5700	2000	12000	6000	13000
			Prices in Naira per tonne			
TOTAL GROSS INCOME	12968	6617	17883	107297	51277	111101
MARGINS OVER PRODUCTION COSTS:						
1 = Margin Over Non-Labour Costs Without Pump:	10893	4666	8966	98380	42262	102085
2 = Margin Over Costs Employing 50% Hired Labour Without Pump:	5619	2813	2865	92279	35877	95700
3 = Margin Over All Costs Without Pump:	346	961	-3236	86178	29492	89315
4 = Margin Over Costs With Pump Without Well and Excluding Labour:	5755	-472	3828	93243	37124	96948
5 = Margin Over Costs Using Pump and Well But Excluding Labour Costs:	5483	-743	3557	92971	36852	96676
6 = Margin Over Costs Using Pump Without Well and Employing 50% Hired Labour:	482	-2324	-2272	87142	30739	90563
7 = Margin Over Costs Using Pump With Well and Employing 50% Hired Labour:	210	-2596	-2544	86870	30467	90291
8 = Margin Over All Costs Using Pump Without Well:	-4792	-4177	-8373	81041	24354	84178
9 = Margin Over All Costs Using Pump and Well:	-5064	-4448	-8645	80769	24083	83906

In common with most farmers surveys the figures reported may contain inaccuracies. In particular, the costing of labour may be subject to error. But every effort was made to cross check data provided. By drawing up these budgets the relative profitability of the different crops, and the basis for farmers' preference of which crops to grow is revealed. The budgets also provide a basis for amendment and fine-tuning.

From the results of the analysis wheat shows the least production cost outlay for each of the different scenarios investigated, while onion and garlic display the highest costs. The ratio of labour costs to total production costs is highest for rice. This is because rice attracts extra labour costs on bird scaring, which is not needed for the other crops. Moreover the most costly production item for onion and garlic is seeds (non-labour), without which their proportion of labour costs would be highest.

The results of the crop budgets indicate that of the main dry season irrigated crops, garlic is clearly the most profitable followed by onion. Wheat is the least profitable crop, which explains the farmers' declining interest in its cultivation. In fact wheat gives negative returns when pumping costs are considered, even without labour costs. This justifies why farmers believe that wheat production is not worthwhile with pumped irrigation. Only less than 30% of the sample farmers reported using pumps for irrigating wheat. On the other hand over 60% of the farmers who grew onion or garlic irrigated by pumping from canals or wells.

Onion is also not very profitable at typical prices during harvest, especially if total production costs without pump and production costs involving pumping and hired labour are considered. Garlic gives high profits even at the harvest time lower price, and all costs inclusive.

The margin on rice seems fairly good, especially if pumping is not involved. Fortunately, there is no need to irrigate rice by pumping. However, actual net incomes for rice are substantially less than the value of production because, apart from meeting production costs, part of subsistence needs are also met by the rice crop, thus reducing the marketable surplus. Only the dry season crops (wheat, onions and garlic) are grown solely for cash.

Storing onion and garlic to take advantage of higher prices which occur later in the season is a sensible idea, which farmers have also recognized. However, storage losses of up to 50% and possible transportation costs would have to be taken into account, which would reduce the margin. Despite this, even reducing the margin by over 50% still makes storage a worthwhile consideration for onion and garlic, rather than selling at the low harvest time prices. Unfortunately, many farmers were often constrained by their immediate cash needs to sell at the low prices. Alternative strategies for storage, processing and marketing of these crops need to be explored if the farmers are to receive more benefits.

9.2.1 Break-Even Yields

Break-even yields at various production costs and prevailing market prices, and the proportion of farmers achieving lower yields are shown in Table 9.11 and Figures 9.14 to 9.16. The production costs were chosen within the scope of the various cost categories investigated in the budget analysis. The proportion of farmers achieving lower yields is a percentage of the samples of those growing each of the different crops.

The results of these analyses demonstrate again that wheat farmers have the highest proportion of those liable to lose at the high production costs. About 93% of the wheat sample farmers achieved less yields than the threshold yields required to break-even at the total production costs including pumping and well. Even excluding pumping costs, over 50% of farmers would be loosing money if they had paid for all inputs and labour used in wheat cultivation. The mean return to wheat does not provide a very attractive reward for farmers' inputs, especially considering the additional risks and uncertainties about water supply, availability of inputs, and lack of markets.

Table9.11 Break-even yields and proportion of farmers achieving lower yields for the principal crops

PROD. COSTS (Rice/Wheat) Naira/Ha	RICE Break-Even Yields (t/ha)	Rice % of Farmers with Lower Yields	WHEAT Break-Even Yields (t/ha)	Wheat % of Farmers with Lower Yields	PROD. COSTS (Onion/Garlic) Naira/ha	ONION Break-Even Yields (t/ha) Price 1	Onion % of Farmers with Lower Yields Price 1	ONION Break-Even Yields (t/ha) Price 2	Onion % of Farmers with Lower Yields Price 2	GARLIC Break-Even Yields (t/ha) Price 1	Garlic % of Farmers with Lower Yields Price 1	GARLIC Break-Even Yields (t/ha) Price 2	Garlic % of Farmers with Lower Yields Price 2
2000	0.4	0.7	0.35	3.8	7500	3.75	12.7	0.63	0.0	1.25	0.0	0.58	0.0
3000	0.6	2.1	0.53	18.9	9000	4.50	12.7	0.75	0.0	1.50	0.0	0.69	0.0
4000	0.8	3.5	0.70	20.8	10500	5.25	21.8	0.88	0.0	1.75	2.5	0.81	0.0
5000	1.0	4.9	0.88	35.8	12000	6.00	25.5	1.00	0.0	2.00	2.5	0.92	0.0
6000	1.2	6.3	1.05	45.3	13500	6.75	34.5	1.13	0.0	2.25	2.5	1.04	0.0
7000	1.4	11.3	1.23	52.8	15000	7.50	49.1	1.25	0.0	2.50	10.0	1.15	0.0
8000	1.6	14.8	1.40	77.4	16500	8.25	52.7	1.38	0.0	2.75	10.0	1.27	0.0
9000	1.8	16.9	1.58	79.2	18000	9.00	58.2	1.50	0.0	3.00	10.0	1.38	0.0
10000	2.0	29.6	1.75	86.8	19500	9.75	58.2	1.63	0.0	3.25	10.0	1.50	0.0
11000	2.2	32.4	1.93	90.6	21000	10.50	76.4	1.75	0.0	3.50	12.5	1.62	0.0
12000	2.4	39.4	2.11	92.5	22500	11.25	83.6	1.88	0.0	3.75	15.0	1.73	2.5
13000	2.6	60.6	2.28	92.5	24000	12.00	83.6	2.00	1.8	4.00	15.0	1.85	2.5
14000	2.8	65.5	2.46	92.5	25500	12.75	89.1	2.13	1.8	4.25	15.0	1.96	2.5
15000	3.0	69.0	2.63	94.3	27000	13.50	89.1	2.25	1.8	4.50	15.0	2.08	2.5
16000	3.2	77.5	2.81	96.2	28500	14.25	90.9	2.38	1.8	4.75	15.0	2.19	2.5
17000	3.4	79.6	2.98	96.2	30000	15.00	90.9	2.50	5.5	5.00	17.5	2.31	2.5
18000	3.6	81.7	3.16	98.1									
20000	4.0	89.4	3.51	100.0									

Note:- The market prices (in Naira) from which the break-even yields have been calculated are as follows: Rice = N5000/tonne; Wheat = N5700/tonne; Onion Price 1 = N2000/tonne; Price 2 = N12000/tonne; Garlic Price 1 = N6000/tonne and Price 2 = N13000/tonne. For Onion and Garlic Price 1 is farm-gate price at harvest and Price 2 is what obtains at other times in the season when production is not common.

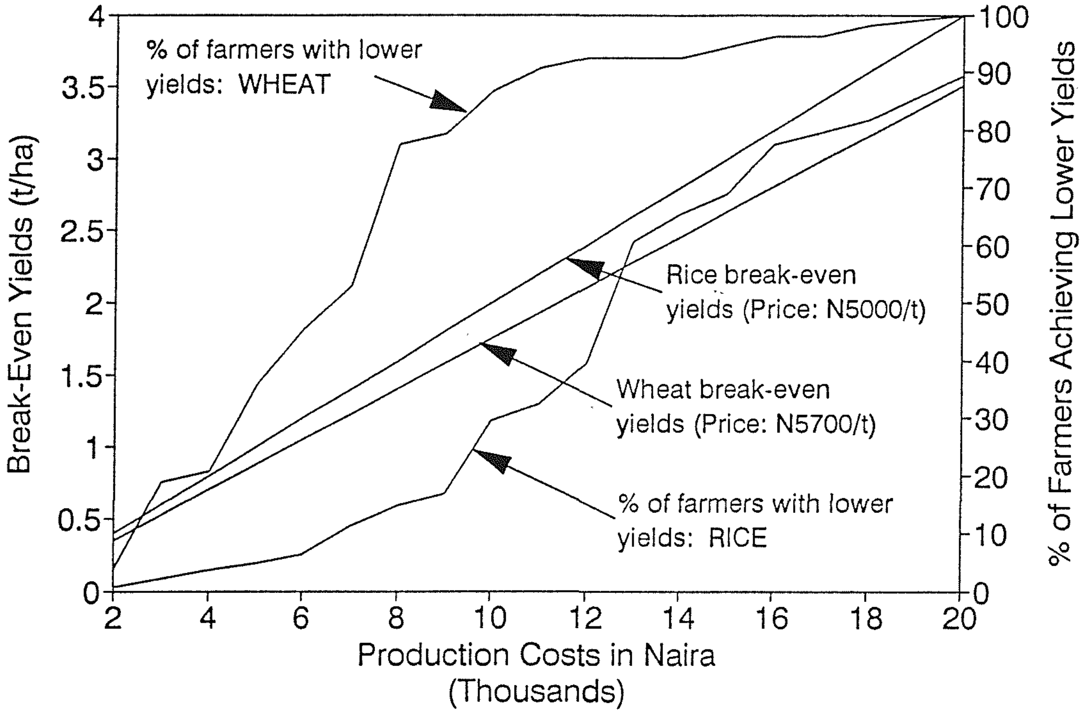


Figure9.14 Break-even yields and proportion of farmers achieving lower yields for rice and wheat

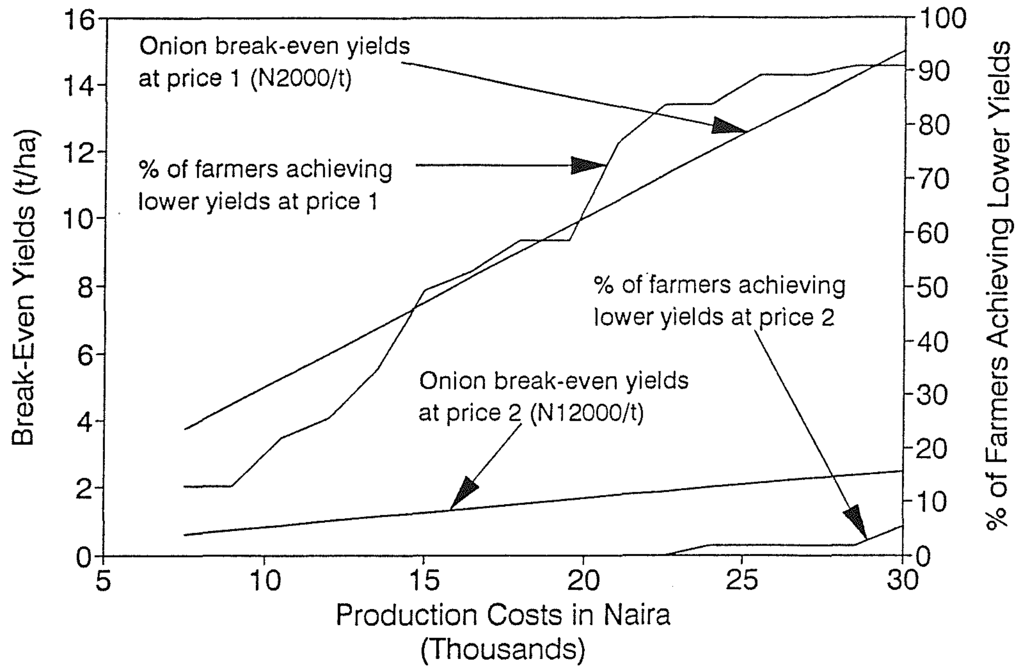


Figure9.15 Break-even yields and proportion of farmers achieving lower yields for onion

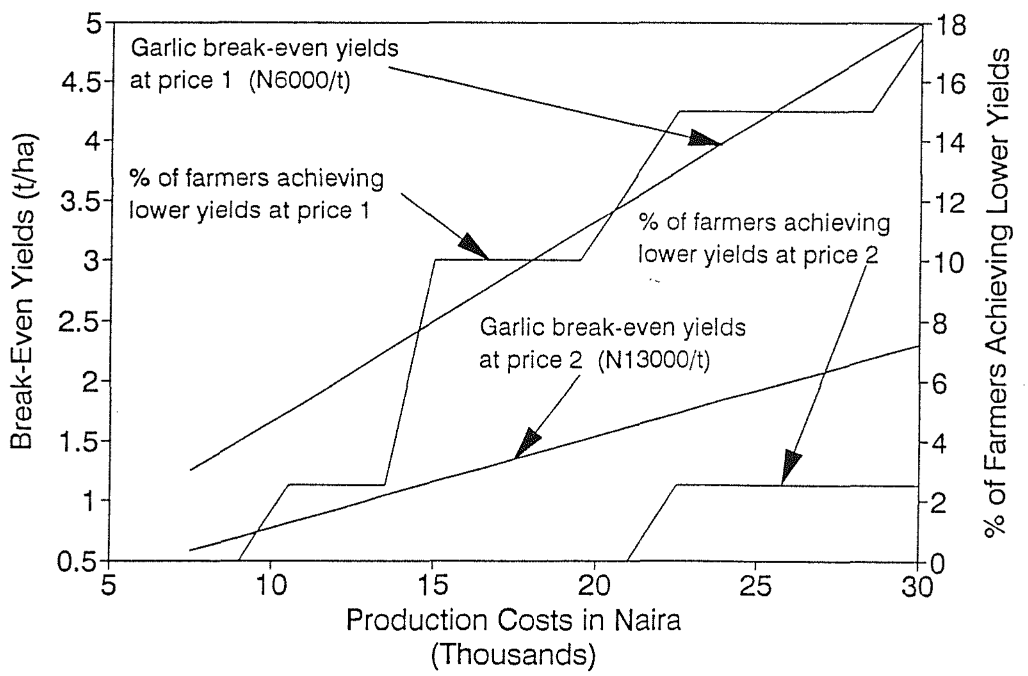


Figure9.16 Break-even yields and proportion of farmers achieving lower yields for garlic

In the case of rice, the break-even yields at the highest production costs (without pumping) coincides with the average rice yields (2.6 t/ha), with about 61% of rice farmers attaining lower yields. These results highlight the need for improved yields for rice, but most particularly for wheat.

Onion and garlic present better results, especially at the higher prices. About 90% of onion farmers would be losing if they produced at the high costs involving pumping and wells and sold at the low harvest time price. As for garlic, even at the highest production costs and lower price, only 15% of the farmers achieved lower than the break-even yields. At the higher prices, the proportion of farmers achieving lower than break-even yields at the highest production costs for onion and garlic drops to a maximum of 2.5%. This reinforces the need for stabilizing the prices of these crops in order that farmers receive more benefits.

9.2.2 Concluding remarks

In conclusion, it is pertinent to note that despite the subsidies provided by the government, mostly on fertilizer, low profitability is one of the major reasons for farmers' waning interest in irrigated farming, particularly wheat. Unless irrigated farming becomes more profitable to attract farmers from other occupations to devote more resources to dry season irrigated farming, it is doubtful whether the existing low dry season cropping intensities and low system performance will be improved.

The main causes of low profitability to farmers are low yields for rice and wheat, and unstable prices for onion and garlic. The average wheat yields of 1.2 t/ha would need to be increased to a threshold of at least about 2 t/ha for it to be profitable. The single most important factor affecting wheat yields is time of planting. Other factors affecting the productivity of wheat include availability of inputs and guaranteed markets, and farmers cultural practices (weeding). There is need to address these constraints and look at measures to improve them.

CHAPTER 10: APPLICATION OF PERFORMANCE INDICATORS AND IDENTIFICATION OF CAUSES OF POOR PERFORMANCE

This chapter describes the performance indicators applied to the Wurno Irrigation Scheme (WIS) which relate to the inputs, processes and outputs of the system. The data requirement and computation methods for these indicators are outlined and their values for the scheme are summarized in Tables 10.1 and 10.2. The chapter also discusses the causes of low performance encountered on the scheme.

10.1 Performance and Performance Indicators

Performance indicators give a quantified picture of the levels of achievement in an irrigation scheme with respect to set objectives, targets or expectations. They enable one to produce figures that can support a qualitative analysis.

A series of indicators were applied to the WIS during the 1991/92 season as shown quantitatively in Table 10.1 together with notional normal levels, and qualitatively in Table 10.2. The normal values for the indicators have been derived from conventional irrigation practice, previous studies, and figures assumed to be reasonably achievable at the scheme. Some of the values were reportedly being achieved within the scheme and other nearby similar irrigation schemes.

Table 10.2 presents a checklist for a qualitative assessment of the issues identified at the WIS. This includes the indicators in Table 10.1 and other variables which are not easily quantifiable, yet give an indication of performance at the scheme. The Table provides an overall picture of the existing conditions in Wurno at a glance.

The results in Tables 10.1 and 10.2 show that the values of the indices in the WIS are mostly deficient. A description of each indicator and the significance of its value for WIS are discussed below.

Table 10.1 Comparison of performance indicators between actual and notional normal levels for the Wurno Irrigation Scheme; 1991/92 season.

	PERFORMANCE INDICATORS		TYPE OF INDICATOR[6]	EXPECTED OR NORMAL VALUE	ACTUAL VALUE FOR WIS.
1.	Scheme Development Ratio, SDR.		P	100%	66.7%
2.	Water Availability Index, WAI.		I	2 - 5	50
3.	Efficiency of Main System Capacity, EMSC.		I	100%	70%
4.	Scheme Command Area Capacity, SCAC.		I	100%	62%
5.	Extent of Main System Flow Lengths, EMSFL.		I	100%	55%
6.	Structures Condition Index, SCI.		I	100%	11%
7.	Environmental Stability Index, ESI.		O	90 - 100%	87.5%
8.	Crop Planting Date Indicator (WHEAT), CPDI (Research Recommendation: November)		P	100%	43%
9.	Cropping Intensity, CI.		O	190%	105%
10.	Mean Crop Yields, CY.	a. Rice: b. Wheat: c. Onion: d. Garlic:	O	3 t/ha 2.5 t/ha 12 t/ha 12 t/ha [7]	2.60 t/ha 1.16 t/ha 8.94 t/ha 8.55 t/ha
11.	Crop Yield Variation due to Cultural Practices, CYVCP (for WHEAT)		P	0[8]	70%[9]
12.	Total Manpower Numbers Ratio per 1000ha, MNR.		I	6 [10]	20
13.	Manpower Quality Ratio, MQR.	a. Professional: b. Middle level: c. Vocational: d. Unskilled:	I	2 3 1 0 [11]	0 3 5 11
14.	Scheme Financial Autonomy Factor, SFAF		P	50%	0%
15.	Scheme Financial Self-sufficiency Factor, SFSF.		P	>= 100%	40%
16.	Maintenance Budget ratio, MBR.		I	62%[12]	16%
17.	Fees Recovery Rate, FRR.		O	90 - 100%	80%
18.	Efficiency of Roads Passibility, ERP.		I, O	100%	80%

[6]Relates to Inputs (I), Processes (P) or Outputs (O)

[7]The expected crop yields are values which some farmers have achieved on the Wurno project. Thus, they are potentially achievable yields. Figures from experimental stations might be higher

[8]There are no standards available, but generally crop yields under experimental conditions are often assumed to be unconstrained by cultural practices.

[9]Due to weeding, water source and irrigation experience.

[10]Based on rehabilitation plans of 1991 which also ties in with a manpower plan for irrigation schemes in Nigeria (**Carter et al., 1986**).

[11]Figures based on proposed staffing arrangements after rehabilitation in 1991.

[12]Average value reported for 17 irrigation projects in the United States of America (**Allen and Brockway, 1977**).

Table 10.2 Qualitative checklist of identified performance measures at the Wurno Irrigation Scheme; 1991/92.

PERFORMANCE MEASURES	VERY POOR	POOR	ADEQUATE	GOOD
1. Scheme Development Ratio				■
2. Water Availability Index		■		
3. Efficiency of Main System Capacity		■		
4. Scheme Command Area Capacity		■		
5. Extent of Main System Flow Lengths		■		
6. Structures Condition Index	■			
7. Environmental Stability Index			■	
8. Crop Planting Date Indicator (WHEAT)		■		
9. Cropping Intensity		■		
10. Mean Crop Yields, CY. a. Rice:			■	
b. Wheat:	■			
c. Onion:			■	
d. Garlic:			■	
11. Crop Yield Variation due to Cultural Practices (WHEAT)				■[13]
12. Total Manpower Numbers Ratio		■		
13. Manpower Quality Ratio		■		
14. Scheme Financial Autonomy Factor	■			
15. Scheme Financial Self-sufficiency Factor		■		
16. Maintenance Budget ratio	■			
17. Fees Recovery Rate				■
18. Efficiency of Roads Passibility			■	
19. Land Levelling		■		
20. Administrative Corruption		■		
21. Staff Motivation and Incentives	■			
22. Land Tenure	■			
23. Mechanization		■		
24. Availability of Farm Inputs		■		
25. Farmer Participation		■		

[13] The value achieved (70%) for this indicator is good in that it identifies 70% of the cause of variation in wheat yields. Once causes are known solutions can be found.

1 Scheme Development Ratio, SDR:

$$\frac{A_{dev}}{A_p}\times 100\%$$

A_{dev} = Total area of the scheme actually developed and provided with irrigation facilities, ha.

A_p = Potential irrigable area within the scheme earmarked for development, ha.

In a phased development, as is common in irrigation schemes, this ratio reveals the proportion of the area developed in terms of the total planned or potential irrigable scheme area at any point in time. This is important because irrigation projects often start with water resources development. As a result, for schemes which have not yet been exploited to their maximum potential, the evaluation of this index during operation gives an indication of under-utilization and relative abundance of water resources while the full development of the scheme is delayed.

Scheme Development Ratio (SDR) needs to be evaluated from time to time to provide historical records of the rate and trends of developments. If SDR is dropping or continues to be less that the maximum proposed value it is an indication of inability to meet proposed development plans. To date only two-thirds of the proposed area for the Wurno Irrigation Scheme has been developed.

2 Water Availability Index, WAI:

$$\frac{W_a}{W_d}\times 100\%$$

W_a = Total amount of water available from the scheme water supply sources, m^3/yr.

W_d = Scheme water needs to meet crop water requirements for the highest planned cropping intensity, m^3/yr.

The water availability index shows the relative scarcity of water supplies available for an irrigation scheme. This is vital for management and water allocation policies. When more than one irrigation scheme share the same water source, W_a is taken as the stipulated quotas for each project. Where a scheme has more than one official source of water, W_a could be derived by summing the individual supply from each of the sources. Crop water requirements are calculated on the basis of the highest expected cropping intensity with allowance for all possible losses.

At Wurno the value of the Water Availability Index (WAI) which portrays the relative scarcity or abundance of water shows that the available water at the source is adequate. This indicates that water supply is not a constraint to production.

3 Efficiency of Main System Capacity, EMSC:

$$\frac{C_a}{C_d} \times 100\%$$

C_a = Actual limiting canal capacities at typical sections of the main system, m^3/s.
C_d = Designed canal capacities for same sections, m^3/s.

Due to poor maintenance the capacities of irrigation distribution canals is often reduced as a result of siltation, breaches, weeds and soil erosion, etc. This indicator reveals the extent to which performance of the scheme is limited by system capacity. The information required here includes survey data of the main system canals and an assessment of the weed conditions. Such surveys at Wurno show that the capacity of the main system canals is reduced by about 30%.

4 Scheme Command Area Capacity, SCAC:

$$\frac{A_c}{A_{dev}} \times 100\%$$

A_c = Scheme total area commanded by gravity flow, ha.
A_{dev} = Total developed irrigable area, ha.

This indicator represents the fraction of irrigable developed area that is commanded by gravity flow where nearly 100% of the scheme is intended to be irrigated as such. However, there is sometimes a policy and design choice not to carry out land levelling to provide command for localized high spots, but farmers often end up attempting to irrigate such 'uncommanded' areas by lifting. In addition, due to poor O & M of the scheme some areas which were originally commanded by gravity become out of command. Thus, this indicator gives the proportion of 'disadvantaged' areas where lifting becomes necessary to provide irrigation water from the canals. Only 60% of the WIS is commanded by gravity flow.

5 Extent of Main System Flow Lengths, EMSFL:

$$\frac{L_a}{L_d} \times 100\%$$

L_a = Actual length of canals sections still flowing, km.
L_d = Total length of main system canals constructed, km.

This measure also demonstrates the practical limitations of the system in supplying water as required. As existing irrigation systems deteriorate, it becomes impossible to get canal water or even drainage to flow in certain areas. Thus, this index reveals the extent of constraint imposed by the inability of the canals to flow in some parts of the system. Nearly half of the lengths of the main system canals at Wurno can no longer flow.

6 Structures Condition Index, SCI:

$$\frac{N_g}{N} \times 100\%$$

N_g = Actual number of structures in good condition (safe, working normally, and attaining design standards).
N = Total number of structures constructed within the system.

Conveyance, regulatory, protective and water measurement structures play an important role in the effective operation, control and equitable distribution of water in irrigation schemes. When they are no longer in a condition to serve their intended purposes, the performance of the system is likely to be affected. Hence the proportion of structures in good working order gives an indication of the degree of control possible. At Wurno only 11% of the irrigation scheme structures are in effective operational condition.

7 Environmental Stability Index, ESI:

$$\frac{A_{af}}{A_{dev}} \times 100\%$$

A_{af} = Total scheme area not affected by environmental problems of waterlogging, salinity, erosion, etc., ha.[14]
A_{dev} = Total developed irrigable area (net command area), ha.

For sustainable development and productivity of irrigation schemes, adverse environmental impacts ought to be minimized. In this context, the emphasis is on the conservation of the natural environment. Early indication of environmental damage is important in order to minimize the cost of remedial actions or permanent loss of natural resources. It is crucial to set standards for water quality, salinity, soil erosion, etc. against which to monitor environmental stability. Thus, performance assessment of irrigation schemes should reveal the effects of the system on the environment. The situation at Wurno is not yet acute regarding adverse environmental impact, but problems of waterlogging and salinity are said to be on the increase.

8 Crop Planting Date Indicator, CPDI:

$$\frac{N_p}{N} \times 100\%$$

N_p = Number of farmers planting within the recommended planting period for a specified crop in a season.
N = Total number of farmers engaged in irrigated cultivation for the season.

[14] Standards may be set for environmental stability, such as to say not more than 10% of scheme area to be affected by these problems.

For weather sensitive crops, such as wheat, the period of planting is critical for their performance and yields. Thus, it is important to give an indication of the distribution of planting dates among farmers for such crops. This could explain the level of production and yields. The degree of farmers compliance to recommended planting dates may reflect their disposition to adopt improved technologies, or it may reveal their problems with following recommended agricultural practices due to circumstances beyond their control. At Wurno the latter is the case and only about 40% of wheat farmers plant within the recommended period.

9 Cropping Intensity, CI:

$$\sum_{1}^{n} \frac{A_{pn}}{A_{dev}} \times 100\%$$

A_{pn} = Total area planted for the season, ha.
A_{dev} = Total developed irrigable scheme area, ha.
n = Number of cropping seasons per year.

Cropping intensity is the ratio of the sum of crop areas for all the cropping seasons in a year and the scheme developed area. It could reveal the capacity of the system to supply water to the entire command area, or part thereof, for each cropping season in a year; or it could indicate the farmers' willingness and ability to do multiple cropping in a year.

Other variants of crop intensity include 'area utilization' and 'irrigation intensity' which are defined as the ratio of cropped area to scheme command area per crop season. The use of cropping intensity which is based on a calendar year is preferred as it provides a more consistent definition. The cropping intensity provides an indication of how effective the management of the scheme has been, not only in supplying irrigation water, but also in convincing the farmers of the importance of planting according to the planned schedules.

The value of Cropping Intensity (CI) shows that only 55% of the proposed cropping intensity is being attained at Wurno.

If the comparison were made by seasons, the dry season cropping intensity index would be even lower, about 10 - 15%.

10 Average Crop Yields, CY:

$$\frac{Y_i}{A_i}$$

Y_i = Total seasonal production of crop i, tonnes.
A_i = Total area planted to crop i, ha.

The average crop yields for any crop in a season is commonly defined as the gross production weight divided by the total area harvested in a season. **Abernethy (1986)** argues that the primary purpose of an irrigation project is to enhance the production of food and fibre, and it is on the basis of its agricultural output that it ought, first and foremost, to be assessed. Various methods exist for determining crop yields, including crop cuttings, and farmers' estimates. Values of crop yields at Wurno indicate that the average yields of rice, onion and garlic are fair, but wheat yields are poor, only at 46% of achievable yields.

11 Crop Yields Variation due to Cultural Practices, CYVCP:

This index highlights the degree to which farmers' cultural practices such as weeding, irrigation experience, frequency of water application, planting date, fertilizer inputs, and farm size affect crop yields. Under experimental conditions these factors are normally maintained at optimal levels so as not to constrain yields. However the actual situation under farmers' practices is often different.

The evaluation of this index can be achieved by the application of correlation and regression analysis. At Wurno it was found that 70% of the variation in wheat yields could be explained by the differences in number of weedings, source of irrigation water, and farmers' irrigation experience. This figure is high, indicating a good identification of causes of poor yields.

12 Manpower Numbers Ratio, MNR:

$$\frac{N}{A_{dev}}$$

N = Total manpower numbers for O & M of the system.
A_{dev}= Total developed irrigable area, ha.

There are no generally accepted standards for manpower numbers for the management, operation and maintenance of irrigation schemes. As discussed in Section 8.1.1, it varies widely from country to country, and from scheme to scheme. However, this measure indicates the efficiency of utilization of human and financial resources in the agency responsible for the management of an irrigation scheme. At Wurno the value of total manpower numbers suggest that the scheme is over-staffed, particularly with low quality personnel.

13 Manpower Quality Ratio, MQR:

$$\frac{N_p}{N}\times 100\%$$

N_p = Number of professional (graduate) and middle level (HND) personnel employed in the scheme.
N = Total manpower numbers for O & M of the system.

The quality and motivation of the manpower responsible for the management, operation and maintenance of an irrigation scheme is a strong indicator of its potential to attain high or low performance. This cannot be easily measured, but the qualifications and skills of the personnel responsible for these functions are among the most important variables.

14 Scheme Financial Autonomy Factor, SFAF:

$$\frac{F_s}{F_g}\times 100\%$$

F_s = Amount of scheme income retained by the managing agency.
F_g = Amount passed to central or provincial government.

It is widely believed that there is greater potential to improve irrigation performance if the agency responsible for management has significant degree of financial control over internally generated revenue rather than being dependent upon the central government for its budget. A study by the IIMI **(ADB, 1986)**, found that financial autonomy is almost always partial, as irrigation agencies generally receive subsidies from the government budget. However, it is generally felt that financial autonomy could lead to better performance of systems through increased accountability of the managers to water users, and through greater participation of the farmers in O & M. Hence a degree of financial autonomy is desirable for irrigation schemes, at least at 50%. When the irrigation fees collected go to the government treasury as part of the general revenues to be allocated through the normal budgetary process, there tends to be suspicion and reluctance on the part of farmers to pay their dues. The managing agency in the Wurno scheme has no degree of financial autonomy.

15 Scheme Financial Self-Sufficiency Factor, SFSF:

$$\frac{I}{C} \times 100\%$$

I = Total annual scheme income from water charges and diverse other revenue sources.

C = Total annual O & M costs.

This factor relates to the ability of the system to sustain itself financially with respect to regular O & M costs. Poor financing results in low staff and farmers incentives, and hence poor operation and maintenance. This ultimately affects water deliveries and overall system performance. Irrigation schemes which are able to generate internal revenues up to, or above their O & M costs are more viable. In addition, they are more likely to be better funded, even when they are not financially autonomous.

It is desirable for schemes to recover 100% of their O & M costs from direct beneficiaries/farmers, or at levels at least commensurate with the benefits received **(ADB, 1986)**. Schemes which are self-financing have more accountability and higher efficiency of resource utilization. The data required to estimate this factor could be obtained from accounting and billing offices of the scheme managing agency. The study of the Wurno Irrigation Scheme reveal that only 40% of its O & M costs are being generated internally.

16 Maintenance Budget Ratio, MBR:

$$\frac{M_m}{M_t} \times 100\%$$

M_m = Amount of annual recurrent expenditure actually applied to maintenance of the scheme.
M_t = Total annual recurrent O & M expenditure.

In many countries a major portion of the O & M budget is spent on personnel (operation) at the expense of maintenance and repair of the irrigation infrastructure. Maintenance, which is often a neglected item, needs to have a fixed quota. This could be done by taking into account the variations in hydrometeorlogical, physical and socio-economic conditions, and the maintenance requirements in any particular system. There are no generally accepted rules for maintenance budget ratio. However, a study of 17 irrigation projects in Idaho (USA) found that maintenance costs averaged 62% of the total O & M budgets **(Burton, 1993; Allen & Brockway, 1977)**. The maintenance budget ratio at Wurno signifies that only 16% of the total O & M expenditure is actually applied to repair and maintenance of the physical infrastructure. Over 80% of the budget is spent on operational costs, mainly staff salaries.

17 Irrigation Service Fees Recovery Rate, ISFRR:

$$\frac{W_c}{W_a} \times 100\%$$

W_c = Annual amount of water charges collected.
W_a = Total annual amount of water charges assessed.

The proportion of irrigation service fees collected out of the total assessed amount is a measure of the performance of the management as well as the willingness of the water users to pay. The willingness of the farmers is largely influenced by their satisfaction with the quality of service provided by the irrigation system. The funds generated from irrigation service fees depends both on the amount levied and on the recovery rate. Setting of fees levels is usually a political decision. The amounts levied may or may not be at the correct levels to meet total O & M costs even if 100% recovery is achieved. Water pricing per volume is the fairest way of charging for irrigation service fees. However, this method is not common because of the relatively high costs and administrative difficulties in applying it in irrigation systems consisting primarily of a large number of small farmers. Thus, direct charging by rates per unit area irrigated is the most common method in use.

It can be observed that the fees recovery ratio for the WIS is relatively high, at 80%. This is partly because the present rate of water charge is low, at only ₦100.00/acre ($12.50/ha). However, the income generated from water charges represents only about 40% of current scheme O & M expenditure. When it is taken into account that the current levels of expenditure themselves are low, the actual proportion of fees generated for O & M are extremely low. Fees recovery is an output measure reflecting the level of service, but at Wurno another reason farmers pay their water charges promptly is due to fear of expulsion from the scheme. This indicates their desire to remain in the scheme. There is a proposal to raise the water charges to over ₦1000.00 per acre after rehabilitation to make the scheme self-financing. In view of the low profit margins for some of the irrigated crops (as discussed in Sections 8.4 and 9.2), it may not be possible to attain such high recovery rates when the fee is increased to these new levels.

18 Efficiency of Roads Passibility, ERP:

$$\frac{R_a}{R_d} \times 100\%$$

R_a = Actual length of roads which has all year round accessibility, km.

R_d = Total length of scheme constructed roads, km.

Roads are constructed around and within an irrigation scheme for the purposes of accessibility to farms, inspection and maintenance, and transportation of farm produce. Thus they are inputs as well as outputs. Ideally they should remain passible all year round to serve the intended objectives. In practice some roads in irrigation schemes, or parts of them, often have limited access at certain times of the year, due to factors such as rainfall, erosion, an waterlogging. This performance measure, therefore, indicates the degree of such problems and the extent access around the scheme is limited. The situation at Wurno is satisfactory except for some stretches of the Lugu-Wurno main road which are often washed away by gully erosion.

10.2 Discussion of causes and effects of poor performance at WIS

Poor quality of irrigation infrastructure and the structure for management have detrimental effects on water control, distribution, and overall system performance. Management and farmers are sometimes able to cope with the increased pressures from quality defects. Occasionally even farmers alone get round such problems by adjusting the infrastructure themselves. However, there is a limit to which these constraints can be overcome.

Physical quality defects introduce a tightrope balance which could lead eventually to total failure of the system. This reaction is often encouraged by the resulting deterioration in social cohesion among farmers **(Huibers & Speelman, 1989)**. When this is compounded with weak management and unfavourable institutional and socio-economic conditions low performance is bound to ensue. The case of the Wurno Irrigation Scheme discussed below confirms these assertions.

10.2.1 Physical conditions

Natural and environmental factors, as well as technical infrastructural defects in the Wurno Irrigation Scheme placed severe pressure on its effective operation and performance.

10.2.1.1 Infrastructural deficiencies

Canals and Drainage network

Although it is obvious that adequate water is available in the scheme reservoir and the upstream Goronyo dam, it is not possible to effectively distribute it around the scheme. The main limitations are due to lack of canals, inadequate canal capacities, and low command. Most of the tertiary canals and drains have disappeared, and it is practically impossible for water to reach some tail-end areas. Even the primary and secondary canals cannot flow for their entire lengths (see Figure 10.1).

Canal capacities in areas still flowing are typically low and incapable of adequately supplying their intended command areas. Attempts at releasing more water into the canals result in over-topping of banks. Command water levels in the canals still flowing are also low. Hence, in some areas farmers have to lift from canals and drains to be able to irrigate their fields.

The main causes of the above problems include erosion, sedimentation, weeds, breaches, low bed levels, and flat embankments. It is also apparent that the original designs were inadequate. This problem has been exacerbated by attempts to develop new areas without due regard to increasing the system canal capacities.

Canal and Drainage Structures

The irrigation structures in the WIS are insufficient to serve the desired functions. Indeed, the level of water control made possible by canal structures in the scheme is very low as most of them have disappeared, collapsed, or are being by-passed. All control gates at secondary or tertiary canal intakes have disappeared. Once water is released into the main canals, it flows freely as directed by farmers or by natural gravity, resulting in much wastage and waterlogging. Faulty construction, inadequate maintenance, cattle trampling and farmers' ignorance of the use of certain structures are the major causes of the poor condition and use of control structures.

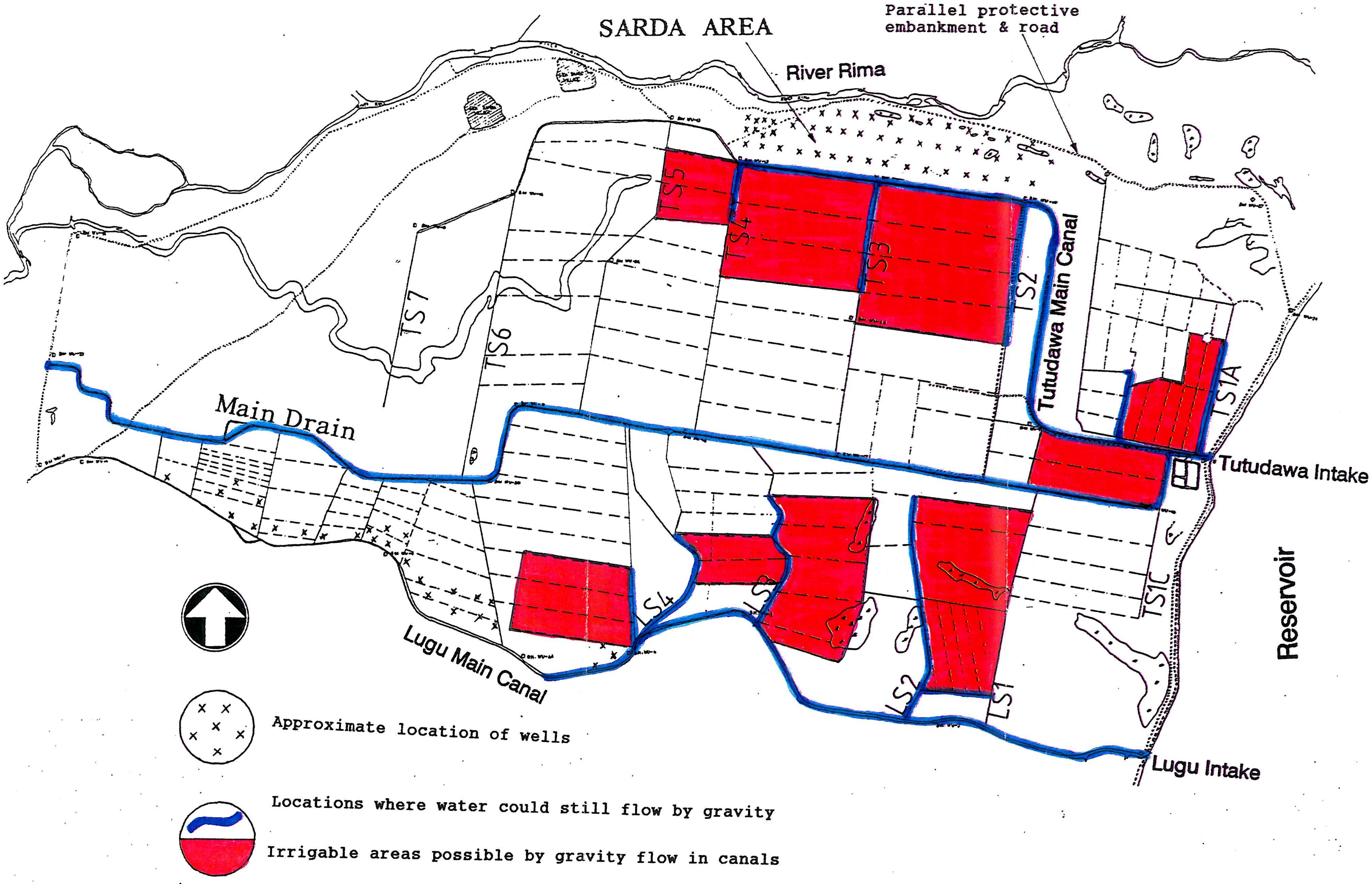


Figure10.1 Wurno irrigation scheme lay-out showing extent in main system to which water could still flow by gravity, May 1992

Field Levels

Field levels are uneven due to lack of land levelling as a result of a policy and design choice to keep construction costs low. Farmers are expected to level their fields to suitable grades, but this is not always possible. This situation forces farmers to subdivide their fields into small plots (basins) of about 3 x 5 m in order to irrigate their crops. Elevation differences of 10 - 40 cm were recorded within farmers fields. This has multiple adverse effects, including:

- Uneven water application
- High water consumption and low application efficiency
- Complicated and time consuming irrigation
- Laborious on-farm construction and maintenance works
- Unequal distribution of production costs among farmers
- Discontentment among farmers about worst affected areas
- Drainage problems.

10.2.1.2 Natural and environmental constraints

The physical terrain and topographical conditions in the WIS impose a high maintenance demand if it is to perform well. These are due mainly to erosion hazards from the escarpment of the Wurno hills to the south, and dangers of floods and waterlogging from the Rima river to the north and west.

The soils on the escarpment are highly erodible, and because they discharge their run-off in the direction of the scheme, erosion impact is considerable (see Plate 10.1 - 10.2). The escarpment is too steep and unsuitable for erosion control vegetation. Thus, a cut-off drain was constructed to control the run-off and protect the Lugu main canal and adjacent Wurno/Lugu road. This has been filled up. Consequently, about 20 ha of the areas directly along the escarpment have been badly affected with washed away roads and canals, with debris and sediments flowing onto the fields.

Plate10.1 A Typical storm run-off stream from the escarpment towards the Lugu main canal

Plate10.2 Gully erosion on the Wurno hills

The course of the Rima river to the north and west of the scheme is extremely unsteady with many bends. This presents the threat of the river breaching its bank and the protective embankment which was constructed parallel to its alignment to keep off floods from the scheme. With the construction of the upstream Goronyo dam this threat is reduced but not eliminated, especially when there are heavy rainstorms and large releases from the Goronyo dam. High water levels in the river also affect drainage conditions in the scheme.

The environmental problems of waterlogging and salinity have developed in the WIS over time due to improper practices. Waterlogging was a result of a combination of poor drainage network, inadequate water control, and canal leakages and breaches. Figure 10.2 shows the waterlogged areas in the scheme as at April 1992, due largely to the Lugu main canal which was leaking at the rate of about 0.2 m^3/s and breaches. Plates 10.3 and 10.4 illustrate breaches on the two main canals which were caused by farmers and cattle crossings. Since the system is poorly connected to the drains, it is difficult for any excess water on the fields to be drained. Breaches cause losses, waterlogging, and considerable difficulties in getting water downstream. Flow measurements revealed that about 50% of water in the Tutudawa main canal is lost in conveyance over about 2 km as a result of breaches and seepage between the intake and TS2 secondary.

The salinity problem is also building up due to waterlogging and high water tables. Some areas of the scheme have been deserted due to excessive waterlogging and salinity while others have reduced productivity. Figure 10.3 presents an overview of the salinity problem as at April 1992. Random soil samples analyzed for electric conductivity show that the soil is moderately to strongly affected by salinity ($EC_{1:2}$ > 8 mmhos/cm). Tests from seemingly unaffected areas show slight effects ($EC_{1:2}$ < 8 mmhos/cm). The total area affected by salinity is estimated to be about 60 ha in various patches. The effect of salinity on crops in the affected areas is obvious as can be seen on Plate 10.5. Improved drainage and good irrigation practices are effective means of reviving the soil fertility and ensuring sustained production.

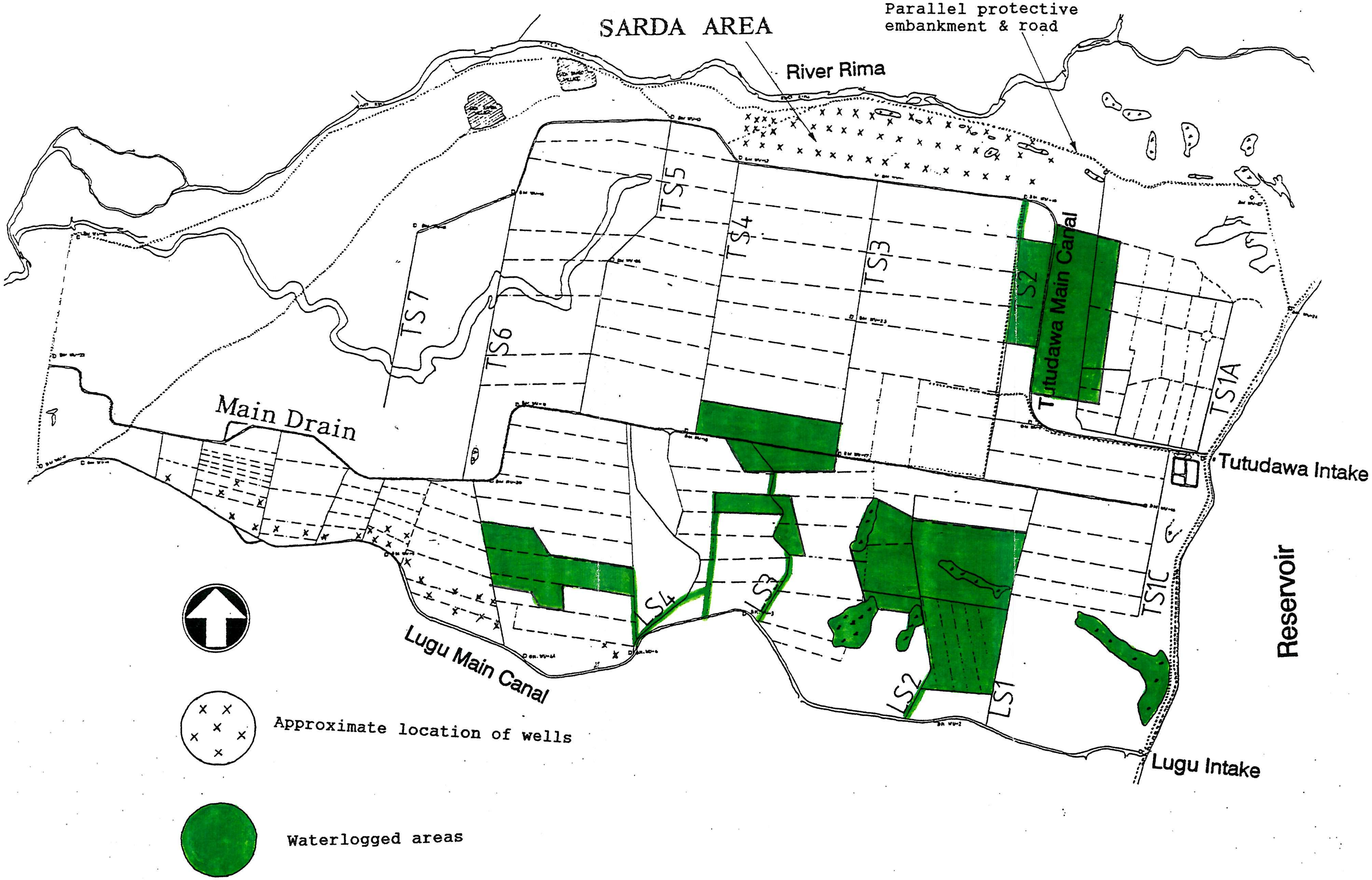


Figure10.2 Wurno irrigation scheme lay-out showing waterlogged areas, April 1992.

Plate10.3 Breach on the Lugu main canal due to cattle crossing

Plate10.4 Breach on the Tutudawa main canal

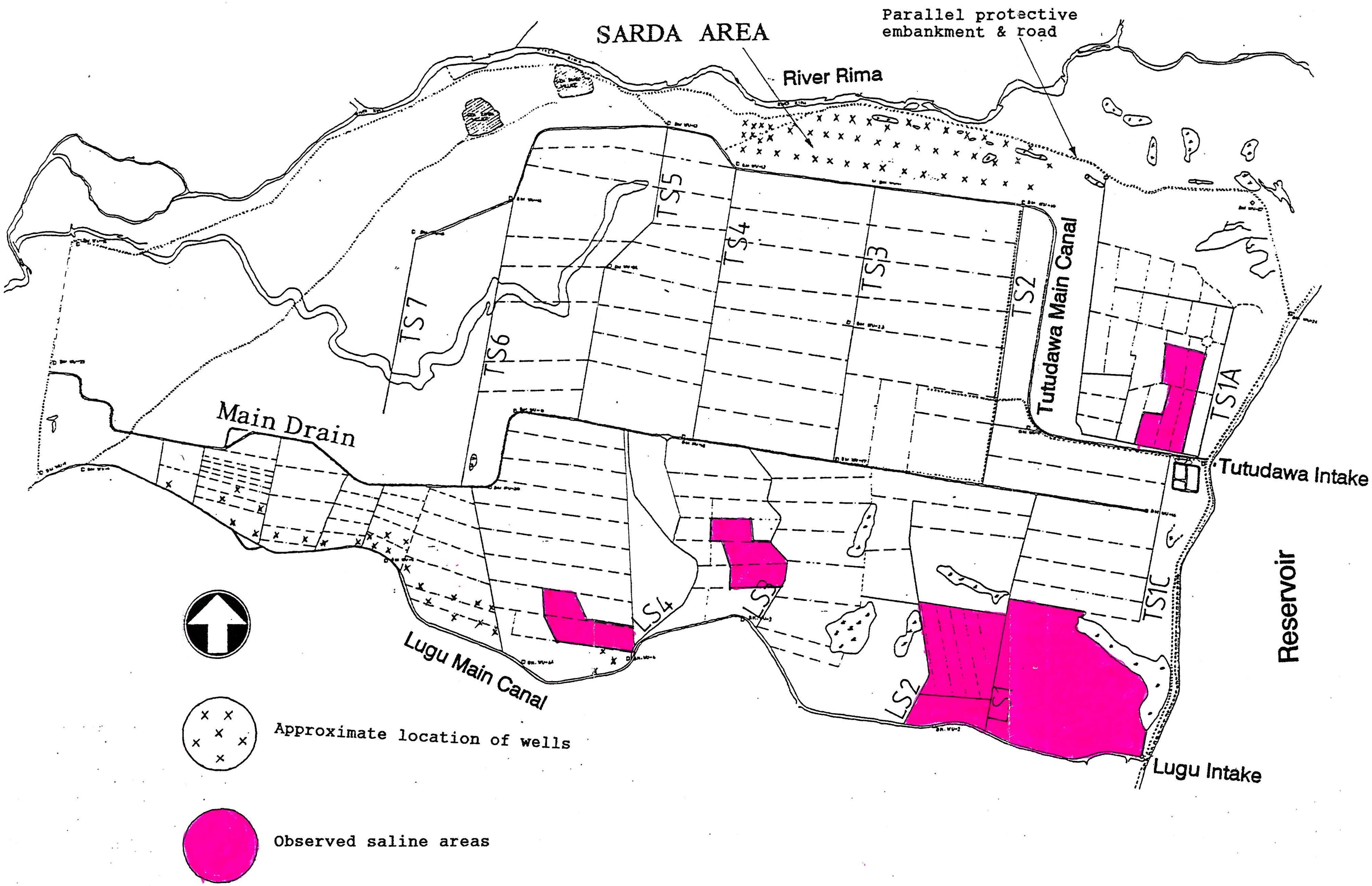


Figure10.3 Wurno irrigation scheme lay-out showing salinity affected areas, April 1992.

Plate10.5 Effects of salinity on crop fields

10.2.2 Management issues

The organization for the management, operation and maintenance of the WIS can best be described as weak. The weaknesses of the management derive from a combination of the following factors:

- Over-staffing and low staff quality;
- Lack of motivation and incentive mechanisms;
- Poor funding for maintenance;
- Lack of financial autonomy by the scheme agency; and
- Lack of clearly defined roles for, and involvement of farmers in the management and maintenance of the irrigation scheme.

As a result of these factors, the management is ineffective in properly operating and maintaining the irrigation scheme. In fact, the only functions in which the management appear to be active are land allocation and collection of water charges. Other than these, even emergency conditions, such as canal breaches and leakages are not given the attention they deserve. For instance, the main breach on the Tutudawa primary canal is said to be over ten years old!. In addition the agency hardly keeps any proper records of its operations. As an example, no one in the scheme has an idea of the actual cropped areas in any growing season.

10.2.3 Institutional and socio-economic conditions

<u>Land tenure problems</u>

The security of land tenure at WIS is very uncertain. The existing policy of allocating plots of land to farmers for only one season has made them very vulnerable as the authorities exploit it for their benefit. Preferential allocation of plots in strategic areas to scheme staff and influential people is common. Many of these are absentee landlords, members of the State bureaucracy or traditional institution. The majority of these influential plot-holders do not cultivate their plots in the dry season, but rent them to peasant local farmers who have allocations in unsuitable areas. In addition they do not contribute to system maintenance.

The land tenure system has a significant negative effect on the motivation of the farmers. A number of farmers cited it as the basis for their unwillingness to properly maintain their allocated plots and adjacent irrigation canals and structures. This is understandable as there is no guarantee of retaining the same plots in subsequent seasons. Others simply give up dry season cultivation, resulting in low cropping intensities. Without security of land tenure, the incentives to farmers to continue to cultivate and properly maintain their plots will remain low.

Irregularities in water charges

The process of water charges collection is fraught with anomalies and corruption by the scheme management. The magnitude of this problem is hard to ascertain, since such unfavourable occurrences are not widely publicised. Moreover, it is difficult to conduct independent research into the problem, as there is connivance from some farmers.

However, the lifestyle of the scheme managers and other evidences support the allegations that there are irregularities in the fee collection process. Apart from the reported payment of illicit monies by some farmers to managers in order to obtain favours, others reportedly 'settle' their water charges by paying only part of the fixed rate for which no receipts are issued. In addition, a number of influential farmers are reportedly completely exempted from paying the water charges. This applies mostly to the scheme staff who own plots in the scheme, and many members of the civil service and elite absentee landlords.

Mechanization and input problems

There is an acute shortage of farm machinery in the WIS. The groups worst hit by this problem are peasant farmers who have no easy access to the few available tractors because the privileged farmers monopolize them for their use. Some of the influential people have access to tractors for most activities, such as double-harrowing, threshing with tractor, and transportation, whilst the majority of farmers do not have the privilege of a tractor even for the most arduous task of land ploughing. The effect of this problem is a vicious circle of delays in land preparation and sowing. This has adverse impact on crop yields, especially wheat whose optimum production is limited to the cold period between November and March.

There are similar problems with availability of other inputs, particularly fertilizers. Peasant farmers find it extremely difficult to obtain fertilizers at the government subsidized rates, whereas black marketeers and influential farmers obtain them relatively easily. There is undue exploitation of the peasant farmers by the black marketeers in the prices of fertilizers which are 2 - 5 times the subsidized rates. Farmers are generally frustrated and discouraged by these problems. Many are forced to use low fertilizer doses while a few appear to be using over-doses, both with resultant adverse effects on crop yields.

<u>Corruption and differential social status</u>

Administrative corruption is perhaps the bane of all public sector enterprises in Nigeria, and one of the main cause of low performance and inefficiency in such establishments. The WIS is no exception. This problem is exacerbated by the weakness of the less privileged and the great influence by those in positions of authority. In addition, due to poor working conditions and incentives in the public service, those in positions of power hardly find any basis for not exploiting the opportunity for their selfish interests.

Some of the above discussions already allude to the problem of corruption and differential social status among farmers and its constraint on performance. Scheme managers have no incentive to manage and maintain the system well, especially as this would conflict with the reported generation of illicit income, which is normally many times their official salary. Apart from the field managers' personal desires to be able to maintain a basic social status, they are also reportedly under intense pressure from their superiors to make illicit financial returns to them. These pressures constrain the managers to direct more of their efforts on what they can get out of the system rather than on improving the performance of the system. The avenues through which managers reportedly make illicit monies include contract awards, defrauding on water charges, bribery from farmers, and abuse of maintenance funds.

The leverage of a few powerful farmers over the majority of peasant farmers on matters such as special plot allocations, acquisition of inputs, lack of cooperation in maintenance, and exemption from paying water charges have detrimental impacts on the effective operation and performance of the scheme. For example, when asked whether they would prefer to work in groups, such as water users associations, the majority of the farmers who replied negatively cited 'lack of cooperation from influential farmers or "big people" ' as their reason for preferring individual work.

Profitability of irrigated crops

The farm budget analysis clearly indicates that the official main dry season irrigated crop, wheat, is not profitable enough to attract farmers to its cultivation. As expected, farmers have been increasingly turning away from cultivating wheat, especially since 1988 when incentives for it were stopped. Onion and garlic are profitable but the market for them is poorly arranged and their production far outstrips the local demand. In addition their farm-gate prices at harvest time are low compared to other times in the year when the crops are not being produced. Farmers' attempts are local storage to take advantage of the higher prices result in high storage losses as the crops are highly perishable. Another problem farmers experience with the cultivation of onion and garlic is with acquisition of seeds and seedlings which are very expensive.

10.2.4 Farmers responses to existing conditions

The farmers in the WIS have responded to the above-mentioned issues in three ways: adaptation, improvement, and abandonment.

Adaptation

As a result of the low canal command in many areas, farmers in such places resort to lifting water from the canals and drains to their fields. Lifting is accomplished by hand using calabash, known as shadoof (see Plate 10.6), or by small pumps. To tackle the severe tail-end problems in some of the areas where the canals no longer flow, farmers lift water from a number of shallow hand dug and tube wells which they provide. In the absence of secondary and tertiary canals, use of siphons, and the inadequacy of controlled off-takes, breaching of main and secondary canal banks is common practice as the only way farmers can easily take water to their fields. On the field level individual farmers adapt to insufficient levelling by constructing several small basins and extra field ditches to serve their plots.

Improvement and Maintenance

Although maintenance of the main system is regarded as the responsibility of the irrigation agency, farmers often take initiatives to weed and de-silt the main and secondary canals. From speaking to farmers it was commonly stated that this practice was particularly common in the past when the system was in a better condition. Indeed, farmers then had organised themselves into informal groups according to hydrological units, primarily for the purpose of maintaining the system. With continued neglect by the authorities, the problems and work-load grew beyond the farmers capabilities. This led to the weakening of such groups to an extent that only very few of them are still operating. A few individual farmers also still undertake digging out of canals in order to gain access to water on their farms, especially if their farms are close to where water stops flowing on its own by gravity (see plate 10.7).

Abandonment

Overwhelming technical and socio-economic constraints initiated farmers wanning interest in dry season irrigation farming, culminating in the decision of some to abandon many parts of the scheme. This is understandable in view of their little benefits from irrigation and availability of other alternative dry season activities and wet season farming

Plate10.6 A variant of the Shadoof irrigation system in practice

Plate10.7 Digging of main canal by farmers in order to enable water to flow further downstream

opportunities. However, the efforts of the farmers indicate that for most of them this decision is a last resort. This is also clearly demonstrated in that farmers who have the means have sunk private wells and/or bought pumps in order to continue with irrigated farming.

10.3 Concluding Remarks

The foregoing discussions about the responses of the farmers give evidence to the fact that many farmers in the Wurno Irrigation Scheme are still interested in irrigated farming. They have utilized the resources at their disposal to deal with the physical and socio-economic difficulties within the scheme. However, their capacity is limited to cope with all the adverse conditions. For example, they do not have the technology to deal with waterlogging and salinity problems. But the measures adopted by them demonstrate clearly that for some farmers it is worthwhile to irrigate and they are prepared to invest their time, labour, and money to obtaining water to carry on dry season farming.

Therefore, it can be argued that for these kind of irrigation schemes, farmers may be able to manage if the environment is with them, and it is not too adverse. However, if the environment is too ominous (floods, erosion/sediments, complex infrastructure, harsh physical and socio-economic conditions, scheme too large), then the system is not sustainable without capable levels of management. If the management is strong and effective, it could complement the farmers' efforts to combat the problems to ensure high performance. However, if the management is weak then the scheme performance is bound, under these conditions, to be poor.

CHAPTER 11: CONCLUSIONS AND RECOMMENDATIONS

This research set out to develop a conceptual framework for performance assessment of medium scale irrigation schemes and provide a detailed case study of a typical scheme in Africa, a task that has been successfully achieved. This chapter draws conclusions on the main issues based on the findings, and highlights the contributions this study has made with respect to the initial objectives. Finally, recommendations are made for application of the proposed methodology and improving the performance of the Wurno Irrigation Scheme.

11.1 Conceptual Framework and Methodology

A conceptual framework and methodology has been developed for performance assessment of medium scale irrigation schemes with joint participation between farmers and an irrigation agency in Africa. This consists of the concepts, steps and processes involved in studying the performance of such irrigation systems, and a logical framework for categorizing irrigation schemes according to the principal characteristics that determine appropriate types of performance assessment.

The author recognizes that the performance of irrigation systems in Africa is a complex process which depends on many factors. These include human and non-human inputs and processes such as environmental, social and economic conditions, water, physical infrastructure, money, land and labour. Others are fertilizers, credits, farm machinery, prices, markets and storage possibilities. Weakness in any of these could be critical to improved performance of the entire irrigation scheme. Thus, in studying performance of irrigation schemes, the author advocates the 'whole system', or irrigated 'farming system' approach because it is necessary to look at each element in the process in order to understand its strengths and weaknesses.

The proposed framework gives an overall perspective on alternative approaches to performance assessment of irrigation schemes. It argues that there could be a variety of different approaches to irrigation performance assessment depending on the type, status, and level of development of the irrigation scheme being assessed, as well as the purpose of the assessment. Therefore, the author asserts that one of the key steps in performance assessment is the categorizing of types of irrigation schemes and assessments. This study outlines some of the possible choices which need to be specified in selecting a particular type of performance assessment. The specification provided will enable any assessment to be placed in its proper context, thereby facilitating comparisons between similar types of schemes. It will also encourage more appropriate planning of performance assessments and better interpretations of their results.

11.1.1 Performance indicators for assessing irrigation schemes

Performance is normally used to refer to the degree of attainment of the objectives, targets or expectations set for an irrigation scheme, or components of it. This is usually measured by evaluating a set of performance criteria or indicators. Therefore, this study maintains that in assessing performance of irrigation schemes, indicators should be chosen which are related to the scheme objectives. Where conflicts exist between objectives, priorities have to be decided, and complementarities defined. Ideally, targets and expectations should be set which are realistic within the capacity of the scheme.

The author recommends that performance indicators, from a whole system perspective, should relate to the inputs, the processes of transforming inputs into outputs, and the outputs themselves. This is a significant variation from common practice of studies of irrigation performance which focus mainly on the evaluation of output indicators. In particular, the technical assessment of irrigation water distribution and utilization in terms of adequacy, equity and efficiency indicators has been a major focus. Economic assessments often centre around the evaluation of economic internal rate of returns (IRR).

This study argues that performance indicators which combine the measures of the conditions and potentials of the irrigation scheme inputs, infrastructure, management and operation processes and the results they produce give a better picture of what goes on in irrigation schemes. Thus, a range of performance indicators have been proposed and described which reflect this thinking. They are considered particularly suitable for evaluation of medium scale, jointly managed irrigation schemes in Africa, and are therefore suggested for use on such schemes.

The proposed performance indicators also include a guide for analysis of the conditions of the physical system and a guide for summary presentation of results. This is often neglected in performance assessments. The author believes that the procedures developed here for detailed analysis of the physical conditions is a useful contribution. Table 10.1 and 10.2 stand out as a summary format of the actual values of the performance indicators evaluated on the Wurno Irrigation Scheme compared with notional normal levels. Such a presentation enables a quick overview to be gained of the performance results of any irrigation scheme studied, and an easy comparison of similar types of schemes. This format is therefore recommended for performance studies. Of all the literature consulted, only **Zhi (1989)** used a similar summary presentation of performance results on his study of a typical large-sized irrigation scheme in South China.

11.1.2 Data collection and analysis procedures

This study has also developed a procedure on the collection of information for evaluating the performance of irrigation schemes. The types of data required and sources of relevant information for performance assessment are highlighted. Some field measurement techniques are also provided. The important tools for data collection and analyses found useful in this study were questionnaires, checklists and statistical analysis. In particular, the detailed investigation of correlation and regression analysis using Statgraphics were found very helpful in exploring and confirming relationships between different variables.

These tools and detailed analysis techniques are advocated. Sample questionnaires and checklists for investigation are provided in the Annexes. The checklist emphasizes the collection of historical and contemporary information on the physical, technical, management, and socio-economic conditions within an irrigation scheme.

11.1.3 Recommendations for further research.

Although the development of the methodology presented in this thesis has been based around the experience with the Wurno Irrigation Scheme, the author believes that it can also be used on other schemes. Some elements of the proposed approach can be adapted to have wide application. For example this study has presented a sequence for the main activities in carrying out performance assessment studies for irrigation schemes which comprise of:

- planning and organization of performance assessment
- rapid appraisal and reconnaissance survey to gain a general overview of the scheme
- detailed study involving detailed data collection and analysis, and
- reporting of findings to make the results available to the public.

The above is general and can be for any type of irrigation scheme and performance assessment. The main choices in the performance assessment methodology which may be site specific include the details of:

- rationale for the assessment
- selection of performance indicators
- types of information available
- measurable field variables
- methods of data processing and analysis.

The author believes that the approach adopted in this research can be used for rehabilitation studies, independent research studies, appraisal studies by funding agencies, and internal performance monitoring.

However, this study does not claim to have provided all the answers concerning the subject of performance assessment for irrigation systems. In particular, it does not profess to have developed a standard set of performance indicators and identified all the important factors that explain particular levels of performance in irrigation schemes. In addition it does not deal with the important issue of water management in great detail.

It has made a contribution, albeit modestly, to the current thinking, debate, and search for consensus on the subject of irrigation performance assessment which has been a focus of attention in the past decade or so. As a result, there is still a very wide scope for further research on this important subject. Some specific issues identified through this study which require further attention are outlined below.

Application of methodology and performance indicators to several other irrigation schemes with similar characteristics. This is thought to be important in order to ascertain the general applicability of the proposed methodology and indicators. By comparing the findings of studies on a number of individual irrigation schemes, it would become possible to make valid generalizations about determinants of irrigation performance in particular settings. This is severely limited unless these studies are consistent in their approach to assessing performance.

Adaptation of methodology to other types of irrigation schemes and regions. Although this study was specifically aimed at medium scale formal irrigation schemes in Africa, it is believed that some of the concepts advanced may be adaptable to the broad macrocosm of irrigation types in other developing countries. Efforts to modify this approach on other schemes and parts of the world could lead to the development of a consensus methodology, and of standardized sets of performance indicators suitable for application in various contexts.

Specific to the Wurno Irrigation Scheme, there is need for a follow-up study. This is with a view to monitoring changes and assessing the impact of the strategies for improving its performance. Since the scheme has been rehabilitated following this study, it would be valuable to assess the outcome of the rehabilitation programme and its effects on the performance of the scheme. The author intends to carry this through on his return to Nigeria.

11.2 The Wurno Irrigation Scheme

The second part of this study applied the concepts developed to contribute a detailed case study on the Wurno Irrigation Scheme, Nigeria. The case study supplies a comprehensive insight into the operation and performance of a typical medium scale irrigation schemes in Africa, thus, providing another contribution to our understanding of such government initiated and managed irrigation schemes.

The case study is useful in field research for understanding different possible conditions. Information from case studies can be used to guide improvement strategies for irrigation schemes, and the planning of future investment policies, rehabilitation design, operation and maintenance. It is also useful for educational purposes, and to enable more realistic assessments and expectations to be made in the planning of similar projects in the future.

Broad based detailed research case studies of the type provided in this study are rare, particularly on government assisted medium scale irrigation schemes in Africa. Only a few such studies have been reported in literature. This study makes an additional contribution. The distinguishing feature of this study is that it provides a detailed analysis of the physical infrastructure, the organizational and institutional arrangements for management, and the socio-economic conditions of the farmers including farm budgets for the Wurno Irrigation Scheme, Nigeria. Similar detailed studies such as this on similar irrigation schemes will encourage comparisons across countries.

11.2.1 Performance of the Wurno Irrigation Scheme

The results of documentation, implementation history, observations and data analysis show the performance of the Wurno Irrigation Scheme to be less than satisfactory. That this is so is clearly demonstrated by the values of the various performance indicators presented in Table 10.1 and 10.2. This is regrettably so despite apparently ample water resources and the high degree of responsiveness demonstrated by many of the scheme farmers. The author is convinced that there are great potentials in the Wurno Irrigation Scheme which are not being effectively utilized at the moment. The reasons found for the poor performance in the scheme are numerous. In summary they include:

- Technical factors relating to adverse physical conditions, poor conditions of physical system and lack of maintenance, resulting in physical constraints on system capacity. In particular inadequate physical infrastructure was a major constraint to adequate levels of water control.
- Economic factors relating to low market and poor price incentives, making irrigated farming financially unprofitable under certain conditions.
- Institutional factors relating to poor farmers involvement and organization, input availability and land tenure problems.
- Social factors arising from differential social status of farmers and illicit corruption practices by managers.
- Operational factors resulting from low management capacity, inadequately qualified staff, poor water management and inadequate funding for maintenance.

The above factors on the Wurno Irrigation Scheme need to be addressed in a rehabilitation process, if its performance is to be improved. Surprisingly, the 1991 rehabilitation study of the scheme carried out by the Sokoto Environmental Protection Programme, SEP (the agency responsible for rehabilitating the scheme), overlooked some of these issues. For example, their study did not include socio-economic aspects. The main preoccupation of the rehabilitation process has been on improving the physical aspects of the scheme. Even in this respect their report was mostly descriptive. The author believes that rehabilitation studies need to carry out detailed analysis of the existing problems in order to deal with all the real issues. It is a matter of concern for the author that without tackling the real issues on the Wurno Irrigation Scheme (as summarized above), the short term solutions may not last.

The farmers have shown a lot of resilience and innovation in resolving some of the constraints in the Wurno Irrigation Scheme. Unfortunately some of them have proved beyond their capability. This was so partially as a result of the lack of well coordinated farmers' associations and delegation of clear responsibilities and rights to them. In the past farmers used to organize informal groups on their own initiative, partly for maintenance of parts of the irrigation system. However, their motivation and cooperation has been declining with continued neglect and deteriorating conditions in the scheme. Obviously there is a limit to the extent of maintenance farmers can cope with on their own, particularly when their returns are not attractive. The dwindling motivation of the farmers and their decision processes are based on their evaluation of the whole irrigated farming business including availability of input resources, production processes, and marketing possibilities.

This condition has been made worse by the ineffective management, which lacks the technical and managerial skills, and the funds to be able to conduct proper operation and maintenance of the system. Apart from the low quality of managerial manpower, there was generally a lack of motivation and incentives for the management and field staff. The civil service structure of the ministry that controls the scheme was characterized by inefficient bureaucracy. Besides poor salaries, slow promotion (not at all related to performance and hard work), and low funding for maintenance, field staff were often subjected to frequent indiscriminate transfers. This was sometimes at the discretion of their seniors at the headquarters for selfish personal reasons, such as not making illicit financial returns. A common solution adopted by field managers to satisfy their superiors and maintain their social status was to extort money from farmers and defraud the government of revenue from water charges.

It is the author's belief that the current performance of the Wurno Irrigation Scheme demonstrates the relationship between the size of a scheme and its management capability. At the tail end of the scheme due to failure of the surface water supplies, individual farmers are putting a lot of effort, and money into development and use of groundwater. Other farmers near the top end of the scheme are investing time and labour in desilting and weeding canals, and in manually lifting water to irrigate their plots. It is believed that in this social environment the size of the scheme is too large for farmers to coordinate and manage themselves, additional management skills are required to identify O & M needs, liaise with farmers and coordinate their activities over the whole scheme. If these skills are to come from government, then better trained, rewarded and motivated staff are required. That this issue has not been address in the rehabilitation process is a matter of concern. One positive measure might be to officially allocate land within the scheme to government agency staff to supplement their salaries and link their income to scheme performance.

11.2.2 Crop production processes

The analyses carried out in this study have revealed the basis for the responses of the farmers in their crop production strategies, some of which have already been discussed above. This shows the importance of such analysis in performance assessment for understanding the linkages that exist, and why performance is as it is.

Many of the decisions made by the farmers were found to be quite reasonable in view of their objectives and experience. The primary objective for most of the farmers in the WIS is to meet their family subsistence needs. Irrigation contributes to meeting this objective and their cash needs, but at the same time there are alternatives for achieving these objectives in rain-fed agriculture, livestock and other production activities. The farmers are generally relatively inexperienced in irrigated agriculture, particularly for the wheat crop. Thus, their strategies are geared towards avoiding risks, and not necessarily profit maximization.

This study has found that the most profitable crops in the WIS in terms of cash returns are garlic and onion. Understandably farmers are increasingly turning to, and investing highly in growing these crops. Wheat, the official main dry season irrigated crop, was found to be the least profitable. Garlic and onion could be even more profitable if their market prices were stabilized. The main reasons found for poor profitability of wheat were low yields, poor markets and uncompetitive prices. These conditions have been worsening since 1988 when government withdrew incentives for the cultivation of wheat. Since then farmers have increasingly been withdrawing from wheat cultivation.

The single most important factor influencing wheat yields was found to be planting date. Due to its high sensitivity to high temperatures, late planting after the recommended date of November had detrimental effects on yields. Unfortunately over 50% of farmers were found to be planting later than the recommended period. The three variables which in combination had the greatest explanation (70%) for variations in wheat yields were:

- farmers' irrigation experience
- source of irrigation water, and
- number of weedings during the crop season.

The study has shown that the more experienced wheat farmers, who irrigated using pumps and/or wells, and weeded 2 - 3 times during the season achieved higher yields. Surprisingly a majority of farmers interviewed were of the opinion that wheat did not require weeding. This shows that the farmers need more education in the cultural practices for wheat cultivation.

Rice was the other important crop in the scheme. This was grown mostly in the wet season without conventional irrigation practice and little use of the infrastructure. Farmers appeared relatively experienced in the cultural practices for rice. This was because rice had been grown for food and cash in the area ever since before the irrigation scheme was establishment.

On the basis of the experience gained on the WIS, it can be concluded that the scheme performance and the willingness of farmers to contribute to that performance depends on:

- the condition of the infrastructure
- the value of production, and
- the level of organization and management.

Thus, for rice little infrastructure was needed in the wet season as the entire area was flooded by blocking the drainage outlet. For dry season production, the value of wheat was low so there was little incentive for farmers to grow it, but some farmers put in tubewells and irrigated onion and garlic which had high value. This showed that farmers were interested in irrigated agriculture if it is profitable. However, they need reliable water supply in quantity and timing to suit their crop needs. Onion and garlic had high initial costs so farmers were willing to invest and grow them only if they could guarantee harvest. With the constraints of the Wurno main canal system this was not so. Therefore, for those depending only on the main canal system water supply, low investment, low risk approach was their strategy in wheat.

For wheat to be successful it needs cheap and easily available water. Farmers irrigated wheat only if they could get water easily from the canals, otherwise they did not bother. Thus, when the canals became weeded or full of sediment they did not clean them. If management were stronger then they might organize and encourage farmers as a group, but as they were not, individual farmers did not take action. Farmers used to organize themselves, but the problem grew bigger than they could handle and management could not help, so it became too big a problem to even try.

11.2.3 Recommendations for improving WIS

It is widely recognized that one of the important elements in a successful irrigation scheme is increased farmer participation. Thus, in the organization for operation and maintenance of the scheme, it is important to clearly spell out responsibilities between farmers and the irrigation agency responsible for management. The farmers should be involved as much as possible from the planning stage while the role of the agency should be minimized. The aim in this approach is not just to transfer financial burdens to farmers, but to give them a sense of belonging and to consider the scheme as their own. This makes them more responsive to the needs and conditions in the scheme such as maintenance. It consequently leads to increased efficiency and improved performance.

Unfortunately formal irrigation schemes in Nigeria in generally lack recognition and coordination of farmers. Farmers have no rights and are not represented in the management decision making processes. Where they need to be involved, they often tend to be coerced rather than given incentives. Due to the lack of devolvement of specific responsibilities and rights to them, they find themselves in a weak position, and do not have any collective sense of belonging in the management and maintenance of the scheme. Even where they attempt to group on their own initiative, they find themselves limited by means and technical know-how. At present roles and responsibilities for the agency and for farmers are not clearly defined on WIS. It is important that this is done.

It is recommended that the irrigation agency should retain responsibility for the operation and maintenance of the head works and main system water distribution. The reasons for a central irrigation agency retaining responsibility at this level include:

- the magnitude of work involved at this level
- the technical expertise required for O & M of these portions of the irrigation system, and
- the need to ensure security of the system.

The roles and responsibilities of the irrigation agency may comprise of the following;

- O & M of the head works and main canals
- allocation of water supplies in the system
- periodic repair and rehabilitation of the main system
- preparation of O & M budgets (with collaboration of water users)
- supply of equipment and materials to farmer groups when necessary
- collection of irrigation service fees
- provision of extension services
- preparation of O & M manuals
- monitoring and evaluation of system performance
- arbitration in disputes between farmers, and
- formation and support of Water Users Associations (WUAs) amongst farmers.

In irrigation development farmers need to be involved from the outset in the decision making process regarding planning, design, and construction. This gives the farmers a sense of belonging and opportunity to participate in ensuring the quality of the system. It also gives them the feeling to regard the system as their own. In the case of Wurno the rehabilitation process provides an excellent opportunity to increase the farmers role and transfer more rights and responsibilities to them. Some of the responsibilities that could be assigned to the farmers groups during the operation and maintenance stage include:

- maintenance of the tertiary system
- organization and management of agricultural operations within the tertiary units
- rotational water distribution among themselves
- collaboration with central agencies in the preparation of operation and maintenance budgets

- representation of farmers interest in the scheme management
- resolution of disputes between farmers
- assist in monitoring performance of the system, and
- collect/assist collection of irrigation service fees.

Besides strengthening the role of the farmers' groups, other issues that require urgent attention on the WIS include:
- problems of land tenure
- supply of inputs and incentives to farmers, and
- storage and processing options for onion and garlic, and their price stabilization.

It has been established that the present insecurity of land tenure at the WIS is one of the main reasons discouraging farmers from taking good care of their allocated plots and adjacent canals. The author recommends that farmers should be given a fixed land tenure contract of at least 10 years. In addition, while it may not be practicable to completely stop allocating land in the scheme to influential absentee landlords, it is advisable to ensure that they comply with regulations within the scheme, such as cultivating their allocated plots whenever due, not subletting plots, paying water charges, and cooperating with local farmers in contributing towards maintenance of the scheme. A stronger water users association amongst farmers, with specific rights, might ensure this.

The supply of inputs and incentives to farmers, especially fertilizers and farm machinery, may not be the immediate responsibility of the irrigation department. However, considering the critical value of these factors to the farmers, and their role in improved productivity in the scheme, it is necessary to arrange for farmers to have easy access to them. One way of implementing this could be to make bulk supply of these inputs at the subsidized prices to farmers for them to distribute among themselves.

Another opportunity for improvement in the WIS worth careful consideration is the provision of storage and processing facilities for onion and garlic. This is not being considered in the rehabilitation programme. These crops are highly perishable and their prices skyrocket late after the growing season. In fact, farmers reported storage losses of up to 50% under their attempted local storage conditions. Effective storage and processing options for these crops could stabilize prices and bring more benefits to farmers.

11.3 Concluding Remarks

There is an increasing interest in the performance of irrigation schemes and how performance can be assessed. This interest is due to disappointments with many irrigation schemes around the world, particularly in the developing countries. For every existing irrigation scheme, there is a need to understand its current performance and reasons for its success or failure. This is with a view to understanding causes of low performance or maintaining or improving successful performance. If we do not understand current performance, then efforts to improve it may be misplaced.

This study has contributed to the current debate on irrigation performance assessment, and provided a detailed case study of a typical medium scale government assisted irrigation scheme in Africa. It has shown how complex performance assessment for irrigation schemes is as a result of the uniqueness of each system. However, it concludes that it is necessary to carry out detailed performance studies prior to redevelopment. Unfortunately this is not done at present. In many rehabilitation programmes little or no time is allocated for comprehensive evaluation and understanding of existing conditions. This study is of the opinion that such rehabilitation programmes may not work, or at the best result in only short-term improvements. Poor or inadequate planning leads to poor future performance.

It has been observed that people generally expect irrigation to be highly productive. But in Africa, farmers still hold to rain-fed agriculture and livestock as other alternative sources of sustenance and income. This is perhaps because population is relatively less dense (compared to Asia, for example), irrigation is not so desperate and not so well entrenched in social habits and culture. So for African conditions, a productive and useful irrigation scheme may be one that produces something, or produces better than rain-fed agriculture. This calls for lower expectations on performance standards.

The study of the Wurno Irrigation Scheme has shown an interesting paradox. On the one hand farmers growing wheat have adopted the low investment, low return approach based on the open channel canal network. Yet on the other hand, other farmers on the same scheme have adopted a high investment, high return approach based on tubewell irrigation. In the case of tubewells, farmers have full control of their water resource and can plan accordingly. This is obviously not the case with the open channel government managed system. This paradox is explained by the farmers, and the results of the analysis in this study, that it is not worth investing efforts and resources in operation, maintenance and cultivation for little returns.

With government withdrawal of incentives on wheat, it is no longer attractive as the margin for it is not good. One wonders why the rehabilitation programme has gone for wheat again in its plans as the main irrigated crop, and wonders whether the farmers' opinion would change. On the basis of this study it would appear not. Perhaps it might be better considering other crops for the dry season such as rice, onion, garlic, maize or beans.

The study of Wurno Irrigation Scheme has also shown that scale in government assisted and managed schemes is not necessarily the key issue. It has been found that the performance of the Wurno Irrigation Scheme has been as bad, if not worse, than other larger scale government assisted irrigation schemes in Africa. Thus, the issue raised in Chapter One, that governments in Africa were looking to <u>smaller</u> scale irrigation schemes as a way forward would appear to be misplaced in the case of schemes such as Wurno. <u>Small</u> scale schemes as described by **Carter (1989)** and **Underhill (1990)** may be successful, but medium scale although 'small' relative to large scale schemes, may still have problems, especially if not owned by farmers.

The main issue is not one of size, but rather of the design-management complex, that is, the ability of society to operate and maintain the system. In the society of one farmer, he/she has no difficulty in managing, operating and maintaining productive irrigated agriculture from a tubewell. In a society of over 600 farmers as at Wurno, with government agency staff and farmer element, the design-management complex becomes more difficult to organize and does not appear to function well. It fails because of lack of incentives for farmers to produce wheat (the government approved crop), and lack of incentives on the part of agency staff to manage well.

Thus, there appears to be a dilemma on this type of irrigation schemes. The dilemma is that this type of scheme is too large to hand over completely to farmers, and too small for government to take over completely! This would entail providing qualified staff as well as amenities for their welfare as incentives to motivate them to high performance, and taking responsibility for organization and control of every aspect of production.

In conclusion it can be said that the thesis of this research has been proved, that:

> the performance of irrigation schemes is, amongst others, a function of the design-management complex. Ideally there should be complementarity between the design and physical quality of an irrigation scheme's infrastructure, and the organization for its management, operation and maintenance."

Without this condition being met, we should be prepared to accept low performance. In the case of the WIS both the primary characteristics of the physical design of the irrigation infrastructure, and the organizational and institutional arrangements within which the system was managed were inauspicious. Hence the low performance.

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ANNEXES

ANNEXE A1:

CHECKLIST FOR COLLECTING INFORMATION FOR PERFORMANCE ASSESSMENT OF IRRIGATION SCHEMES.

SECTION I: BASIC GENERAL INFORMATION

A. Scheme identity

- Name of irrigation scheme ....
- Surrounding Villages/towns ....
- District/province...................................
- State/Country ....
- Route and distance from nearest town(s) ....

B. Physical environment

- Latitude and longitude ....
- Altitude (metres above mean sea level) ....
- Natural region ....
- Mean annual rainfall (mm) ....
- Average minimum and maximum temperature ....
- Topographic conditions ....
- Soil types (light, medium, heavy) ....
- Annual evaporation (mm) ....
- Peak daily evaporation (mm) ....
- Periods of wet season .... dry season ....

If possible obtain meteorological data from the nearest station for the recent 5 - 10 years on rainfall, temperature, wind speed and direction, relative humidity, pan evaporation, radiation, etc.

C. Historical developments

- Date of initial construction ....
- Initial developed command area (ha) ....
- Total proposed (design) area (ha) ....
- Changes in command area due to expansion/rehabilitation:

	Year	Area (ha)
	19....	....
	......	....
	......	....

- Present status and command area ....
- Original project objectives: ....
- Subsequent changes in objectives: ....
- Is irrigation absolutely essential for survival in the area? Yes/No.
- How long is the farmers experience with irrigated agricultural technology (years)?.
- Are there any existing water rights in the project area? Briefly describe (if any).

D. Farming system

- Describe the existing land tenure systems.
- What are the main crops in the area?
  Wet season .... Dry season ....
- Estimate the cropping intensities in the project area.
  Wet season .... Dry season ....
- Cropping calendar:

Crops/ variety	Cropped area (ha)	Growing period (months)	Season (wet/dry)
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....

- Have there been any changes in the cropping pattern?
- What are the crops that farmers prefer to grow?
- Describe the causes of the changes in cropping pattern and the farmers preference for particular crops.
- What are the major constraints to increased agricultural production and cropping intensity?
- What other major opportunities are there for subsistence and cash in the project area?

E. Demographic and social characteristics

- Number of farmers in the scheme ....
- How many households are there in each of the villages participating in the irrigation scheme?
- What is the estimated total populations of each of the villages (if possible)?

- Describe the different ethnic groups represented in the scheme and their proportions.
- What is the ratio of male to female farmers?
- What is the literacy level of the farmers?
- What is the composition of local farmers and absentee land owners?
- Investigate the social structure, cohesion and existence of any social and cultural organizations.
- What are the procedures for resolving conflicts, particularly those relating to water and land in the irrigation system.

SECTION II: TECHNICAL ASSESSMENT

Obtain base maps of the scheme showing the lay-out of the entire irrigation system. This should include the following features if possible: project boundaries, water sources, reservoirs, wells, main roads, protective embankments/dykes, cut-off drains, canals and drainage network, irrigated areas, crop types (if possible), potentially irrigable areas, villages, project headquarters/offices/workshops (if any), topographic features, hills, swamps, waterlogged areas, saline areas, soil types, approximate scale and north direction. For participating villages off the map show their directions using arrows and indicate the distances.

A. Water sources

- Name of river system and flow regime.
- Has river ever changed alignment in the past? Is it likely to change its course in the future?
- For every dam and/or flood protection reservoir, estimate the following characteristics:

Type of dam (rock-fill, earth-fill, concrete, etc.); ......
Capacity of reservoir (Million cubic metres); ....
Area inundated by reservoir (ha); ....
Height of the dam embankment (m); ....
Length of the dam embankment (km); ....
Capacity of dam spillways (m^3/s); ....

- Describe the general condition of the dam embankment, slopes, spillway structures, and fuse plugs.
- What is the estimated silt load entering the reservoir (low, medium, high, etc.)?
- What is the water quality of the reservoir for irrigation (good, average, poor)? Measure the electrical conductivity and pH (if possible).
- Are there any night storage reservoirs within the scheme? State the capacity for each reservoir.
- Are there other irrigation, industrial, or domestic systems using the same source of water? For each system give: name, location (upstream or downstream), area served, estimated population, and estimated requirement/year.
- If there are any existing water quotas or rights for individual projects, state the amounts for each system.
- What is the security of water supply for the scheme (good, average, poor)?

Other water Sources

- Number of wells by types (tube wells, shallow hand dug wells, boreholes, etc.).
- Methods of abstraction (hand, low-lift pumps, electric pumps, etc.).
- Average command area per well (ha) ....
- Average depths of the wells (m) ....
- Water table depths (wet/dry season) ....

B. Intake and diversion structures

- What is the method of abstraction from the reservoirs (gravity, pumping, etc.)?
- Describe the types of headworks diversion structures and their conditions (weirs, gated pipes, etc.).
- What is the maximum discharge capacity for each intake structure?
- Describe the arrangement for controlling the rate of flow into the canal system. Are there measuring structures at the intake?

- What is the condition of any existing protective embankment/dyke parallel to the river alignment?
  Height of embankment (m) ....
  Length of embankment (km) ....

C. Canal and drainage networks

- Number, design discharges and total lengths of main canals in lined and unlined conditions.
- Number, design discharges and total lengths of secondary canals in lined and unlined conditions.
- Number, design discharges and total lengths of tertiary canals in lined and unlined conditions.
- Number, design discharges and total lengths of drains (main, cut-off, secondary, tertiary and collectors).
- Describe the conditions of weeds, siltation, and breaches in the system canals (main secondary, tertiary). For each problem categorize the stretches of canals into severe, fair, good, excellent.
- Describe the conditions of the drainage networks regarding weeds and siltation. Categorize the stretches according to severity of problem: severe, fair, good, excellent.
- If possible run profile survey of the main system canals and drains in order to plot longitudinal and cross sections at intervals of say 100 metres. Assess the actual canal capacities, canal slopes, command water levels, and other canal hydraulic characteristics. How do these compare with the design values?
- Determine the extents to which water can flow in the system canals.
- Where does the main drain discharge? (river, lake, swamp, etc.).

D. Canal and drainage structures

- Obtain an inventory of the conveyance, regulating, water measurement, and protective structures constructed in the scheme and their present conditions. Classify them by types and specify for each category the numbers of those working normally and those damaged.

- What is the capacity of the system structures to control water? (gated outlets, locked gated, no control, etc.).

E. Access Roads

- Total length of perimeter roads around the scheme.
- Total length of canal and drainage inspection roads.
- Total length of farm access roads.
- Describe the type of each class of roads (tarmac, dry season laterite, etc.) and the length of each type.
- State the proportion of the roads which are all-weather, seasonal, etc.
- Describe the present condition of the roads around and within the scheme (good, fair, very bad, nonexistent, etc.).

F. Field level and environmental problems

- Has land levelling and smoothening ever been carried out in the project?
- Describe the micro-relief (regular, slightly undulating, undulating, broken, etc.).
- What is the method of irrigation? (basin, furrow, border strip, overhead, drip, etc.).
- Number of irrigation blocks (tertiary units).
- Average size of tertiary units (ha).
- Estimate the total areas within the scheme which are affected by the following problems: salinity/alkalinity, waterlogging, soil erosion.
- What are the causes of the salinity, waterlogging, and soil erosion?
- Measure the electrical conductivity (EC), Sodium Adsorption Ratio (SAR), and Cation Exchangeable capacity (CEC) on samples of the soil extracts in the following locations: severely affected areas, moderately affected areas, and apparently unaffected areas.

- How is water distributed between farmers? ("take as you like", water measurement, time share, scheduling by area/days, etc.).
- Is the system of water distribution in the wet season different from the dry season? How does it differ, and why?
- By what methods do farmers obtain water? (gravity flow from canals, lifting/pumping from drains, lifting or pumping from wells, etc.).
- How do the farmers control the discharge of water to their fields? (siphons, outlet structures, pipes, breached canal banks, shadoof, pumps, etc.).
- Are fields irrigated continuously or by rotation? If by rotation, give typical irrigation intervals for each crop in days.
- For how many days during the week is irrigation practised?
- For how many hours during the day is irrigation normally practised? Daytime ..... Nighttime .....

SECTION III: MANAGEMENT ASSESSMENT

A. Roles and responsibilities

- Who has overall responsibility for the irrigation system? (farmers, government ministry/agency, private organizations, etc.).
- Review the organizations and management set-up and division of roles and responsibilities. Specific responsibilities to investigate include construction and diversion of water, canals, drains, structures, etc.; water distribution to the fields; application of water to the crops; etc.
- Are there formal or informal farmers organizations? If so, what are their rights and responsibilities?
- Are all farmers members of the organization, including absentee land owners? What is the level of coordination and cooperation? (good, fair poor, etc.). Is the organization dominated by some few powerful members? If any, who are they?

- How are organizations composed? (by hydrologic areas within the scheme, by villages, etc.).
- State the specific responsibilities of the government agencies in the scheme.
- Who holds responsibility for such functions as selection of farmers in the scheme, control of land tenure, choice of crops, timing of cultivation operations, preparation of irrigation schedules, collection of irrigation service fees, operation and maintenance of main and tertiary systems, etc.?

B. Organizational structure

- Describe the structure of the farmers organizations, stating any linkages with external or higher-level organizations, scheme agency and government support.
- Are there any official positions within the farmers organizations? Who are the current office holders? How and when are they selected?
- How are the officials paid for each position? (monetary and/or other benefits and privileges, etc.).
- How do the farmers organization relate to the irrigation agency? To what extent are farmers involved in management decision making and planning?
- What are the organizational linkages between the irrigation agency at scheme level and other agencies at local, state, and federal government levels?
- Are there clear job descriptions for each job category in the irrigation agency and the farmers organization?
- Are there any areas where agency staff are accountable to the farmers?
- Sketch the organizational chart for the irrigation agency and farmers organizations, indicating the points of linkages.

C. Management skills and motivation

- Do farmers show initiative, motivation and capacity to sustain irrigated agriculture?
- Is irrigation absolutely essential for their survival? What is their general attitude towards irrigation?

- State the duration of farmers experience with irrigated agricultural technology regarding: diverting water, controlling floods, digging and maintaining canals, water distribution, and application of water to various crops. Is rain-fed agriculture a long established and cultural practice?
- Describe the motivation and attitudes of the irrigation agency staff towards irrigation, and their commitment to their jobs. Do staff also own plots of land and practice irrigation within the project?
- State the number of irrigation agency staff in each of the following categories: professionals (graduates with relevant experience); middle level (HND and OND); Artisans (technical/vocational certificates and/or relevant experience); and unskilled labour.
- What are the salary scales for each job category, and the staff's perception of their salaries (good, satisfactory, poor, awful).
- Do salaries reflect the performance of individual staff members?
- What incentives are provided for staff to boost their morale to work? (conveniences and amenities, housing, transport, bonuses, recognition and status, etc.).
- What training and promotion opportunities exist for staff?
- Are staff allowed to stay in the scheme for a reasonable period of time (say 10 years), or are they subjected to frequent transfers? Who orders transfers, and on what basis are staff transferred?

D. Scheme management operation

- Are there regular meetings of the scheme management and/or farmers organizations?
- What kind of issues are discussed at such meetings, if any?
- Are there annual management plans and targets at project level in order to realize the stated policy objectives at the state/national levels?
- Are irrigation indents and schedules prepared in advance? By whom? Are they strictly followed? What

are the water allocation policies, particularly in periods of shortage?

- Are operation and maintenance procedures clearly defined, in say O & M manuals?
- Are annual pre-season plans and budgets prepared for the scheme? By whom? How are they implemented?
- What are the communication channels between agency and farmers?
- Do established rules and procedures exist for conflict resolution, routine maintenance, emergency maintenance, etc.?
- How is maintenance carried out? (direct labour within agency, labour mobilized by the farmers, contract to farmers/outsiders, etc.).
- Is there a regular monitoring and evaluation system within the scheme? What kind of information are collected regularly. How is the information used? Are there checking procedures to confirm the accuracy and reliability of the data?

E. Scheme financial resources

- What are the means of mobilizing both human and financial resources for the scheme regarding: construction, rehabilitation, expansion, maintenance, repairs, etc.?
- Do irrigation fees exist? What are the levels of the charges? If the charges have changed over the years, state the amount for selected years when they changed.
- What is the method of charging for irrigation water? (flat rate, volumetric rate, per cropped area, etc.).
- What is the total assessed water charges per season and/or year? Who collects the fees?
- What is the recovery rate?
- What are the other sources of revenue for the scheme besides water charges? (land tax, other taxes, sale of fishing rights in the scheme reservoir, etc.). What is the total amount normally collected from these other sources?
- Are all farmers in the scheme required to pay the established fees and charges? If some individuals or

groups of farmers are exempted, who are they, and why? Estimate the total number of those exempted.

- What is the level of financial autonomy of the irrigation agency or farmers organizations over the revenues collected within the scheme? Is it all or partially retained for use in the scheme, or transferred to a regional or central treasury?
- What is the total annual expenditures of the scheme under the following headings: staff salaries, allowances, materials, equipment and running costs, office running costs, hired labour, contracted civil works, miscellaneous, etc.?
- Estimate the total annual amount actually spent on maintenance and repair of physical facilities.
- How are the scheme expenditures financed? (direct from revenues within the scheme, provincial/state budget, central treasury, etc.).

SECTION IV: SOCIO-ECONOMIC ASSESSMENT

A. Agricultural policy and economic environment

- What are the government present policies towards agriculture, and irrigation in particular? How have the policies changed over the recent years?
- Are there government taxes or subsidies on farm inputs and produce? What are the tax or subsidy levels, if any, on the different crops and inputs?
- Does government enforce cropping restrictions, or are farmers free to make their choices?
- Do effective legislation exist for dealing with irrigation offenses and enforcement of rules?
- What social and economic infrastructure and services are provided in or within easy access of the project? (banks, health clinics, rural service centres, schools, police station, portable water supply, electricity, telecommunication, crop processing plants, etc.). If not in the project, state distances to the nearest locations for each facility and service.
- Do farmers obtain easy access to credits for farm inputs. What are the interest rates?

- Are there any local agricultural processing and storage facilities provided for farm produce?
- How is transportation of farm produce arranged to the markets? Where are the nearest market outlets for farm produce? (state distances).
- List other existing agricultural and non-agricultural activities within the project area (livestock, fisheries, petty trading, crafts, hired labour, etc.).

B. Agricultural crop production

- Classify the farm size distribution according the basic unit of holdings (hectares or acres):

1 ...... %	2 ...... %	3 ......%	4 .....%
5 ....%	6-10.....%	10-20....%	>20....%

- Estimate the yields of the crops produced in the scheme:

Crop/variety	Total area (ha)	Ave Yields (kg/ha)
....	....	....
....	....	....
....	....	....
....	....	....

Sample crop yields for the current season from a cross section of farmers to find out the variation in yields. Validate the results with crop cutting experiments, if possible. How do irrigated crop yields compare with rain-fed crop yields in locations around the project?

- Describe the farmers farming practices and level of technical knowledge for each crop from land preparation to harvesting and storage. How is the farmers' disposition towards improved agricultural technology?
- What are the typical rates of seed, fertilizer, pesticides, and other farm inputs per unit area?
- What are the major constraints to increased agricultural production? (land, water, labour, capital assets, financial assets, management, pests and diseases, weeds, marketing and prices, uncontrolled grazing of animals, etc.).

- If there are labour shortage problems, when are the seasons when the problems are most acute?

C. Agricultural support services

- Does a separate agency exist for agricultural support services? (extension, training, credit, marketing, etc.). What is the level of inter-agency coordination between it and the irrigation agency?
- Are agricultural extension staff available to advise farmers on irrigated farming practices and improved agricultural technology? How qualified are the extension staff? How often do they visit farmers?
- Are demonstration farms within the scheme? What crops are grown? How are their yields compared to the farmers' yields?
- Are there farmers' village cooperative societies for buying or selling farm produce, inputs, credits, etc.? What other purposes do they serve, if any?
- What are the farm-gate prices for the principal crops? How do they vary with other locations or with time?
- Where do farmers obtain principal farm inputs such as land preparation machinery, improved seeds, fertilizers, pesticides, etc.? Are there problems with farmers obtaining these inputs?
- Does the scheme have easy access to external markets or export?

D. Farm budgets

- Estimate the seasonal/annual farm income for the different crops in the scheme.
- What are the estimated expenses of the farmers per season for each of the different crops?
- Obtain an inventory of farmers depreciable assets and consumable items (machinery, wells, pumps, fuel, lubricants, etc.).
- Obtain information on prices of farm produce and the various inputs used by farmers.
- Estimate the amount of surplus farm products for sale, and the amounts for family consumption (home use).
- Evaluate the relative profitability between the different crops grown in the scheme.

ANNEXE A2: FARMERS QUESTIONNAIRE.

INTRODUCTION.

The Sokoto State Government, with the assistance of the Federal Government of Nigeria and the European Economic Community (EEC), is planning to the rehabilitate the Wurno Irrigation Scheme. We are carrying out research to identify the factors constraining farmers and staff performance within the scheme in order to properly address the issues that need improvements. We would greatly appreciate your cooperation in responding to this survey as much as possible and to the best of your knowledge. Please note that it is not mandatory to disclose your identity, and that all information provided will be treated with strict confidence. Thank you very much for your anticipated cooperation.

1. Date of interview. ....19.........

2 (a). Name of interviewee (optional). ....

2 (b). District/Village. ....

3. Sex. M [ ] F [ ]

4. Age.

< 20 Years	[ ]	21-30	[ ]	31-40	[ ]
41-50	[ ]	51-60	[ ]	> 60	[ ]

5. Educational level.

Never went to school	[ ]
Primary school leaver	[ ]
Secondary school leaver	[ ]
Diploma/Technical certificate	[ ]
Graduate	[ ]

6. How many acres of land do you hold within the irrigation scheme?

1 acre	[ ]	2 acres	[ ]
3 acres	[ ]	4 acres	[ ]
5 - 10 acres	[ ]	>10 acres	[ ]

7. What is the nature of your land holding?

Land owner	[ ]	Tenant	[ ]
Labourer	[ ]	Share cropper	[ ]

8. Where is the location of your plots of land within the scheme?

Main canal	Sec. canal	Block number	Acre #.
....	....	....	....
....	....	....	....

9. How many years have you been practising irrigated farming in this scheme? ....Years

10. Some people do not bother to farm in the dry season, what are your objectives for engaging in irrigated farming during the dry season?

....
....
....

11. Apart from irrigated farming during the dry season what other occupations do you normally engage in?

-Periods of time engaged in these activities.

Civil servant	[ ]	January - December
Wet season farming	[ ]	May - October
Animal rearing (*)	[ ]	....
Fishing	[ ]	....
Business/Trading	[ ]	....
Crafts and handiwork	[ ]	....
Hired labourer	[ ]	....
Others (specify)		....

(*) Please indicate number of animals;

Cattle:- Sheep:- Goats:- Donkeys:- Camels:- Others:

12. If you do not farm during the dry season, what are the factors that prevent you from doing so?

....
....
....
....

13. Please indicate the areas and crops you cultivated in the recent seasons.

WET SEASON 1991

Crop	**Area Cultivated**	**Planting Date**	**Total Yield**
Rice	.......acres	....	....bags
....	.......acres	....	....bags
....	.......acres	....	....bags

DRY SEASON 1991/1992

Crop	**Area Cultivated**	**Planting Date**	**Total Yield**
Wheat	.......acres	....	....bags
Onions	.......acres	....	....bags
Garlics	.......acres	....	....bags
....	.......acres	....	....bags

14. How do you normally obtain water to irrigate your dry season crops?

Gravity flow from canals	[ ]	Drains	[ ]
Lifting by bucket/calabash from canal	[ ]	Drains	[ ]
Pumping from the canals	[ ]	Drains	[ ]
Pumping from hand dug well	[ ]	Tubewell	[ ]

15 (a). If you have other sources of water apart from water in the reservoir and canal system, what factors prompted you to seek these alternatives?

No canal or drain network in my area [ ]
Distance from headworks and canals [ ]
Lack of maintenance of canals [ ]
Lack of cooperation with management [ ]
Other reasons (please specify) ....

15 (b). Please give the following specifications about your alternative sources of water.

Type	Year made	Approx. depth	Construction cost
Tubewell	19.....	...........m	..........Naira
Hand dug well	19.....	...........m	..........Naira

16. If you own a pump, please estimate the following associated costs:

Cost of pump	Repair/maintenance costs	Fuel costs.
N...........	N ..../Year	N...../Year

17. If you did not cultivate your entire allocated land area during the dry season what are the factors that hindered you from doing so?

No water supply to my area. [ ]
Inadequate water supply. [ ]
Unreliable water supply. [ ]
Water not supplied at the time needed. [ ]
Too much water in my area. [ ]
Other reasons (Please specify). ....
....

18. Research has shown that the optimum planting date for wheat is 15 November. What factors cause you to plant later than this recommended date?

I do not know of the research results. [ ]
I could not acquire seeds on time [ ]
I could not obtain fertilizer on time. [ ]
I could not get machinery for early land preparation. [ ]
My wet season rice was harvested late. [ ]
Field was waterlogged so I was waiting for it to drain [ ]
Other reasons (Please specify). ....
....

19. If you do not cultivate wheat during the dry season, why do you prefer growing other crops to wheat?

....
....
....
....
....

20 (a). How many times do you irrigate your crops during the dry season?

Wheat....... Onions........ Garlic......

20 (b). How often do you irrigate your dry season crops?

- Every day [ ]
- Weekly [ ]
- Irregularly [ ]
- Regularly, every...........days. [ ]

21. In your own opinion, what are the major problems and constraints affecting the performance of the irrigation system.

....
....
....
....
....

22. Could you please suggest the critical areas in the operation and management of the irrigation system that you think need improvements.

....
....
....
....
....
....

23. What is your source of power for the following farming activities?

A = Animals **H** = Hired labourers
P = Personal and family labour **T** = Tractors/machines

i. Ploughing and harrowing [ ]
ii Seedbed/field channels preparation [ ]
iii. Planting [ ]
iv. Fertilizer application [ ]
v. Irrigation [ ]
vi. Weeding [ ]
vii. Harvesting [ ]
viii Threshing [ ]
ix. Transportation [ ]

24. Do you have problems hiring a tractor for farming activities?

Yes [ ] No [ ]

25(a). Do you normally experience labour shortage during (circle one for each)

Land Preparation?	Weeding?	Harvesting?	Threshing?
Yes/No	Yes/No	Yes/No	Yes/No

25(b). How much do you pay per acre for hired labourer during these operations?

Seedbed Prep.	Weeding	Harvesting	Threshing
N......./acre	N....../acre	N..../acre	N.../acre

25(c) How many times do you weed your crops?

Rice	Wheat	Onions	Garlics
......	......	......	....

26. How much do you spend on buying seeds per acre of land?

Rice	Wheat	Onions	Garlics
N..../acre	N..../acre	N..../acre	N...../acre

27. Please indicate the types of fertilizers you use for your crops. (eg. Urea, NPK, DAP, Superphosphate, etc.)?

Crop	Fertilizer	Cost/bag	Bags/acre	Applications
Rice	....	N.......	....	......
Wheat	....	N.......	....	......
Onions	....	N.......	....	......
Garlics	....	N.......	....	......

28 (a). Would you prefer carrying out farm work and maintenance of the irrigation system in cooperative groups and water user associations?

Yes [ ] No [ ]

28 (b). If yes, why has such associations not been organized in the past? ....
....
....

28 (c). If no, what are your reasons for preferring individual work?

....

....

....

29. What is the drainage and soil condition in your plot?

Never waterlogged. [ ]

Waterlogged and saline. [ ]

Occasionally waterlogged but not saline. [ ]

-Estimate periods of the year when waterlogged ....

30. Do you or any of your workers ever suffer from any water-borne or water-related diseases such as (please circle as applicable):-

Cholera: Yes/No Bilharzia: Yes/No

Malaria: Yes/No Guinea worm: Yes/No

River blindness: Yes/No

In the following section, could you please express your own opinion about how you feel concerning the following issues in the management, operation and performance of the Wurno Irrigation System. Use the columns on the right hand side to check one score for each issue.

SCORE: **V**= Very Good

S= Satisfactory

N= Not satisfactory

D= Don't know/not sure

Please check one for each issue.	V	S	N	D
31. The maintenance conditions and functionality of canals, drains and structures.				
32. Yield this year compared with previous seasons.				
33. Availability of canal water to your farm.				
34. Reliability of water supply to your farm.				
35. Supply of water according to the time you need it.				
36. Adequacy and quantity of water delivered to your farm				
37. Equity and fairness of water distribution to farmers.				

38. Drainage of excess water and waterlogging conditions of your area.				
39. The existing procedures for communication between farmers and the management.				
40. The established irrigation service fees.				
41. Availability of human labour for farm operations.				
42. Availability of farm power and machinery to farmers.				
43. The level of farmers' involvement in the management, operation and maintenance of the irrigation system.				
44. Availability and cost of inputs such as improved seeds, fertilizers and chemicals to farmers.				
45. Marketing conditions and price of the farm produce.				
46. Availability of extension service to farmers.				
47. Availability of transport for farm produce.				
48. Provision of storage facilities for farm produce.				
49. Availability of credit for farm inputs.				
50. Provision and quality of educational facilities within the project area.				
51. Provision of portable water supply in and around the project.				
52. Provision and condition of sanitary and health facilities in and around the project.				
53. The occurrence of water-borne and water-related diseases around the project area.				

54.Supplementary comments to questions 31-53, and any other further comments (continue on reverse side if necessary).

....

....

....

....

....

....

THANK YOU VERY MUCH FOR YOUR COOPERATION

ANNEXE A3: MANAGEMENT QUESTIONNAIRE.

INTRODUCTION.

The Sokoto State Government, with the assistance of the Federal Government of Nigeria and the European Economic Community (EEC), is planning to rehabilitate the Wurno Irrigation Scheme. We are carrying out research to identify the factors constraining farmers and staff performance within the scheme in order to properly address the issues that need improvements. We would greatly appreciate your cooperation in responding to this survey as much as possible and to the best of your knowledge. Please note that it is not mandatory to disclose your identity, and that all information provided will be treated with strict confidence. Thank you very much for your anticipated cooperation.

1. Date of interview. ....19.......
2. Name of interviewee (optional). ....
3. Sex. M [ ] F [ ]

4. Age.

< 20 Years [ ] 21-30 [ ] 31-40 [ ]
41-50 [ ] 51-60 [ ] > 60 [ ]

5. Highest educational qualification ....
....

6. Other training undertaken ....
....

7. Position and grade level ....
....

8. Length of service in the Ministry of Agriculture (please indicate only since when you have been involved with the Wurno Irrigation Scheme).

..................Years.

9. Please briefly describe your job and responsibilities especially as regards the Wurno Irrigation Scheme.

....
....
....
....
....

10. What is your perception of your salary level and other entitlements regarding your responsibilities on the Wurno Irrigation Scheme?

Very good	[ ]
Satisfactory	[ ]
Poor	[ ]
Awful	[ ]
Not sure	[ ]

11. What working incentives and motivation mechanisms would you suggest should be provided to enhance the performance of workers?

....
....
....
....
....

12. What are the Sokoto State Government's policy objectives for its involvement in irrigated agriculture?

....
....
....
....
....

13. What were the original objectives for the establishment of the Wurno Irrigation Scheme?

....
....
....
....

13 (b). If there has been any subsequent changes of objectives regarding the Wurno Scheme, please briefly state the new objectives.

....
....
....
....

14. Please indicate to what extent you think the objectives of the Wurno Irrigation Scheme are being achieved.

....
....
....
....

15. In your own opinion, what are the major problems and constraints affecting the performance of the Wurno irrigation system.

....
....
....
....
....

16. Could you please suggest the critical areas in the management, operation and maintenance of the irrigation system that you think need improvements.

....
....
....
....
....

17. What are the established fees and taxes (e.g. water charges) which farmers are required to pay in the Wurno Irrigation scheme?

Type of Fees/Tax	Amount per year or season (Naira)
....	....
....	....
....	....

18. What is the estimated collection rate of the assessed fees ....%

19. Please state the existing avenues by which the management communicates with farmers.

....

....

....

....

....

20. Is there an overall monitoring and evaluation of the irrigation system?

Yes [ ] No [ ]

21. What kinds of data and records are collected in the system on a regular basis?

Daily	Weekly	Monthly	Seasonal/yearly
....	....	....	....
....	....	....	....
....	....	....	....

In the following section, could you please express your own opinion about how you feel concerning the following issues in the management, operation and performance of the Wurno Irrigation System. Use the columns on the right hand side to check one score for each issue.

SCORE: **V** = Very Good
S = Satisfactory
N = Not satisfactory
D = Don't know/not sure

Please check one for each issue.	V	S	N	D
22. The present number of staff who have direct responsibilities on the Wurno Irrigation Scheme.				
23. The qualifications and quality of staff in the scheme				
24. The existing working incentives and motivation mechanisms for project staff.				
25. The maintenance conditions and functionality of canals and structures.				

26. Yield this year compared with previous seasons.				
27. Availability of canal water to the fields within the project area.				
28. Reliability of water supply to farmers.				
29. Supply of water according to the time it is needed by the farmers.				
30. Adequacy and quantity of water delivered to farmers.				
31. Equity and fairness of water distribution to farmers.				
32. Drainage of excess water and waterlogging conditions within the scheme.				
33. The existing procedures of communication between farmers and the management.				
34. Established irrigation service fees.				
35. Availability of human labour within the scheme.				
36. Availability of farm power and machinery to farmers.				
37. The level of farmers' involvement in the management, operation and maintenance of the irrigation system.				
38. Availability and cost of inputs such as improved seeds fertilizers and agro-chemicals to farmers.				
39. Marketing conditions and price of the produce.				
40. Provision of extension service to farmers.				
41. Availability of transport for farm produce.				
42. Provision of storage facilities for farm produce.				
43. Availability of credit for farm inputs.				
44. Provision and quality of educational facilities within the project area.				
45. Provision of portable water supply in the project.				
46. Provision and condition of sanitary and health facilities.				
47. Occurrence of water-borne and water-related diseases such as cholera, bilharzia, malaria, guinea-worm, river-blindness within the project area.				

48. Supplementary comments to questions 22-47 or any other further comments.

THANK YOU VERY MUCH FOR YOUR COOPERATION

ANNEXE B1:

Net surface irrigation crop water requirements for WHEAT.

Irrigation Season	Stagger Decade	ETO	ETO	Kc	ETc	Pre-Irrigation	RAIN	Total Requirement	Decade Module	Mean Requirement	Average Module
months		mm/ day	mm/ decade		mm/ decade	mm/ decade	mm/ decade	mm/ decade	l/s.ha	mm/ decade	l/s.ha
November	i	5.9	59.0		0.0	100		100	1.16		
1 - 10	ii	5.9	59.0		0.0			0	0.00	33.3	0.39
	iii	5.9	59.0		0.0			0	0.00		
11 - 20	i	5.9	59.0	0.43	25.4			25	0.29		
	ii	5.9	59.0		0.0	100		100	1.16	41.8	0.48
	iii	5.9	59.0		0.0			0	0.00		
21 - 30	i	5.9	59.0	0.49	28.9			29	0.34		
	ii	5.9	59.0	0.43	25.4			25	0.29	51.4	0.60
	iii	5.9	59.0		0.0	100		100	1.16		
December	i	5.5	55.0	0.68	37.4			37	0.43		
1 - 10	ii	5.5	55.0	0.49	27.0			27	0.31	29.3	0.34
	iii	5.5	55.0	0.43	23.7			24	0.27		
11 - 20	i	5.5	55.0	0.98	53.9			54	0.63		
	ii	5.5	55.0	0.68	37.4			37	0.43	39.4	0.46
	iii	5.5	55.0	0.49	27.0			27	0.31		
21 - 30	i	5.5	55.0	1.15	63.2			63	0.73		
	ii	5.5	55.0	0.98	53.9			54	0.63	51.5	0.60
	iii	5.5	55.0	0.68	37.4			37	0.43		
January	i	6.2	62.0	1.15	71.3			71	0.83		
1 - 10	ii	6.2	62.0	1.15	71.3			71	0.83	67.8	0.79
	iii	6.2	62.0	0.98	60.8			61	0.70		
11 - 20	i	6.2	62.0	1.15	71.3			71	0.83		
	ii	6.2	62.0	1.15	71.3			71	0.83	71.3	0.83
	iii	6.2	62.0	1.15	71.3			71	0.83		
21 - 30	i	6.2	62.0	1.15	71.3			71	0.83		
	ii	6.2	62.0	1.15	71.3			71	0.83	71.3	0.83
	iii	6.2	62.0	1.15	71.3			71	0.83		
February	i	6.9	69.0	1.05	72.5			72	0.84		
1 - 10	ii	6.9	69.0	1.15	79.4			79	0.92	77.1	0.89
	iii	6.9	69.0	1.15	79.4			79	0.92		
11 - 20	i	6.9	69.0	0.83	57.3			57	0.66		
	ii	6.9	69.0	1.05	72.5			72	0.84	69.7	0.81
	iii	6.9	69.0	1.15	79.4			79	0.92		
21 - 30	i	6.9	69.0	0.59	40.7			41	0.47		
	ii	6.9	69.0	0.83	57.3			57	0.66	56.8	0.66
	iii	6.9	69.0	1.05	72.5			72	0.84		
March	i	7.5	75.0	0.34	25.5			26	0.30		
1 - 10	ii	7.5	75.0	0.59	44.3			44	0.51	44.0	0.51
	iii	7.5	75.0	0.83	62.3			62	0.72		
11 - 20	i	7.5	75.0	0.00	0.0			0	0.00		
	ii	7.5	75.0	0.34	25.5			26	0.30	23.3	0.27
	iii	7.5	75.0	0.59	44.3			44	0.51		
21 - 30	i	7.5	75.0		0.0			0	0.00		
	ii	7.5	75.0	0.00	0.0			0	0.00	8.5	0.10
	iii	7.5	75.0	0.34	25.5			26	0.30		
April	i	7.6	76.0		0.0			0	0.00		
1 - 10	ii	7.6	76.0		0.0			0	0.00	0.0	0.00
	iii	7.6	76.0	0.00	0.0			0	0.00		
11 - 20	i	7.6	76.0		0.0			0	0.00		
	ii	7.6	76.0		0.0			0	0.00	0.0	0.00
	iii	7.6	76.0		0.0			0	0.00		
21 - 30	i	7.6	76.0		0.0			0	0.00		
	ii	7.6	76.0		0.0			0	0.00	0.0	0.00
	iii	7.6	76.0		0.0			0	0.00		

ANNEXE B2:

Net surface irrigation crop water requirements for ONION.

Irrigation Season months	Stagger Decade	ETO mm/d	ETO mm/ decade	Kc	ETc mm/ decade	Pre-Irrigation mm/ decade	RAIN mm/ decade	Total Requirement mm/ decade	Decade Module l/s.ha	Mean Requirement mm/ decade	Average Module l/s.ha
November	i	5.9	59.0		0.0	100		100	1.16		
1 - 10	ii	5.9	59.0		0.0			0	0.00	33.3	0.39
	iii	5.9	59.0		0.0			0	0.00		
11 - 20	i	5.9	59.0	0.40	23.6			24	0.27		
	ii	5.9	59.0		0.0	100		100	1.16	41.2	0.48
	iii	5.9	59.0		0.0			0	0.00		
21 - 30	i	5.9	59.0	0.40	23.6			24	0.27		
	ii	5.9	59.0	0.40	23.6			24	0.27	49.1	0.57
	iii	5.9	59.0		0.0	100		100	1.16		
December	i	5.5	55.0	0.50	27.5			28	0.32		
1 - 10	ii	5.5	55.0	0.40	22.0			22	0.26	23.8	0.28
	iii	5.5	55.0	0.40	22.0			22	0.26		
11 - 20	i	5.5	55.0	0.70	38.5			39	0.45		
	ii	5.5	55.0	0.50	27.5			28	0.32	29.3	0.34
	iii	5.5	55.0	0.40	22.0			22	0.26		
21 - 30	i	5.5	55.0	0.90	49.5			50	0.57		
	ii	5.5	55.0	0.70	38.5			39	0.45	38.5	0.45
	iii	5.5	55.0	0.50	27.5			28	0.32		
January	i	6.2	62.0	1.05	65.1			65	0.76		
1 - 10	ii	6.2	62.0	0.90	55.8			56	0.65	54.8	0.64
	iii	6.2	62.0	0.70	43.4			43	0.50		
11 - 20	i	6.2	62.0	1.05	65.1			65	0.76		
	ii	6.2	62.0	1.05	65.1			65	0.76	62.0	0.72
	iii	6.2	62.0	0.90	55.8			56	0.65		
21 - 30	i	6.2	62.0	1.05	65.1			65	0.76		
	ii	6.2	62.0	1.05	65.1			65	0.76	65.1	0.76
	iii	6.2	62.0	1.05	65.1			65	0.76		
February	i	6.9	69.0	1.04	71.8			72	0.83		
1 - 10	ii	6.9	69.0	1.05	72.5			72	0.84	72.2	0.84
	iii	6.9	69.0	1.05	72.5			72	0.84		
11 - 20	i	6.9	69.0	1.00	69.0			69	0.80		
	ii	6.9	69.0	1.04	71.8			72	0.83	71.1	0.82
	iii	6.9	69.0	1.05	72.5			72	0.84		
21 - 30	i	6.9	69.0	0.95	65.6			66	0.76		
	ii	6.9	69.0	1.00	69.0			69	0.80	68.8	0.80
	iii	6.9	69.0	1.04	71.8			72	0.83		
March	i	7.5	75.0	0.90	67.5			68	0.78		
1 - 10	ii	7.5	75.0	0.95	71.3			71	0.83	71.3	0.83
	iii	7.5	75.0	1.00	75.0			75	0.87		
11 - 20	i	7.5	75.0	0.80	60.0			60	0.70		
	ii	7.5	75.0	0.90	67.5			68	0.78	66.3	0.77
	iii	7.5	75.0	0.95	71.3			71	0.83		
21 - 30	i	7.5	75.0		0.0			0	0.00		
	ii	7.5	75.0	0.80	60.0			60	0.70	42.5	0.49
	iii	7.5	75.0	0.90	67.5			68	0.78		
April	i	7.6	76.0		0.0			0	0.00		
1 - 10	ii	7.6	76.0		0.0			0	0.00	20.3	0.24
	iii	7.6	76.0	0.80	60.8			61	0.71		
11 - 20	i	7.6	76.0		0.0			0	0.00		
	ii	7.6	76.0		0.0			0	0.00	0.0	0.00
	iii	7.6	76.0		0.0			0	0.00		
21 - 30	i	7.6	76.0		0.0			0	0.00		
	ii	7.6	76.0		0.0			0	0.00	0.0	0.00
	iii	7.6	76.0		0.0			0	0.00		

ANNEXE B3:

Net surface irrigation crop water requirements for TOMATO.

Irrigation Season months	Stagger Decade	ETO mm/d	ETO mm/ decade	Kc	ETc mm/ decade	Pre-Irrigation mm/ decade	RAIN mm/ decade	Total Requirement mm/ decade	Decade Module l/s.ha	Mean Requirement mm/ decade	Average Module l/s.ha
November	i	5.9	59.0		0.0	100		100	1.16		
1 - 10	ii	5.9	59.0		0.0			0	0.00	33.3	0.39
	iii	5.9	59.0		0.0			0	0.00		
11 - 20	i	5.9	59.0	0.45	26.6			27	0.31		
	ii	5.9	59.0		0.0	100		100	1.16	42.2	0.49
	iii	5.9	59.0		0.0			0	0.00		
21 - 30	i	5.9	59.0	0.45	26.6			27	0.31		
	ii	5.9	59.0	0.45	26.6			27	0.31	51.0	0.59
	iii	5.9	59.0		0.0	100		100	1.16		
December	i	5.5	55.0	0.45	24.8			25	0.29		
1 - 10	ii	5.5	55.0	0.45	24.8			25	0.29	24.8	0.29
	iii	5.5	55.0	0.45	24.8			25	0.29		
11 - 20	i	5.5	55.0	0.55	30.3			30	0.35		
	ii	5.5	55.0	0.45	24.8			25	0.29	26.6	0.31
	iii	5.5	55.0	0.45	24.8			25	0.29		
21 - 30	i	5.5	55.0	0.75	41.3			41	0.48		
	ii	5.5	55.0	0.55	30.3			30	0.35	32.1	0.37
	iii	5.5	55.0	0.45	24.8			25	0.29		
January	i	6.2	62.0	0.94	58.3			58	0.68		
1 - 10	ii	6.2	62.0	0.75	46.5			47	0.54	46.3	0.54
	iii	6.2	62.0	0.55	34.1			34	0.40		
11 - 20	i	6.2	62.0	1.11	68.8			69	0.80		
	ii	6.2	62.0	0.94	58.3			58	0.68	57.9	0.67
	iii	6.2	62.0	0.75	46.5			47	0.54		
21 - 30	i	6.2	62.0	1.20	74.4			74	0.86		
	ii	6.2	62.0	1.11	68.8			69	0.80	67.2	0.78
	iii	6.2	62.0	0.94	58.3			58	0.68		
February	i	6.9	69.0	1.20	82.8			83	0.96		
1 - 10	ii	6.9	69.0	1.20	82.8			83	0.96	80.7	0.94
	iii	6.9	69.0	1.11	76.6			77	0.89		
11 - 20	i	6.9	69.0	1.20	82.8			83	0.96		
	ii	6.9	69.0	1.20	82.8			83	0.96	82.8	0.96
	iii	6.9	69.0	1.20	82.8			83	0.96		
21 - 30	i	6.9	69.0	1.18	81.4			81	0.94		
	ii	6.9	69.0	1.20	82.8			83	0.96	82.3	0.96
	iii	6.9	69.0	1.20	82.8			83	0.96		
March	i	7.5	75.0	1.03	77.3			77	0.90		
1 - 10	ii	7.5	75.0	1.18	88.5			89	1.03	85.3	0.99
	iii	7.5	75.0	1.20	90.0			90	1.04		
11 - 20	i	7.5	75.0	0.80	60.0			60	0.70		
	ii	7.5	75.0	1.03	77.3			77	0.90	75.3	0.87
	iii	7.5	75.0	1.18	88.5			89	1.03		
21 - 30	i	7.5	75.0	0.65	48.8			49	0.57		
	ii	7.5	75.0	0.80	60.0			60	0.70	62.0	0.72
	iii	7.5	75.0	1.03	77.3			77	0.90		
April	i	7.6	76.0		0.0			0	0.00		
1 - 10	ii	7.6	76.0	0.65	49.4			49	0.57	36.7	0.43
	iii	7.6	76.0	0.80	60.8			61	0.71		
11 - 20	i	7.6	76.0		0.0			0	0.00		
	ii	7.6	76.0		0.0			0	0.00	16.5	0.19
	iii	7.6	76.0	0.65	49.4			49	0.57		
21 - 30	i	7.6	76.0		0.0			0	0.00		
	ii	7.6	76.0		0.0			0	0.00	0.0	0.00
	iii	7.6	76.0		0.0			0	0.00		

ANNEXE C1:

Spreadsheet calculation schedule of canal design discharges for the main system, Wurno irrigation Scheme.

Offtake/ Structure	Chainage	Actual Bed Width	Chosen Bed Width	Canal Bed Slope	Hydraulic Bed Level	Possible Flow	Possible Depth	Possible FSL	Diff. b/w FSL & BTL	Design Flow	Design Depth	Design FSL
	m	m	m		m.a.s.l	m^3/s	m	m.a.s.l	m	m^3/s	m	m.a.s.l
			LUGU MAIN CANAL									
0+000	0	5.2	2	0.000357	257.133	1	0.84	257.973	0.502	1.2078	0.93	258.063
	17	5.2	2	0.000357	257.127	1	0.84	257.967	0.508	1.2078	0.93	258.057
	100	2	2	0.000357	257.097	1	0.84	257.937	0.418	1.2078	0.93	258.027
	200	2	2	0.000357	257.061	1	0.84	257.901	0.284	1.2078	0.93	257.991
	300	3.2	2	0.000357	257.026	1	0.84	257.866	0.183	1.2078	0.93	257.956
	400	3	2	0.000357	256.990	1	0.84	257.830	0.198	1.2078	0.93	257.92
L1-436	436	2.5	2	0.000357	256.977	1	0.84	257.817	0.286	1.2078	0.93	257.907
	500	2	2	0.000357	256.954	1	0.73	257.684	0.494	1.0402	0.86	257.814
	600	2	2	0.000357	256.919	1	0.73	257.649	0.434	1.0402	0.86	257.779
	700	2	2	0.000357	256.883	1	0.73	257.613	0.390	1.0402	0.86	257.743
	800	2	2	0.000357	256.847	1	0.73	257.577	0.334	1.0402	0.86	257.707
	900	4	2	0.000357	256.812	1	0.73	257.542	0.009	1.0402	0.86	257.672
	1000	2	2	0.000357	256.776	1	0.73	257.506	0.709	1.0402	0.86	257.636
	1100	2.8	2	0.000357	256.740	1	0.73	257.470	0.312	1.0402	0.86	257.6
	1200	2.8	2	0.000357	256.705	1	0.73	257.435	0.260	1.0402	0.86	257.565
L2-1250	1250	2.4	2	0.000357	256.687	1	0.73	257.417	0.228	1.0402	0.86	257.547
	1300	2	2	0.000357	256.669	0.88	0.65	257.319	0.276	0.8286	0.77	257.439
	1400	2	2	0.000357	256.633	0.88	0.65	257.283	0.427	0.8286	0.77	257.403
	1500	2.8	2	0.000357	256.598	0.88	0.65	257.248	0.532	0.8286	0.77	257.368
	1600	2	2	0.000357	256.562	0.88	0.65	257.212	0.481	0.8286	0.77	257.332
	1700	4	2	0.000357	256.526	0.88	0.65	257.176	0.527	0.8286	0.77	257.296
	1800	3	2	0.000357	256.491	0.88	0.65	257.141	0.917	0.8286	0.77	257.261
	1900	2	2	0.000357	256.455	0.88	0.65	257.105	0.532	0.8286	0.77	257.225
	2000	2.3	2	0.000357	256.419	0.86	0.65	257.069	0.986	0.8286	0.77	257.169
	2100	3	2	0.000357	256.384	0.88	0.65	257.034	0.631	0.8286	0.77	257.154
	2200	3.2	2	0.000357	256.348	0.88	0.65	256.998	0.496	0.8286	0.77	257.118
L3-2208	2208	3.1	2	0.000357	256.345	0.88	0.65	256.995	0.550	0.8286	0.77	257.115
	2300	3	2	0.000357	256.312	0.7007	0.58	256.892	0.704	0.5848	0.64	256.952
	2400	3	2	0.000357	256.276	0.7007	0.58	256.856	0.757	0.5848	0.64	256.916
	2500	2	2	0.000357	256.241	0.7007	0.58	256.821	0.732	0.5848	0.64	256.881
	2600	2.4	2	0.000357	256.205	0.7007	0.58	256.785	0.753	0.5848	0.64	256.845
	2700	3	2	0.000357	256.169	0.7007	0.58	256.749	0.589	0.5848	0.64	256.809
	2800	2.8	2	0.000357	256.134	0.7007	0.58	256.714	0.564	0.5848	0.64	256.774
L4-2900	2900	2	2	0.000357	256.098	0.7007	0.58	256.678	0.430	0.5848	0.64	256.738
	3000	2	2	0.000357	256.062	0.4339	0.45	256.512	0.824	0.3154	0.45	256.512
	3100	2	2	0.000357	256.027	0.4339	0.45	256.477	0.649	0.3154	0.45	256.477
	3200	3	2	0.000357	255.991	0.4339	0.45	256.441	0.873	0.3154	0.45	256.441
	3300	2	2	0.000357	255.955	0.4339	0.45	256.405	0.741	0.3154	0.45	256.405
STOP-340	3400	2	2	0.000357	255.920	0.4339	0.45	256.370	0.816	0.3154	0.45	256.37
	3500											
	3600											
FC1-3670	3670											
	3700											
	3800											
	3900											
	4000											
	4100											
	4200											
	4300											
	4400											
	4500											
	4600											
	4700											
	4725											

Offtake/ Structure	Chainage	Actual Bed Width	Chosen Bed Width	Canal Bed Slope	Hydraulic Bed Level	Possible Flow	Possible Depth	Possible FSL	Diff. b/w FSL & BTL	Design Flow	Design Depth	Design FSL
				TUTUDAWA MAIN CANAL								
	m	m	m		m.a.s.l	m^3/s	m	m.a.s.l	m	m^3/s	m	m.a.s.l
0+000	0	4	4	0.000219	256.641	1.4	0.85	257.491	1.042	1.821	0.98	257.621
	19	4	4	0.000219	256.637	1.4	0.85	257.487	1.046	1.821	0.98	257.617
T1A-66	66	3.8	4	0.000219	256.627	1.4	0.85	257.477	0.651	1.821	0.98	257.607
	100	3.6	4	0.000219	256.619	1.2871	0.81	257.429	0.294	1.702	0.95	257.569
	200	2.6	4	0.000219	256.597	1.2871	0.81	257.407	0.438	1.702	0.95	257.547
T1C-202	202	3.95	4	0.000219	256.597	1.2871	0.81	257.407	0.292	1.702	0.95	257.547
	300	5.3	4	0.000219	256.575	1.0859	0.74	257.315	0.237	1.489	0.88	257.455
	400	5.3	4	0.000219	256.554	1.0859	0.74	257.294	0.152	1.489	0.88	257.434
	500	3.7	4	0.000219	256.532	1.0859	0.74	257.272	-0.204	1.489	0.88	257.412
	600	4.5	4	0.000219	256.510	1.0859	0.74	257.250	-0.332	1.489	0.88	257.39
	700	4	4	0.000219	256.488	1.0859	0.74	257.228	-0.474	1.489	0.88	257.368
	800	6	4	0.000219	256.466	1.0859	0.74	257.206	0.092	1.489	0.88	257.346
	900	5	4	0.000219	256.444	1.0859	0.74	257.184	0.219	1.489	0.88	257.324
	1000	4	4	0.000219	256.422	1.0859	0.74	257.162	0.324	1.489	0.88	257.302
	1100	4	4	0.000219	256.400	1.0859	0.74	257.140	0.194	1.489	0.88	257.28
	1200	3.6	4	0.000219	256.378	1.0859	0.74	257.118	-0.268	1.489	0.88	257.258
	1300	3.3	4	0.000219	256.356	1.0859	0.74	257.096	-0.375	1.489	0.88	257.236
	1400	4	4	0.000219	256.334	1.0859	0.74	257.074	-0.424	1.489	0.88	257.214
	1500	4	4	0.000219	256.312	1.0859	0.74	257.052	-0.067	1.489	0.88	257.192
	1600	4	4	0.000219	256.291	1.0859	0.74	257.031	0.093	1.489	0.88	257.171
	1700	4	4	0.000219	256.269	1.0859	0.74	257.009	0.065	1.489	0.88	257.149
	1800	4	4	0.000219	256.247	1.0859	0.74	256.987	0.297	1.489	0.88	257.127
	1900	4	4	0.000219	256.225	1.0859	0.74	256.965	0.148	1.489	0.88	257.105
	2000	4	4	0.000219	256.203	1.0859	0.74	256.943	0.187	1.489	0.88	257.083
T2-2075	2075	3	4	0.000219	256.186	1.0859	0.74	256.926	0.271	1.489	0.88	257.066
	2100	2	4	0.000219	256.181	0.9109	0.67	256.851	0.414	1.0742	0.73	256.911
	2200	1.2	4	0.000219	256.159	0.9109	0.67	256.829	0.047	1.0742	0.73	256.889
	2300	2.5	4	0.000219	256.137	0.9109	0.67	256.807	0.263	1.0742	0.73	256.867
	2400	2	4	0.000219	256.115	0.9109	0.67	256.785	0.280	1.0742	0.73	256.845
	2500	2	4	0.000219	256.093	0.9109	0.67	256.763	0.059	1.0742	0.73	256.823
	2600	1.2	4	0.000219	256.071	0.9109	0.67	256.741	0.224	1.0742	0.73	256.801
	2700	1.3	4	0.000219	256.049	0.9109	0.67	256.719	-0.064	1.0742	0.73	256.779
	2800	2	4	0.000219	256.027	0.9109	0.67	256.697	-0.084	1.0742	0.73	256.757
T3-2808	2808	2	4	0.000219	256.026	0.9109	0.67	256.696	-0.063	1.0742	0.73	256.756
	2900	2	4	0.000219	256.006	0.7609	0.6	256.606	0.047	0.7778	0.61	256.616
	3000	2	4	0.000219	255.984	0.7609	0.6	256.584	0.410	0.7778	0.61	256.594
	3100	2	4	0.000219	255.962	0.7609	0.6	256.562	0.342	0.7778	0.61	256.572
	3200	2	4	0.000219	255.940	0.7609	0.6	256.540	-0.016	0.7778	0.61	256.55
	3300	1	4	0.000219	255.918	0.7609	0.6	256.518	0.168	0.7778	0.61	256.528
	3400	1.6	4	0.000219	255.896	0.7609	0.6	256.496	0.005	0.7778	0.61	256.506
T4-3492	3492	1.8	4	0.000219	255.876	0.7609	0.6	256.476	0.116	0.7778	0.61	256.486
	3500	2	4	0.000219	255.874	0.5522	0.5	256.374	0.308	0.5425	0.49	256.364
	3600	2	4	0.000219	255.852	0.5522	0.5	256.352	0.120	0.5425	0.49	256.342
	3700	2	4	0.000219	255.830	0	0.5	256.330	-0.015	0.5425	0.49	256.32
STOP-380	3800	2	4	0.000219	255.808	0	0.5	256.308	-0.113	0.5425	0.49	256.298
	3900											
T5-3910	3910											
	4000											
	4100											
	4200											
	4300											
	4400											
	4500											
	4600											
	4700											
	4800											
	4900											

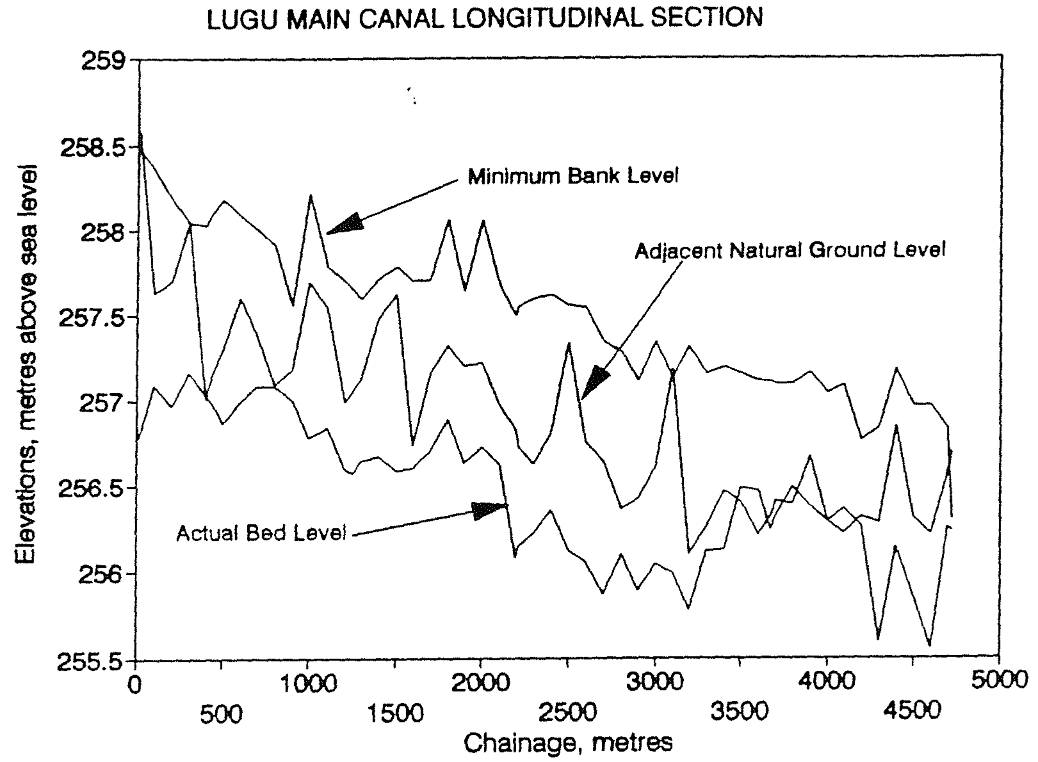
Offtake/ Structure	Chainage	Actual Bed Width	Chosen Bed Width	Canal Bed Slope	Hydraulic Bed Level	Possible Flow	Possible Depth	Possible FSL	Diff. b/w FSL & BTL	Design Flow	Design Depth	Design FSL
	m	m	m		m.a.s.l	m^3/s	m	m.a.s.l	m	m^3/s	m	m.a.s.l
	5000											
	5100											
			LUGU SECONDARY L2									
0+000	0	2	1.2	0.000302	256.423	0.12	0.35	256.773	0.695	0.1692	0.49	256.913
	100	2	1.2	0.000302	256.393	0.12	0.35	256.743	0.465	0.1692	0.49	256.883
	200	1	1.2	0.000302	256.363	0.12	0.35	256.713	0.215	0.1692	0.49	256.853
	300	1.4	1.2	0.000302	256.333	0.12	0.35	256.683	0.099	0.1692	0.49	256.823
	400	1.6	1.2	0.000302	256.303	0.12	0.35	256.653	0.079	0.1692	0.49	256.793
	500	1.2	1.2	0.000302	256.272	0.12	0.35	256.622	0.037	0.1692	0.49	256.762
	600	1.6	1.2	0.000302	256.242	0.12	0.35	256.592	-0.152	0.1692	0.49	256.732
	700	1.4	1.2	0.000302	256.212	0.12	0.35	256.562	0.058	0.1692	0.49	256.702
	800	1.2	1.2	0.000302	256.182	0.12	0.35	256.532	0.254	0.1692	0.49	256.672
	900	1.4	1.2	0.000302	256.152	0.12	0.35	256.502	0.354	0.1692	0.49	256.642
	1000	1.4	1.2	0.000302	256.122	0.12	0.35	256.472	-0.214	0.1692	0.49	256.612
	1022.5											
			LUGU SECONDARY L3									
0+000	0	0.6	1.2	0.001142	256.584	0.1793	0.30642	256.891	0.326	0.1793	0.3064	256.891
	100	1.2	1.2	0.001142	256.470	0.1793	0.30642	256.777	0.370	0.1793	0.3064	256.777
STR-184	184	1.3	1.2	0.001142	256.374	0.1793	0.30642	256.681	0.429	0.1793	0.3064	256.681
	200	1.4	1.2	0.001142	256.356	0.1793	0.30642	256.662	0.528	0.1793	0.3064	256.662
	300	1.4	1.2	0.001142	256.242	0.1793	0.30642	256.548	0.442	0.1793	0.3064	256.548
	400	1.2	1.2	0.001142	256.128	0.1793	0.30642	256.434	0.488	0.1793	0.3064	256.434
	500	1.2	1.2	0.001142	256.013	0.1793	0.30642	256.320	0.593	0.1793	0.3064	256.32
	600	1.2	1.2	0.001142	255.899	0.1793	0.30642	256.206	-0.043	0.1793	0.3064	256.206
	700											
	800											
	825											
			LUGU SECONDARY L4A									
0+000	0	0.4	1.4	0.000824	256.291	0.3	0.41	256.701	0.366	0.2668	0.39	256.681
STR-013	13	1	1.4	0.000824	256.280	0.3	0.41	256.690	0.376	0.2668	0.39	256.67
	50	1.6	1.4	0.000824	256.249	0.3	0.41	256.659	0.326	0.2668	0.39	256.639
	100	1.6	1.4	0.000824	256.208	0.3	0.41	256.618	0.367	0.2668	0.39	256.598
STR-114	114	1.5	1.4	0.000824	256.197	0.3	0.41	256.607	0.320	0.2668	0.39	256.587
	200	1.4	1.4	0.000824	256.126	0.3	0.41	256.536	0.333	0.2668	0.39	256.516
	300	2	1.4	0.000824	256.044	0.3	0.41	256.454	0.155	0.2668	0.39	256.434
STR-304.4	304.4	2	1.4	0.000824	256.040	0.3	0.41	256.450	0.159	0.2668	0.39	256.43
STR-309.7	309.7	1.7	1.4	0.000824	256.036	0.3	0.41	256.446	0.171	0.2668	0.39	256.426
	400	1.4	1.4	0.000824	255.961	0.3	0.41	256.371	0.253	0.2668	0.39	256.351
STR-466.8	466.8	1.4	1.4	0.000824	255.906	0.3	0.41	256.316	0.178	0.2668	0.39	256.296
	500	1.4	1.4	0.000824	255.879	0.3	0.41	256.289	-0.055	0.2668	0.39	256.269
STR-579	579	1.4	1.4	0.000824	255.814	0.3	0.41	256.224	0.175	0.2668	0.39	256.204
STR-589	589	1.7	1.4	0.000824	255.806	0.3	0.41	256.216	0.093	0.2668	0.39	256.196
	600	2	1.4	0.000824	255.797	0.3	0.41	256.207	0.011	0.2668	0.39	256.187
	700	1.4	1.4	0.000824	255.714	0.3	0.41	256.124	0.179	0.2668	0.39	256.104
	800	1.4	1.4	0.000824	255.632	0.3	0.41	256.042	0.101	0.2668	0.39	256.022
	900	1.2	1.4	0.000824	255.549	0.3	0.41	255.959	0.394	0.2668	0.39	255.939
STR-977	977	1.4	1.4	0.000824	255.486	0.3	0.41	255.896	0.313	0.2668	0.39	255.876
STR-983.8	983.8	1.6	1.4	0.000824	255.480	0.3	0.41	255.890	0.175	0.2668	0.39	255.87
	1000	1.6	1.4	0.000824	255.467	0.3	0.41	255.877	0.188	0.2668	0.39	255.857
	1100											
	1200											

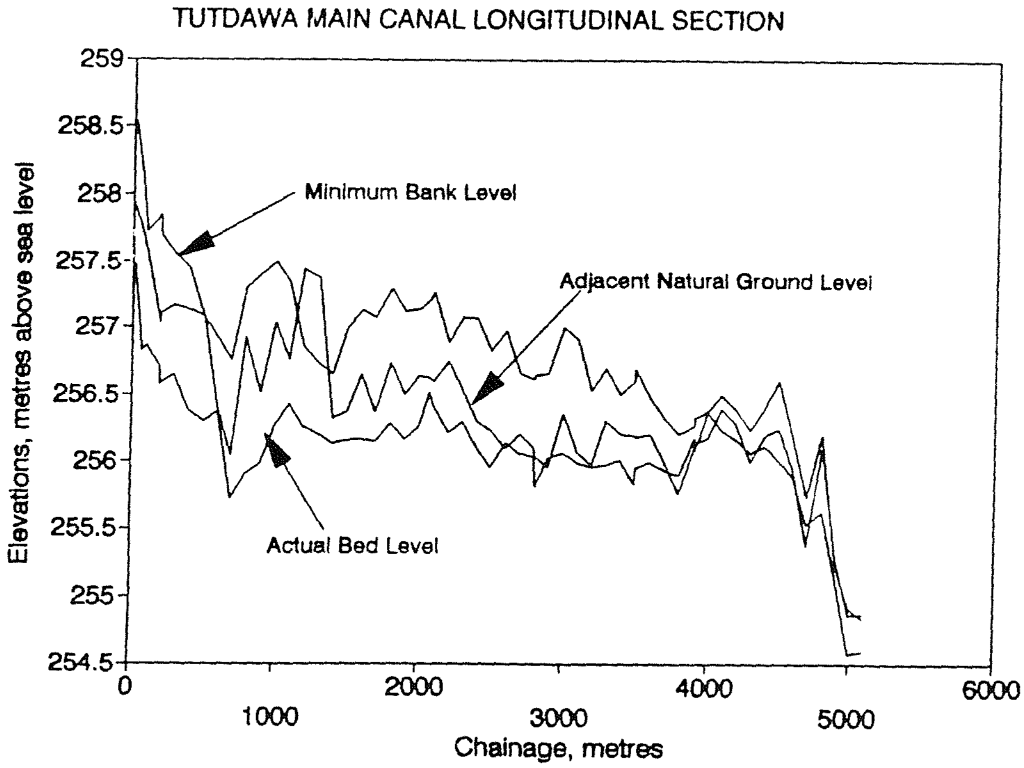
Offtake/ Structure	Chainage	Actual Bed Width	Chosen Bed Width	Canal Bed Slope	Hydraulic Bed Level	Possible Flow	Possible Depth	Possible FSL	Diff. b/w FSL & BTL	Design Flow	Design Depth	Design FSL
	m	m	m		m.a.s.l	m^3/s	m	m.a.s.l	m	m^3/s	m	m.a.s.l
STR-1257.	1257.2											
	1300											
	1362											
			LUGU SECONDARY L4B									
0+000	0	0.8	1	0.00228	256.262	0.1	0.2	256.462	0.345	0.2668	0.39	256.652
STR- 08	8	1	1	0.00228	256.243	0.1	0.2	256.443	0.164	0.2668	0.39	256.633
	100	1	1	0.00228	256.034	0.1	0.2	256.234	0.173	0.2668	0.39	256.424
	200	1.2	1	0.00228	255.806	0.1	0.2	256.006	0.077	0.2668	0.39	256.196
	300	1.4	1	0.00228	255.578	0.1	0.2	255.778	-0.205	0.2668	0.39	255.968
	400	1.6	1	0.00228	255.350	0.1	0.2	255.550	-0.214	0.2668	0.39	255.74
	500	2	1	0.00228	255.122	0.1	0.2	255.322	0.024	0.2668	0.39	255.512
	600											
	625											
			TUTUDAWA SECONDARY T1A									
0+000	0	2	2	0.000657	256.938	0.7	0.59	257.528	0.215	0.1129	0.21	257.148
T1A1-19.2	19.2	2	2	0.000657	256.926	0.7	0.59	257.516	0.227	0.1129	0.21	257.136
	100	2	2	0.000657	256.873	0.7	0.59	257.463	0.280	0.1129	0.21	257.083
	200	2	2	0.000657	256.807	0.7	0.59	257.397	0.219	0.1129	0.21	257.017
	300	2	2	0.000657	256.741	0.7	0.59	257.331	0.165	0.1129	0.21	256.951
	400	2	2	0.000657	256.676	0.7	0.59	257.266	0.865	0.1129	0.21	256.886
	500	2	2	0.000657	256.610	0.7	0.59	257.200	0.221	0.1129	0.21	256.82
	600	2	2	0.000657	256.544	0.7	0.59	257.134	0.430	0.1129	0.21	256.754
	700	2	2	0.000657	256.478	0.7	0.59	257.068	0.296	0.1129	0.21	256.688
STR-749.2	749.2											
	800											
	900											
	1000											
	1072											
			TUTUDAWA SECONDARY T1C									
0+000	0	1.2	1.2	0.000754	256.686	0.2012	0.37	257.056	0.149	0.2012	0.37	257.056
STR-09	9	1.2	1.2	0.000754	256.679	0.2012	0.37	257.049	0.156	0.2012	0.37	257.049
	100	1.6	1.2	0.000754	256.610	0.2012	0.37	256.980	0.225	0.2012	0.37	256.98
STR-153.4	153.4	1.2	1.2	0.000754	256.570	0.2012	0.37	256.940	0.248	0.2012	0.37	256.94
	200	1.2	1.2	0.000754	256.535	0.2012	0.37	256.905	0.265	0.2012	0.37	256.905
	300	2	1.2	0.000754	256.459	0.2012	0.37	256.829	0.171	0.2012	0.37	256.829
STR-310.4	310.4	1.6	1.2	0.000754	256.452	0.2012	0.37	256.822	0.205	0.2012	0.37	256.822
	400	1.6	1.2	0.000754	256.384	0.2012	0.37	256.754	0.280	0.2012	0.37	256.754
	500	1.6	1.2	0.000754	256.309	0.2012	0.37	256.679	0.475	0.2012	0.37	256.679
	600	1.2	1.2	0.000754	256.233	0.2012	0.37	256.603	0.371	0.2012	0.37	256.603
STR-615.3	615.3	1.2	1.2	0.000754	256.222	0.2012	0.37	256.592	0.363	0.2012	0.37	256.592
	700	1.2	1.2	0.000754	256.158	0.2012	0.37	256.528	0.407	0.2012	0.37	256.528
	800	1	1.2	0.000754	256.082	0.2012	0.37	256.452	0.473	0.2012	0.37	256.452
STR-829.4	829.4	1.6	1.2	0.000754	256.060	0.2012	0.37	256.430	0.435	0.2012	0.37	256.43
			TUTUDAWA SECONDARY T2									
0+000	0	0.6	2	0.000229	256.454	0.175	0.37	256.824	0.229	0.2751	0.47	256.924
	50	2	2	0.000229	256.443	0.175	0.37	256.813	-0.012	0.2751	0.47	256.913
	100	2.8	2	0.000229	256.431	0.175	0.37	256.801	0.202	0.2751	0.47	256.901
STR-185	185	2.6	2	0.000229	256.412	0.175	0.37	256.782	0.255	0.2751	0.47	256.882
	200	2.6	2	0.000229	256.408	0.175	0.37	256.778	0.262	0.2751	0.47	256.878

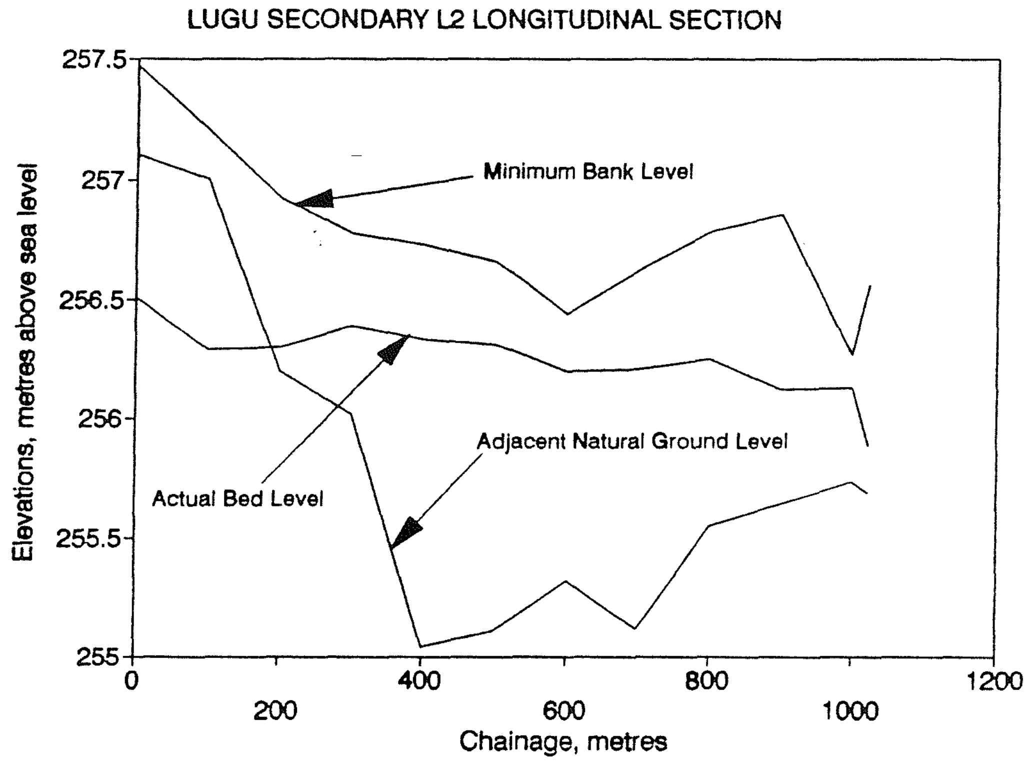
Offtake/ Structure	Chainage	Actual Bed Width	Chosen Bed Width	Canal Bed Slope	Hydraulic Bed Level	Possible Flow	Possible Depth	Possible FSL	Diff. b/w FSL & BTL	Design Flow	Design Depth	Design FSL
	m	m	m		m.a.s.l	m^3/s	m	m.a.s.l	m	m^3/s	m	m.a.s.l
	300	2.6	2	0.000229	256.385	0.175	0.37	256.755	0.055	0.2751	0.47	256.855
STR-350	350	2	2	0.000229	256.374	0.175	0.37	256.744	0.181	0.2751	0.47	256.844
	400	2	2	0.000229	256.363	0.175	0.37	256.733	0.058	0.2751	0.47	256.833
	500	2	2	0.000229	256.340	0.175	0.37	256.710	0.093	0.2751	0.47	256.81
STR-521	521	2	2	0.000229	256.335	0.175	0.37	256.705	0.132	0.2751	0.47	256.805
	600	2	2	0.000229	256.317	0.175	0.37	256.687	0.133	0.2751	0.47	256.787
STR-692	692											
	700											
	800											
STR-811	811											
	900											
STR-935	935											
	1000											
	1050											
			TUTUDAWA SECONDARY T3									
0+000	0	1.4	1	0.000603	255.945	0.15	0.36	256.305	0.377	0.2571	0.48	256.425
	100	1	1	0.000603	255.885	0.15	0.36	256.245	0.177	0.2571	0.48	256.365
	200	1	1	0.000603	255.825	0.15	0.36	256.185	0.067	0.2571	0.48	256.305
STR-210.4	210.4	0.8	1	0.000603	255.818	0.15	0.36	256.178	0.021	0.2571	0.48	256.298
	300	0.8	1	0.000603	255.764	0.15	0.36	256.124	0.022	0.2571	0.48	256.244
STR-375	375	1	1	0.000603	255.719	0.15	0.36	256.079	0.092	0.2571	0.48	256.199
	400	3.2	1	0.000603	255.704	0.15	0.36	256.064	0.132	0.2571	0.48	256.184
	500	1	1	0.000603	255.644	0.15	0.36	256.004	0.023	0.2571	0.48	256.124
STR-564	564	1	1	0.000603	255.605	0.15	0.36	255.965	0.422	0.2571	0.48	256.085
	600	1	1	0.000603	255.584	0.15	0.36	255.944	0.019	0.2571	0.48	256.064
	700	1.2	1	0.000603	255.523	0.15	0.36	255.883	-0.080	0.2571	0.48	256.003
STR-712	712											
	800											
STR-858	858											
	900											
	1000											
STR-1062	1062											
	1100											
STR-1200	1200											
	1300											
STR-1375	1375											
			TUTUDAWA SECONDARY T4									
0+000	0	0.8	1.4	0.001109	255.866	0.2087	0.31	256.176	0.492	0.2087	0.31	256.176
	100	1.6	1.4	0.001109	255.755	0.2087	0.31	256.065	0.323	0.2087	0.31	256.065
STR-155.7	155.7	1.4	1.4	0.001109	255.693	0.2087	0.31	256.003	0.087	0.2087	0.31	256.003
	200	1.4	1.4	0.001109	255.644	0.2087	0.31	255.954	0.015	0.2087	0.31	255.954
	300	2	1.4	0.001109	255.533	0.2087	0.31	255.843	0.146	0.2087	0.31	255.843
STR-308	308											
	400											
STR-460.5	460.5											
	500											
	600											
STR-612	612											
	700											
STR-765	765											
	800											
	900											
STR-917.2	917.2											

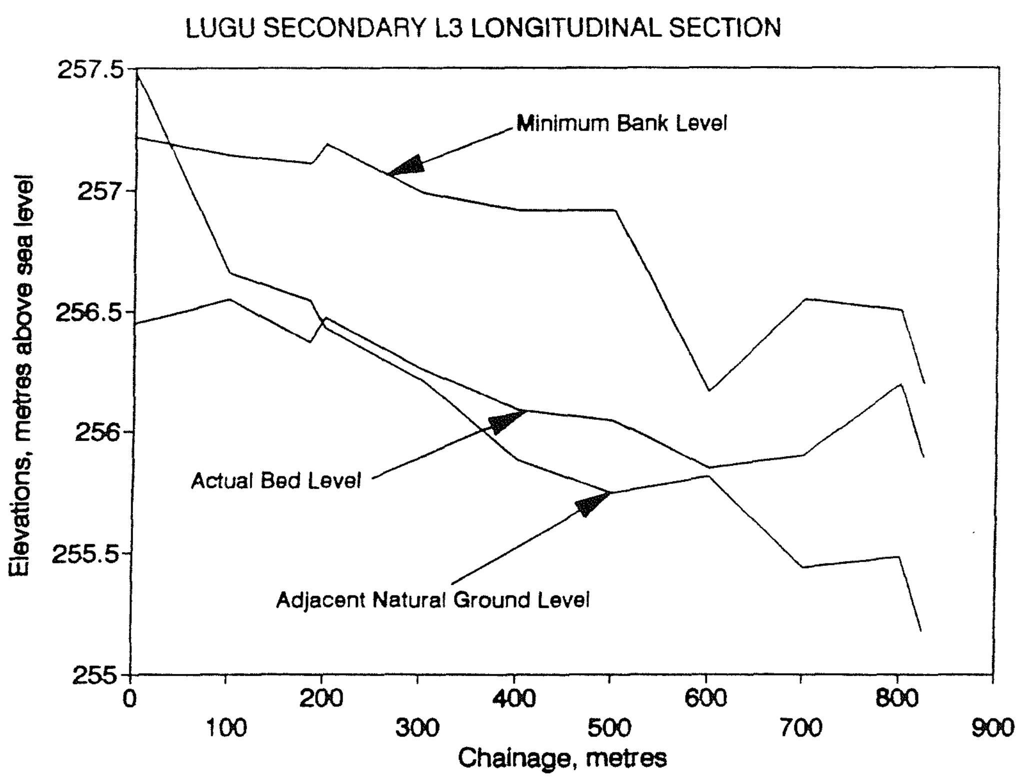
ANNEXE C2:

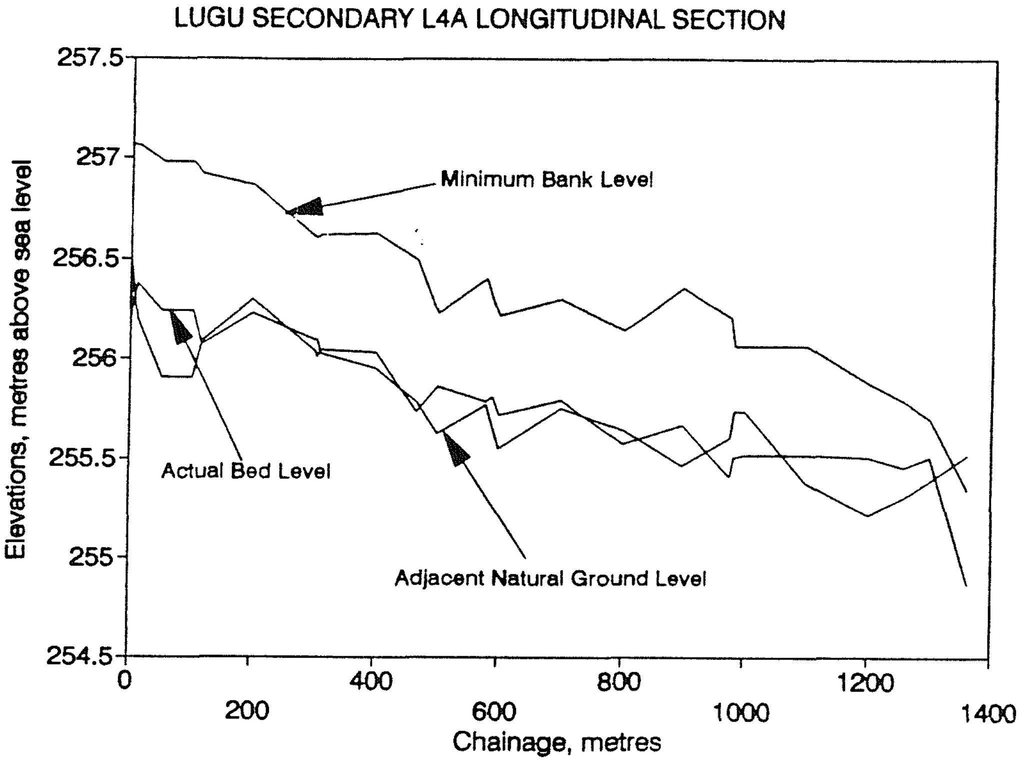
Longitudinal profiles for the main system canals, Wurno Irrigation Scheme as at March 1992.

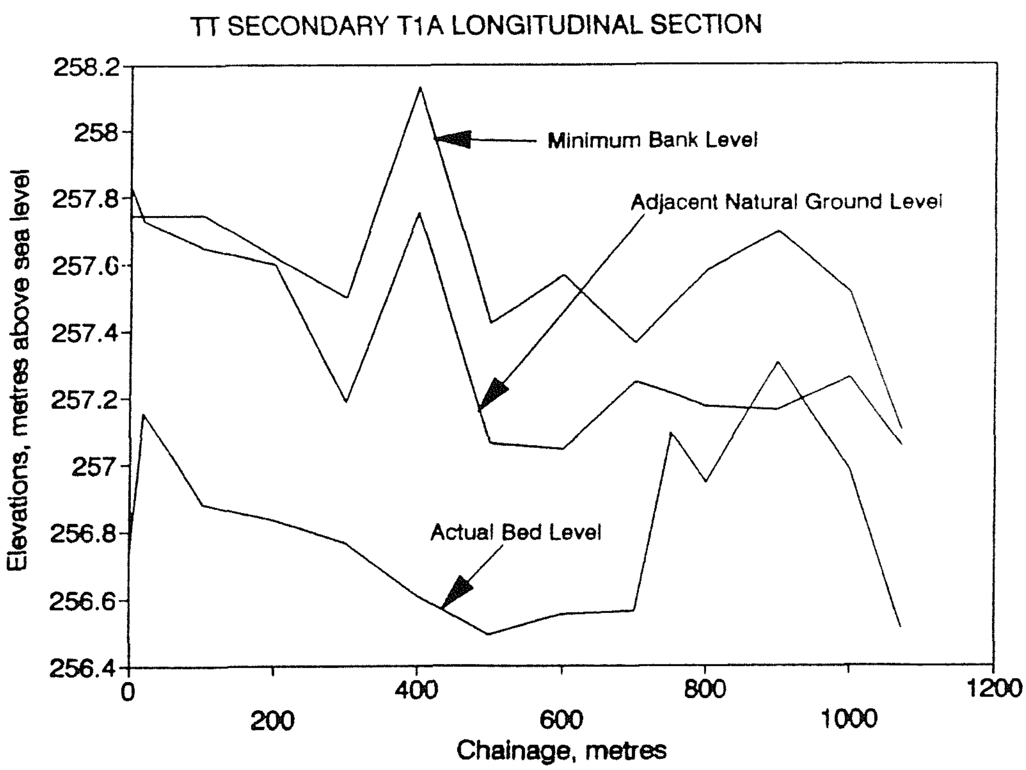


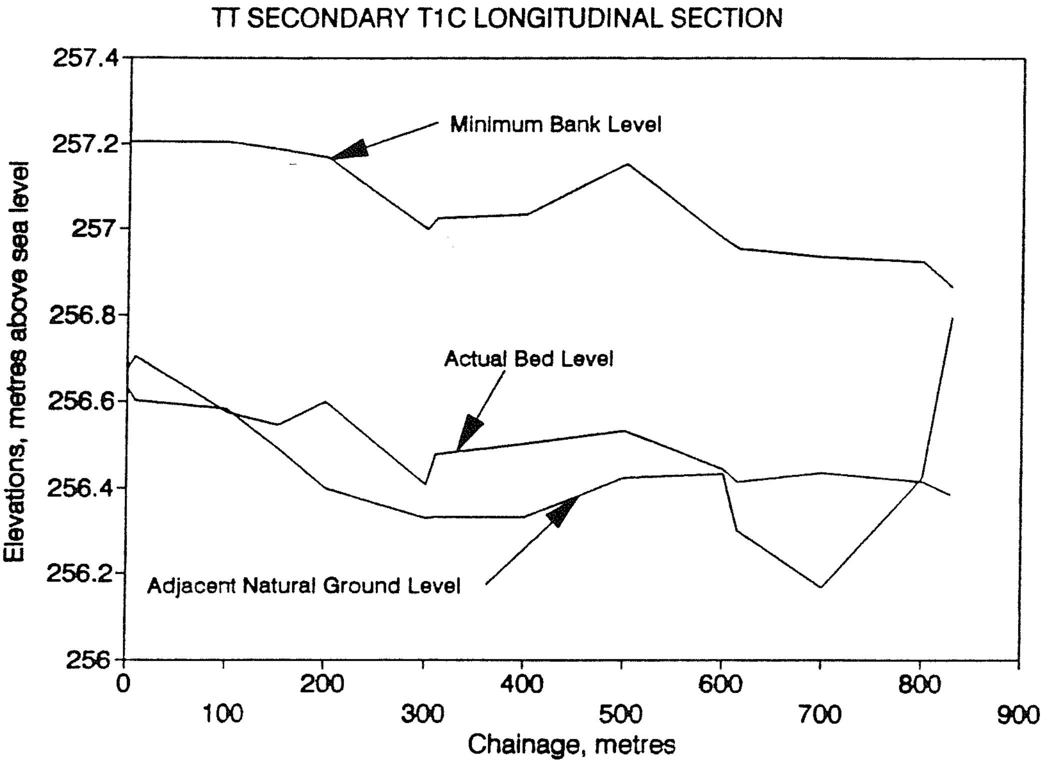



LUGU SECONDARY L2 LONGITUDINAL SECTION
Minimum Bank Level
Adjacent Natural Ground Level
Actual Bed Level
Elevations, metres above sea level
257.5
257
256.5
256
255.5
255
0
200
400
600
800
1000
1200
Chainage, metres

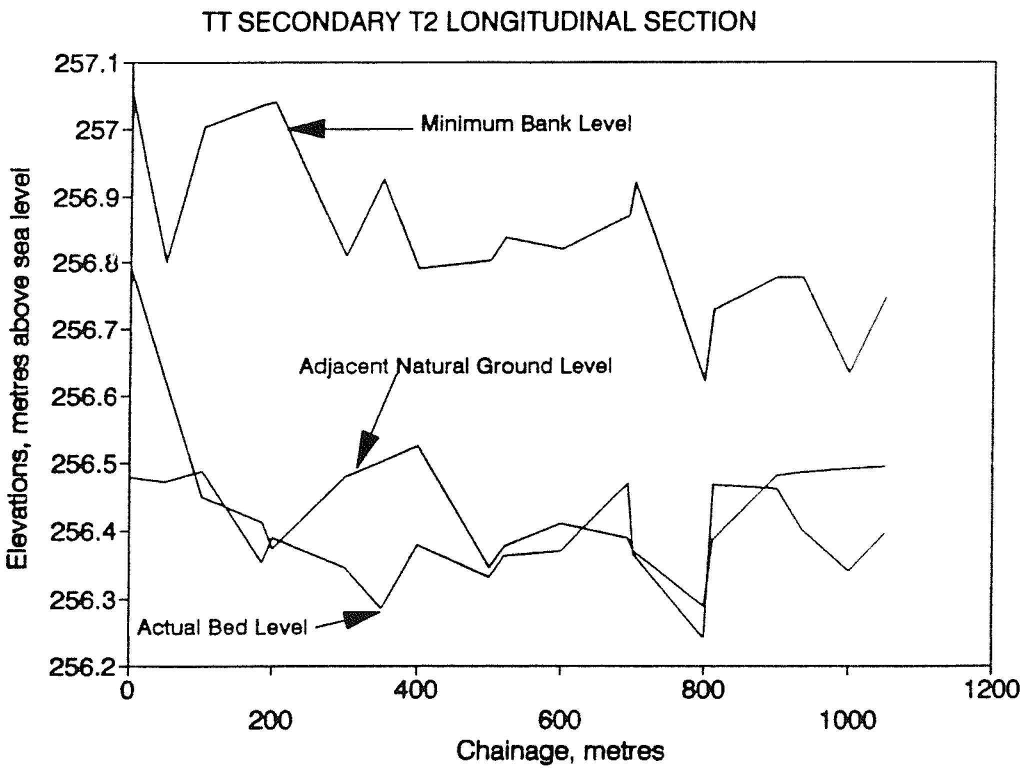

LUGU SECONDARY L3 LONGITUDINAL SECTION
Minimum Bank Level
Actual Bed Level
Adjacent Natural Ground Level
Elevations, metres above sea level
257.5
257
256.5
256
255.5
255
0
100
200
300
400
500
600
700
800
900
Chainage, metres


LUGU SECONDARY L4A LONGITUDINAL SECTION
257.5
257
256.5
256
255.5
255
254.5
Elevations, metres above sea level
Minimum Bank Level
Actual Bed Level
Adjacent Natural Ground Level
0
200
400
600
800
1000
1200
1400
Chainage, metres

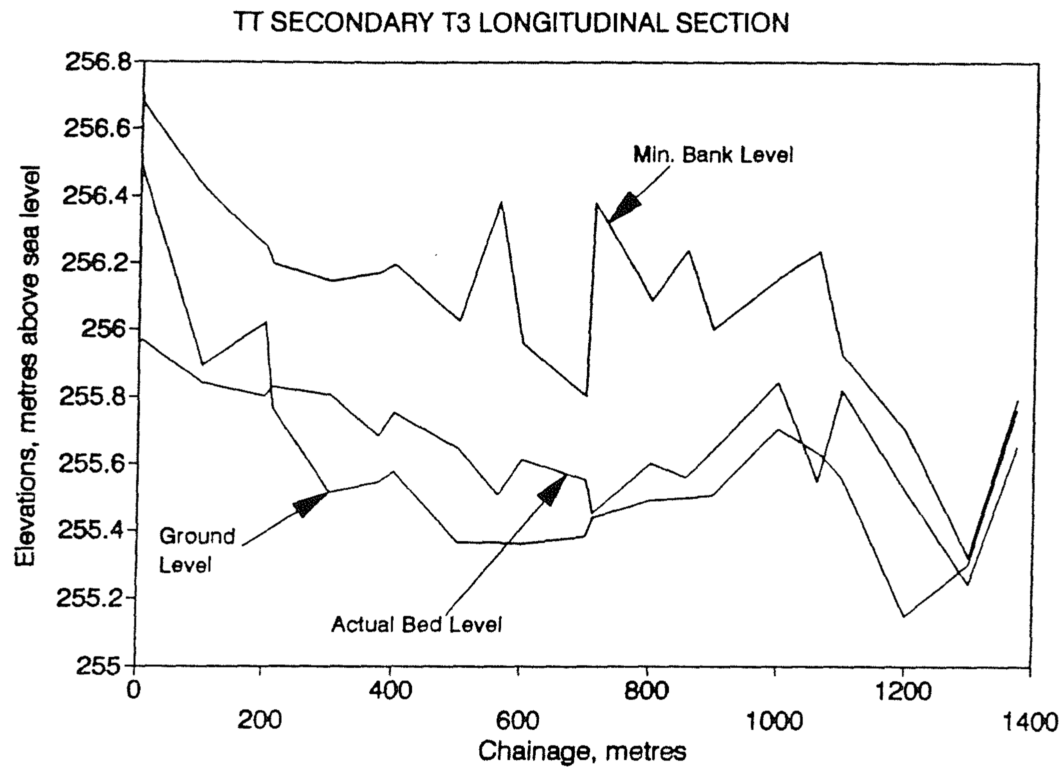

TT SECONDARY T1A LONGITUDINAL SECTION
258.2
258
257.8
257.6
257.4
257.2
257
256.8
256.6
256.4
Elevations, metres above sea level
Minimum Bank Level
Adjacent Natural Ground Level
Actual Bed Level
0
200
400
600
800
1000
1200
Chainage, metres

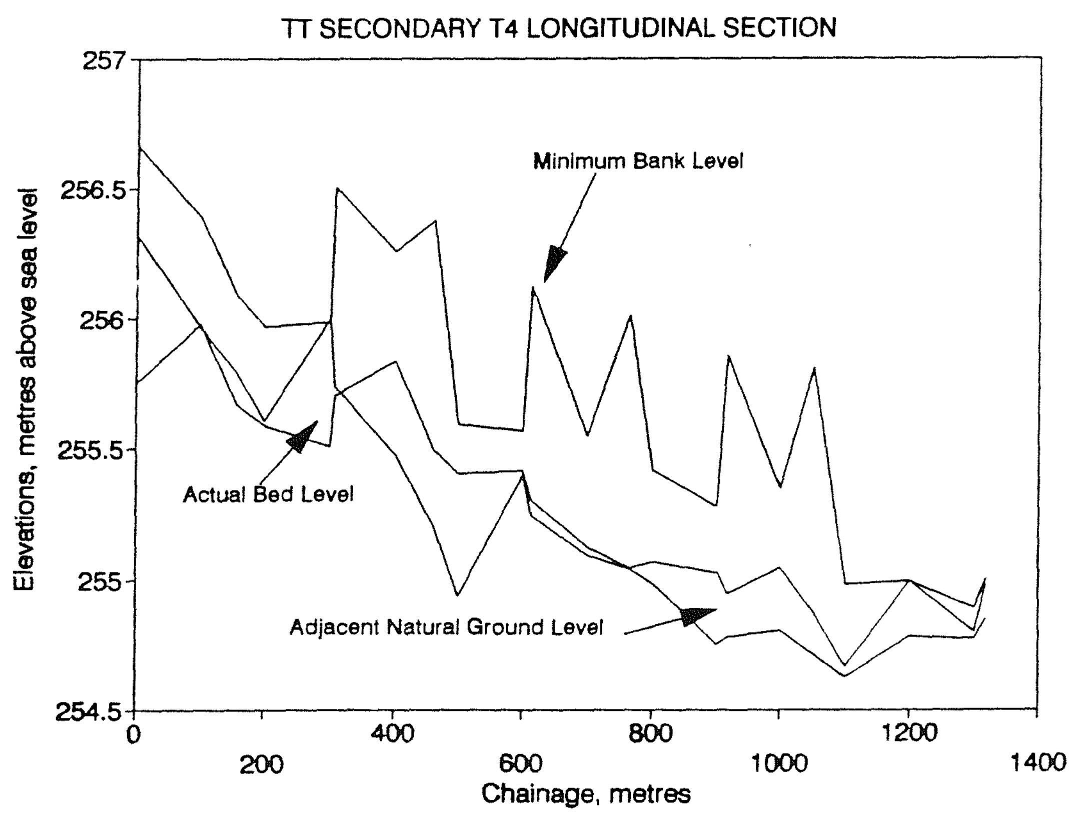


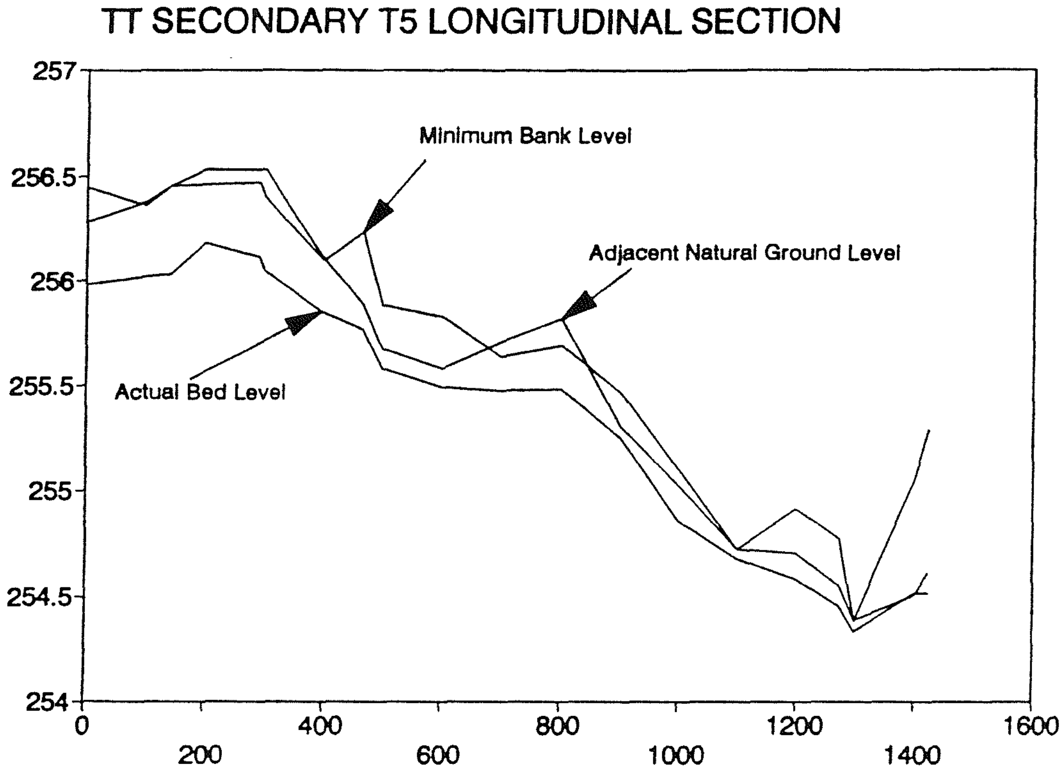
TT SECONDARY T1C LONGITUDINAL SECTION
Minimum Bank Level
Actual Bed Level
Adjacent Natural Ground Level
Elevations, metres above sea level
257.4
257.2
257
256.8
256.6
256.4
256.2
256
0
100
200
300
400
500
600
700
800
900
Chainage, metres



TT SECONDARY T2 LONGITUDINAL SECTION
Minimum Bank Level
Adjacent Natural Ground Level
Actual Bed Level
Elevations, metres above sea level
257.1
257
256.9
256.8
256.7
256.6
256.5
256.4
256.3
256.2
0
200
400
600
800
1000
1200
Chainage, metres


TT SECONDARY T3 LONGITUDINAL SECTION
Min. Bank Level
Ground Level
Actual Bed Level
Elevations, metres above sea level
Chainage, metres
256.8
256.6
256.4
256.2
256
255.8
255.6
255.4
255.2
255
0
200
400
600
800
1000
1200
1400


TT SECONDARY T4 LONGITUDINAL SECTION
Minimum Bank Level
Actual Bed Level
Adjacent Natural Ground Level
Elevations, metres above sea level
Chainage, metres
257
256.5
256
255.5
255
254.5
0
200
400
600
800
1000
1200
1400



TT SECONDARY T5 LONGITUDINAL SECTION
Minimum Bank Level
Adjacent Natural Ground Level
Actual Bed Level
257
256.5
256
255.5
255
254.5
254
0
200
400
600
800
1000
1200
1400
1600

ANNEXE C3:

Spreadsheet computation schedule for existing main system canal capacities and actual water levels: Wurno irrigation scheme, March 1992.

Main Canal	Sec. Canal	Tert. Unit Name	Tert. Unit Area	Tert. Canal Flows	Tert. Cumulative D/S Flows	Sec. Canal Area	Sec. Canal Length	Dist. of Sec. Offtake from Main Intake	Gross Sec. Head Flow	Main Canal Cumulative D/S Area	Net Flow at Head of Main Canal U/S Reach	Gross Flow at Head of Main Canal U/S Reach
		Block	ha	l/s	l/s	ha	km	km	l/s	ha	l/s	l/s
LUGU	D1	ALL	50	127.1	127.1	50.0		0.436	141.3	359.1	1174.2	1200.32
LUGU	D2L	1A	2.4	6.2	161.6	63.6	1.122	1.25	169.2	309.1	990.8	1032.89
LUGU	D2L	1B	2.0	5.1								
LUGU	D2L	2	8.9	22.6								
LUGU	D2R	1	2.0	5.1								
LUGU	D2R	2	2.4	6.2								
LUGU	D2R	3	2.4	6.2								
LUGU	D2R	4	2.4	6.2								
LUGU	D2R	5	3.6	9.3								
LUGU	D2R	6	17.8	45.3								
LUGU	D2R	7	7.3	18.5								
LUGU	D2R	8	12.1	30.9								
LUGU	D3L	1A	2.0	5.1	173.4	68.2	0.825	2.208	179.3	245.5	782.3	821.62
LUGU	D3L	1B	4.0	10.3								
LUGU	D3L	2	7.3	18.5								
LUGU	D3L	3	3.2	8.2								
LUGU	D3L	4	7.0	17.9								
LUGU	D3L	5	7.3	18.5								
LUGU	D3L	6	5.7	14.4								
LUGU	D3R	1	5.7	14.4								
LUGU	D3R	2	3.2	8.2								
LUGU	D3R	3	4.0	10.3								
LUGU	D3R	4	4.0	10.3								
LUGU	D3R	5	4.0	10.3								

Main Canal	Sec. Canal	Tert. Unit Name	Tert. Unit Area	Tert. Canal Flows	Tert. Cumulative D/S Flows	Sec. Canal Area	Sec. Canal Length	Dist. of Sec. Offtake from Main Intake	Gross Sec. Head Flow	Main Canal Cumulative D/S Area	Net Flow at Head of Main Canal U/S Reach	Gross Flow at Head of Main Canal U/S Reach
		Block	ha	l/s	l/s	ha	km	km	l/s	ha	l/s	l/s
LUGU	D3R	6	4.9	12.4								
LUGU	D3R	7	5.7	14.4								
LUGU	D4L	1	6.1	15.4	252.2	99.2	1.362	2.9	266.8	177.3	582.1	602.97
LUGU	D4L	2	8.1	20.6								
LUGU	D4L	3	10.9	27.8								
LUGU	D4L	4	13.4	34.0								
LUGU	D4L	5	14.2	36.0								
LUGU	D4L	6	11.3	28.8								
LUGU	D4L	7	8.1	20.6								
LUGU	D4L	8	6.9	17.5								
LUGU	D4L	9	5.7	14.4								
LUGU	D4L	10	3.2	8.2								
LUGU	D4R	1	4.9	12.4								
LUGU	D4R	2	3.2	8.2								
LUGU	D4R	3	3.2	8.2								
LUGU	FC1	1	2.4	6.2	50.4	19.8			56.1	78.1	283.8	315.35
LUGU	FC1	2	4.9	12.4								
LUGU	FC1	3	4.5	11.3								
LUGU	FC1	4	4.0	10.3								
LUGU	FC1	5	2.8	7.2								
LUGU	FC1	6	1.2	3.1								
LUGU	FC2	1	2.0	5.1	21.6	8.5			24.0	58.3	205.0	227.76
LUGU	FC2	2	2.0	5.1								

Main Canal	Sec. Canal	Tert. Unit Name	Tert. Unit Area	Tert. Canal Flows	Tert. Cumulative D/S Flows	Sec. Canal Area	Sec. Canal Length	Dist. of Sec. Offtake from Main intake	Gross Sec. Head Flow	Main Canal Cumulative D/S Area	Net Flow at Head of Main Canal U/S Reach	Gross Flow at Head of Main Canal U/S Reach
		Block	ha	l/s	l/s	ha	km	km	l/s	ha	l/s	l/s
LUGU	FC2	3	1.2	3.1								
LUGU	FC2	4	1.6	4.1								
LUGU	FC2	5	1.6	4.1								
LUGU	FC3	1	1.6	4.1	23.7	9.3			26.3	49.8	162.9	180.97
LUGU	FC3	2	1.6	4.1								
LUGU	FC3	3	2.0	5.1								
LUGU	FC3	4	2.0	5.1								
LUGU	FC3	5	2.0	5.1								
LUGU	FC4	1	2.0	5.1	44.3	17.4			49.2	40.5	122.9	136.56
LUGU	FC4	2	5.7	14.4								
LUGU	FC4	3	5.3	13.4								
LUGU	FC4	4	4.5	11.3								
LUGU	FC5	1	4.0	10.3	49.4	19.4			54.9	23.1	66.3	73.72
LUGU	FC5	2	2.4	6.2								
LUGU	FC5	3	2.4	6.2								
LUGU	FC5	4	1.2	3.1								
LUGU	FC5	5	1.2	3.1								
LUGU	FC5	6	1.6	4.1								
LUGU	FC5	7	1.2	3.1								
LUGU	FC5	8	2.0	5.1								
LUGU	FC5	9	3.2	8.2								
LUGU	FC6	1	1.2	3.1	9.3	3.6			10.3	3.6	10.3	11.44

Main Canal	Sec. Canal	Tert. Unit Name	Tert. Unit Area	Tert. Canal Flows	Tert. Cumulative D/S Flows	Sec. Canal Area	Sec. Canal Length	Dist. of Sec. Offtake from Main Intake	Gross Sec. Head Flow	Main Canal Cumulative D/S Area	Net Flow at Head of Main Canal U/S Reach	Gross Flow at Head of Main Canal U/S Reach
		Block	ha	l/s	l/s	ha	km	km	l/s	ha	l/s	l/s
LUGU	FC6	2	2.4	6.2								
T.T	T1A	1	1.6	4.1	108.1	42.5	1.072	0.066	112.9	568.7	1814.5	1820.53
T.T	T1A	2	2.0	5.1								
T.T	T1A	3	1.6	4.1								
T.T	T1A	4	2.4	6.2								
T.T	T1A	5	4.0	10.3								
T.T	T1A1	6	4.9	12.4								
T.T	T1A1	7	2.4	6.2								
T.T	T1A1	8	3.2	8.2								
T.T	T1A1	9&10	5.7	14.4								
T.T	T1A1	11	4.0	10.3								
T.T	T1A1	12	1.6	4.1								
T.T	T1A1	13	2.4	6.2								
T.T	T1A1	14	1.6	4.1								
T.T	T1A1	15	2.4	6.2								
T.T	T1A1	16	2.4	6.2								
T.T	T1C	1	12.1	30.9	194.6	76.5	0.829	0.202	201.2	526.2	1690.0	1701.58
T.T	T1C	2	13.0	32.9								
T.T	T1C	3	18.2	46.3								
T.T	T1C	4	12.1	30.9								
T.T	T1C	5A	10.5	26.8								
T.T	T1C	5B	10.5	26.8								
T.T	T2L	1	17.8	45.3	263.6	103.6	1.05	2.075	275.1	449.7	1349.3	1488.76

Main Canal	Sec. Canal	Tert. Unit Name	Tert. Unit Area	Tert. Canal Flows	Tert. Cumulative D/S Flows	Sec. Canal Area	Sec. Canal Length	Dist. of Sec. Offtake from Main intake	Gross Sec. Head Flow	Main Canal Cumulative D/S Area	Net Flow at Head of Main Canal U/S Reach	Gross Flow at Head of Main Canal U/S Reach
		Block	ha	l/s	l/s	ha	km	km	l/s	ha	l/s	l/s
T.T	T2L	2	8.1	20.6								
T.T	T2L	3	8.5	21.6								
T.T	T2R	1	11.3	28.8								
T.T	T2R	2	11.3	28.8								
T.T	T2R	3	11.7	29.9								
T.T	T2R	4	11.3	28.8								
T.T	T2R	5	11.3	28.8								
T.T	T2R	6	12.1	30.9								
T.T	T3	1	12.1	30.9	243.0	95.5	1.375	2.808	257.1	346.0	1034.9	1074.23
T.T	T3	2	12.1	30.9								
T.T	T3	3	12.1	30.9								
T.T	T3	4	12.1	30.9								
T.T	T3	5	13.0	32.9								
T.T	T3	6	11.3	28.8								
T.T	T3	7	11.3	28.8								
T.T	T3	8	11.3	28.8								
T.T	T4	1	4.0	10.3	197.7	77.7	1.319	3.492	208.7	268.3	751.2	777.76
T.T	T4	2	4.9	12.4								
T.T	T4	3	6.1	15.4								
T.T	T4	4	6.1	15.4								
T.T	T4	5	7.3	18.5								
T.T	T4	6	8.9	22.6								
T.T	T4	7	10.5	26.8								
T.T	T4	8	10.5	26.8								

Main Canal	Sec. Canal	Tert. Unit Name	Tert. Unit Area	Tert. Canal Flows	Tert. Cumulative D/S Flows	Sec. Canal Area	Sec. Canal Length	Dist. of Sec. Offtake from Main Intake	Gross Sec. Head Flow	Main Canal Cumulative D/S Area	Net Flow at Head of Main Canal U/S Reach	Gross Flow at Head of Main Canal U/S Reach
		Block	ha	l/s	l/s	ha	km	km	l/s	ha	l/s	l/s
T.T	T4	9	19.4	49.4								
T.T	T5	1	8.1	20.6	204.9	80.6	1.425	3.91	217.3	190.6	531.2	542.49
T.T	T5	2	9.3	23.7								
T.T	T5	3	6.1	15.4								
T.T	T5	4	6.1	15.4								
T.T	T5	5	6.1	15.4								
T.T	T5	6	8.5	21.6								
T.T	T5	7	8.1	20.6								
T.T	T5	8	9.7	24.7								
T.T	T5	9	18.6	47.4								
T.T	T6	ALL	60.0	152.6	152.6	60.0	1.05	5.195	159.3	110.0	293.7	313.90
T.T	T7	ALL	50.0	127.1	127.1	50.0	0.725	5.72	130.9	50.0	130.9	134.47

ANNEXE D:

Spreadsheet solution of the Manning's Equation for flow depth using the Newton-Raphson numerical method.

**** INPUT DATA ****			********* RESULTS *********		
			(after 10 iterations only)		
FLOW RATE	0.5848	m^3/s			
CANAL SLOP	0.0004	decimal	Calculated depth =	0.63	m
MANNING'S N	0.035		DEPTH+FREEBOARD	0.63	m
SIDE SLOPE L	1.5	h:1v	Desired flow =	0.58	m^3/s
SIDE SLOPE	1.5	h:1v	Check flow =	0.58	m^3/s
BASE WIDTH	2	m	Velocity =	0.32	m/s
FREEBOARD	0	M			

--- Below is the iterative section that uses Newton-Raphson method to
--- solve for normal depth by repeating the NR process in 10 columns.
--- NB Only 10 iterations are used, so check the resultant flows.
--- NB Do not change any of the cells below this line, unless you
--- NB wish to increase number of iterations by horizontal copying.

iteration no	0	1	2	3	4	5	6	7	8	9	10
depth d1(m)	0.50	0.65	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
area(m^2)	1.38	1.92	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85
perim(m)	3.80	4.33	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27
hy.rd(m)	0.36	0.44	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Q at d1	0.38	0.61	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
f(d1)	-0.20	0.03	0.00	-0.00	0.00	-0.00	0.00	-0.00	0.00	-0.00	0.00
now calculate slope using f'(d)=(f(d)-f(d-0.01))/0.01											
d1-0.01	0.49	0.64	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
a (d1-.01)	1.34	1.88	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81
p (d1-.01)	3.77	4.29	4.23	4.23	4.23	4.23	4.23	4.23	4.23	4.23	4.23
r (d1-.01)	0.36	0.44	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
f (d1-.01)	0.37	0.60	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
Q at d-.01	0.37	0.60	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
f(d1-.01)	-0.21	0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
f'(d1)	1.38	1.75	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
now calculate new guess of depth using d2=d1-(f(d)/f'(d))											
deltaD	-0.15	0.02	0.00	-0.00	0.00	-0.00	0.00	-0.00	0.00	-0.00	0.00
d2=d1-deltaD	0.65	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63

... then copy new depth d2 to top of next column and repeat 10 times