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NORTHERN REGION AGRICULTURAL DEVELOPMENT PROJECT
TECHNICAL ASSISTANCE FOR ENGINEERING SERVICES
YEM/87/015

WATER MANAGEMENT PLAN
SA'DAH PLAIN
TARGET AREA

Final
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in association with
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DARWISH CONSULTING ENGINEERS

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SUMMARY

BACKGROUND

This report is one of the seven Target Area Water Management Plans that are combined into a Regional Water Management Plan for the NORADEP area. It is designed for implementation by SSHARDA, in liaison with other specialist agencies.

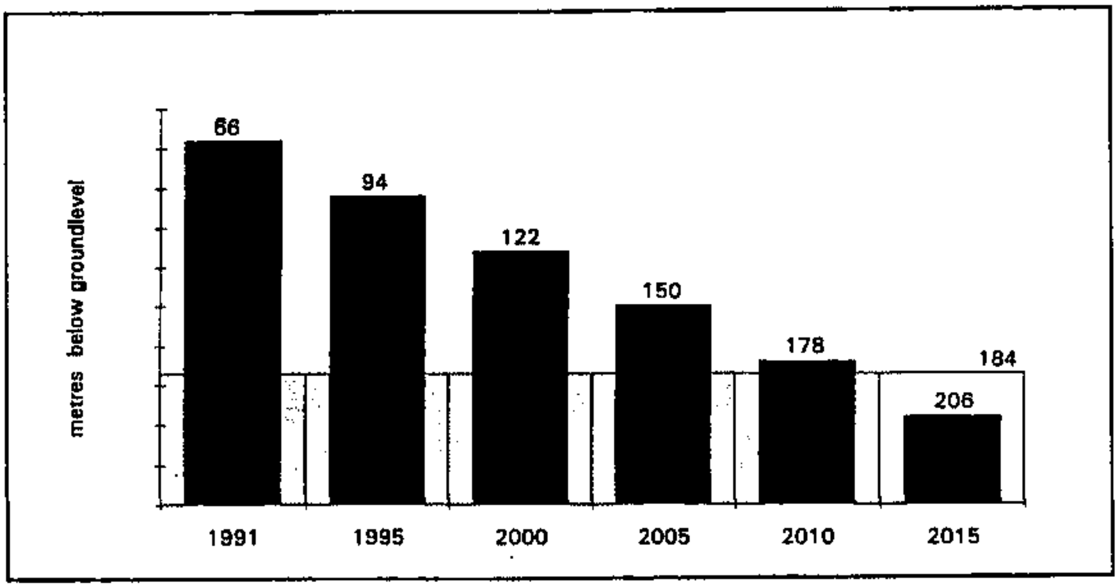
The plan is based on extensive studies, carried out over the last three years, into groundwater, agricultural and socio-economics, hydrology, land use and multipurpose dams. Although the studies provide the most comprehensive basis for water management planning available for any region in Yemen, much work remains to be done, in particular on the establishment of detailed knowledge of the complete aquifer system under the Sa'dah Plain, and on the training of extension, research and support staff to play their full and proper part in development.

MAJOR PROBLEMS

Mining of Groundwater

In 1991 abstraction from the aquifer was more than four times the recharge, and the water level fell by 5.6 m. If pumping continues at this rate, over 50% of the wells in the Sa'dah Plain will be dry by the year 2015 (Fig. S.1), and the cost of water will have increased 250% by 2010 (Fig. S.2).

Fig. S.1 *Projected Fall in Groundwater Level*



Increasing Cost of Water

The capital component of the cost of water is more than three times the running costs - diesel, operation and maintenance - (Fig. S.2). Farmers do not take account of this capital component and as a result are effectively losing money on some crops. This is shown in Fig. S.3, where the gross benefit excludes the capital costs and the net benefit includes them. Note the very poor returns on cereals and the excellent returns to be made from growing fuelwood.

Fig. S.2 *Increase in Cost of Water*

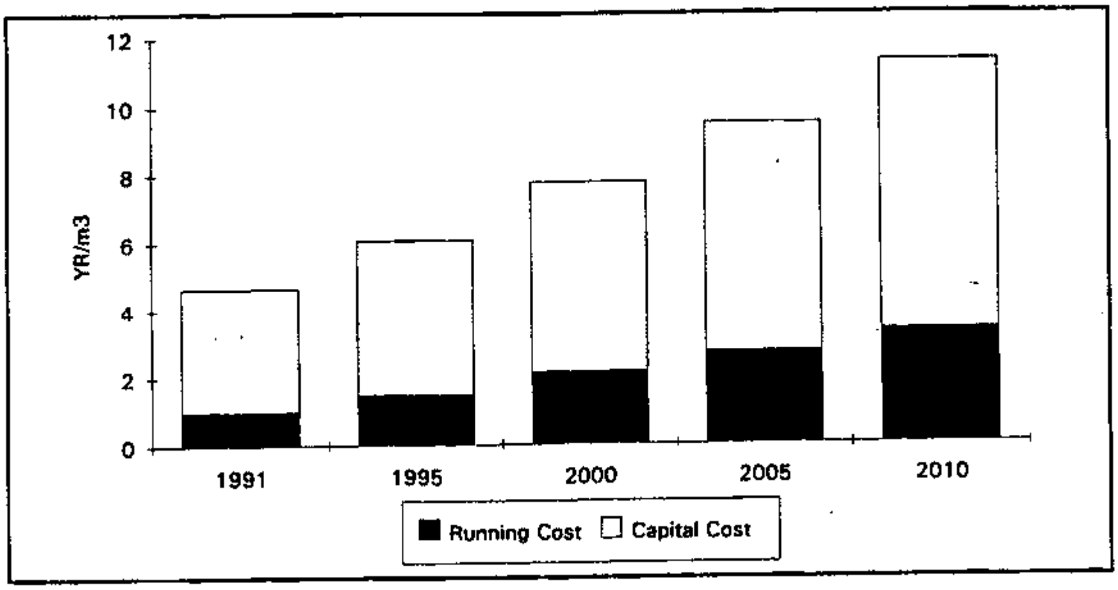
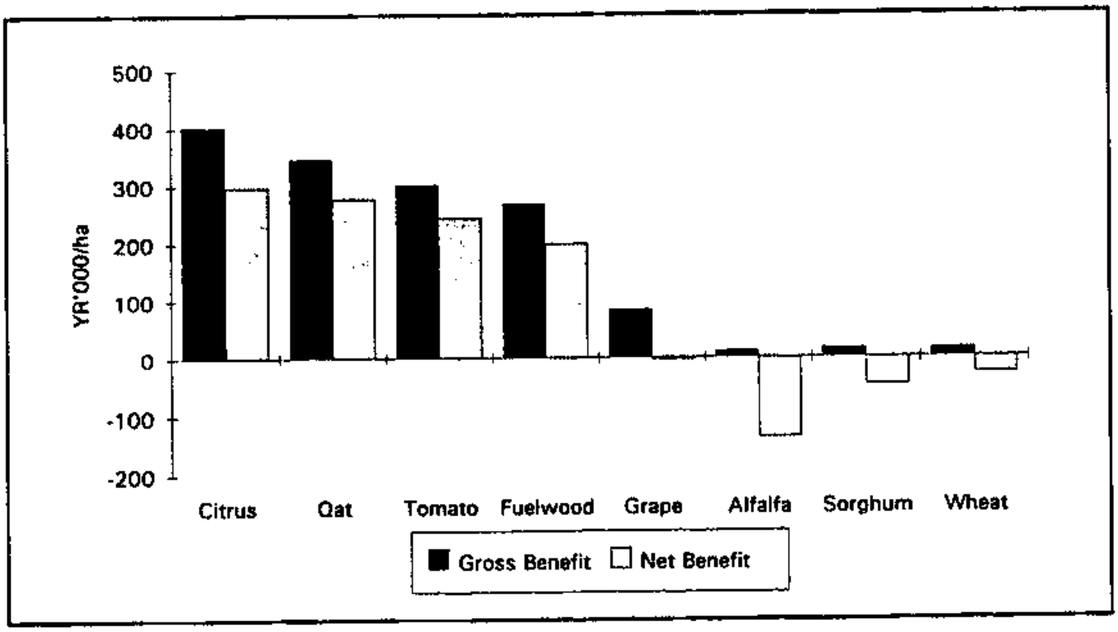


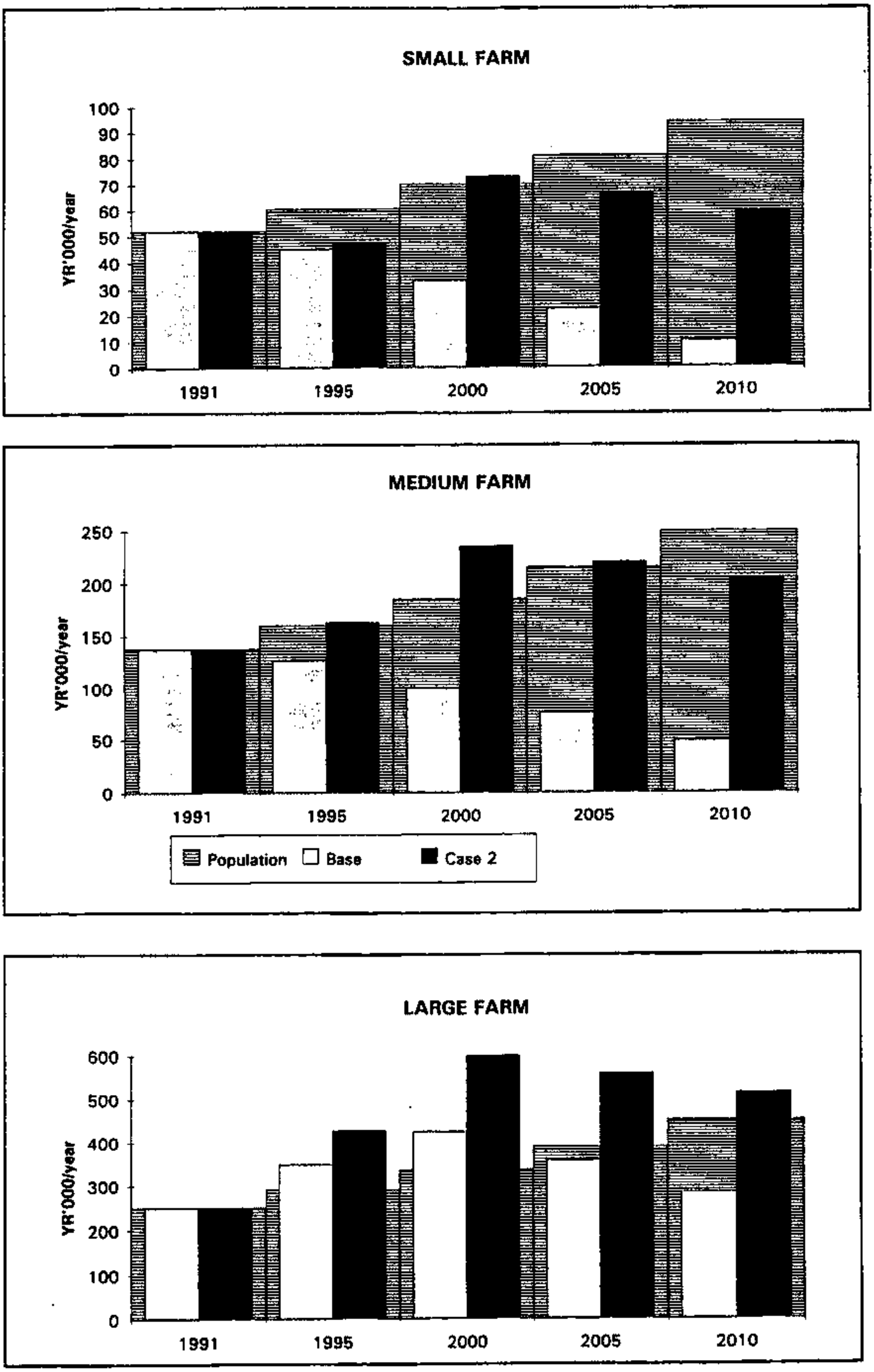
Fig. S.3 *Actual Crop Returns*



Falling Farm Incomes

Much needed improvements in irrigation practices and crop husbandry, combined with the introduction of modern irrigation methods, could reduce water use by over 40%. The effect of this on farm incomes (excluding the capital component) is shown in Fig. S.4, together with an indication of the rate at which incomes would have to increase to maintain current standards of living with a population growth of 3% a year. Only the larger farmers will maintain or increase their living standard without diversifying away from their current cropping patterns.

Fig. S.4 *Effect of Water Cost Increases on Farm Incomes*



Legend Base - Current yields/irrigation
Case 2 - Improved yields/some modern irrigation

Institutional Constraints
There are many institutional constraints to be overcome if the plan is to succeed, but the major ones are the willingness and ability to enforce groundwater control legislation; the lack of involvement by LCCDs and the local leadership; shortage of experienced research and extension staff and the resources required for them to be effective; and the inability to deliver credit efficiently to all farmers.

PLAN OBJECTIVES

The immediate objectives of the plan are to:

- Reduce groundwater abstraction, while maintaining farmers' income levels.

- Establish the human, physical and data resources base needed for longterm planning and action.

These are pragmatic and achievable objectives. SSHARDA and other relevant institutions already have the resources to commence implementation, **if those resources were to be applied in the appropriate way.** Further resources can readily be made available from the NORADEP Project until the end of the current World Bank credit and, for example, from the World Bank funded Land and Water Conservation Project, which has recently started; indeed, some of the actions recommended in this plan are included in the LWCP. Proposals for projects, prepared by SSHARDA based on the plan, and put forward for funding would be looked upon favourably.

NECESSARY ACTIONS

The main components of the plan are:

- **Involving local leadership and farming communities** in the planning/implementation/review cycle.

- **Enforcing existing and pending legislation** on groundwater exploitation and abstraction.

- Encouraging the **introduction of modern irrigation methods** through demonstration activities, and by facilitating purchase by farmers.

- Promoting the use of gabions, reno mattresses and improved earthworks to **strengthen traditional spate diversion structures;** and encourage **conjunctive use of spate and well water.**

- Encouraging a **move away from the irrigation of low value crops (mainly cereals)**, and the diversification into high value less water-demanding activities, both on-farm and in the private agro-industrial sector.

- **Making use of traditional crop varieties** and husbandry techniques in research and extension programmes to maximise rain/runoff-fed yields.

- Simplifying and increasing **access to credit.**

- Gathering, processing, publishing and using all relevant data on groundwater, climate, agriculture, research and marketing.

- Expanding the knowledge, experience and scope of research and **extension staff** by training and the provision of objective driven management, which **must include the physical and financial resources needed** to perform their duties.

This list is not in order of priority; all actions are equally necessary, though it must be said that without **full involvement of local people from the start nothing will be achieved.** Fig. S.5 is an outline Plan of Action.

TARGETS

Precise targets can only be set during the detailed planning phase, but the following would be typical:

- 50% reduction in drilling in 5 years.

- 40% reduction in abstraction in 5 years, by improving efficiency.

- 100% reduction in abstraction in 10 years, by diversifying away from irrigated agriculture.

- 50% reduction in area under groundwater irrigated cereals in 5 years.

- 25% increase in yields on rainfed and spate irrigated land in 5 years, 50% on groundwater irrigated land in 10 years.

- 500 ha under fuelwood on terraces and runoff areas in 5 years.

- 1000 ha under modern irrigation in 5 years.

- 10 improved spate diversion structures in 5 years.

- 50% improvement in small livestock productivity in 5 years.

Not all of these targets may be realistic, but they are a good illustration of what SSHARDA must aim at.

IMPLEMENTATION

An interim legislative framework already exists within which groundwater development could be controlled. It is not being used.

Able extension staff are available. They are without adequate resources to support the ambitious and progressive farmers in the Sa'dah Plain who are eager to improve their agriculture and adopt new techniques.

It is not the function of this report to deal with detailed implementation of the plan but, in order to provide a basis for the detailed planning process, outline Implementation Programmes have been prepared for the Sa'dah Plain and the NORADEP Region (Figs. S.5 and S.6).

Fig S.5 *Sa'dah Target Area Plan of Action/Implementation Schedule*

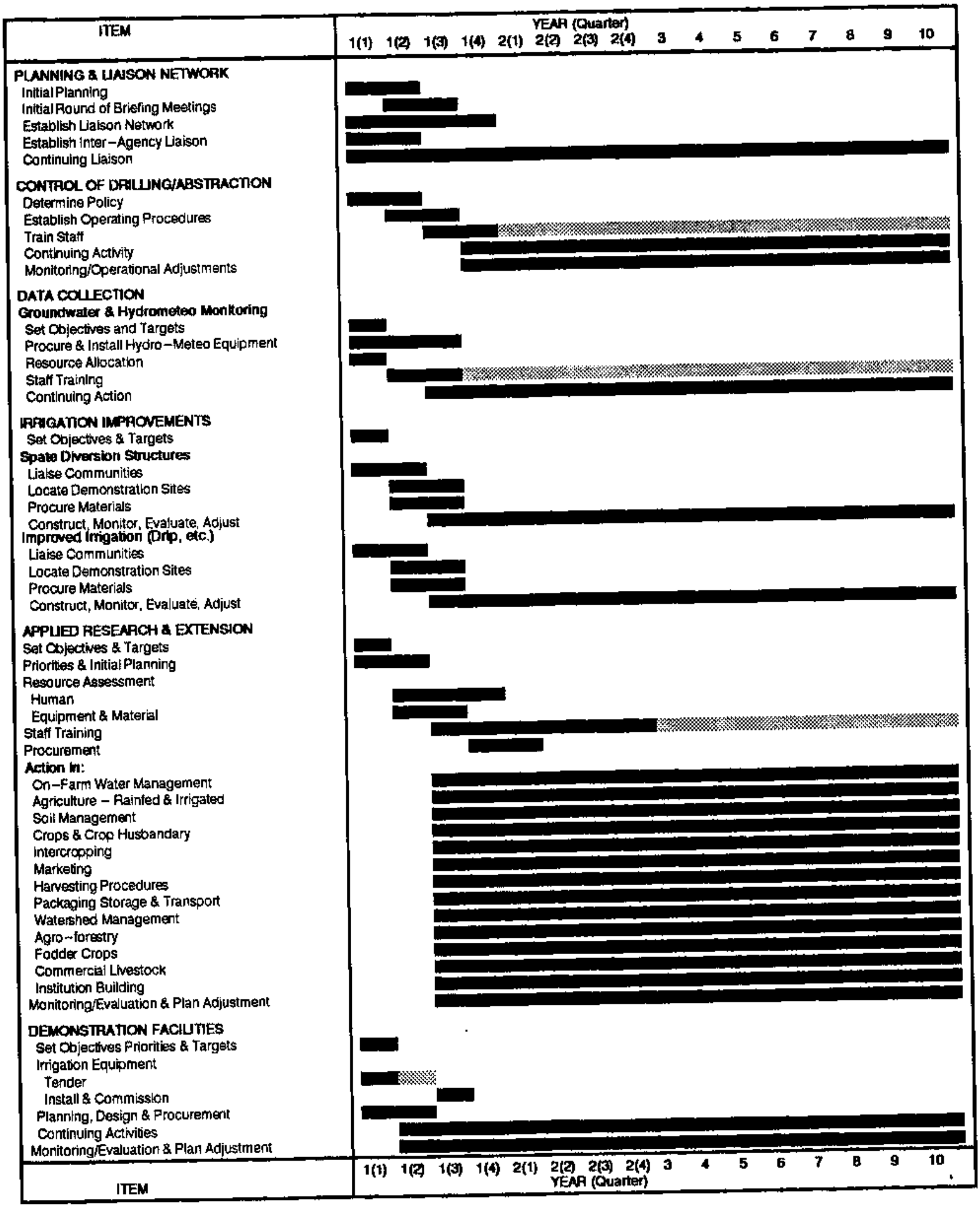


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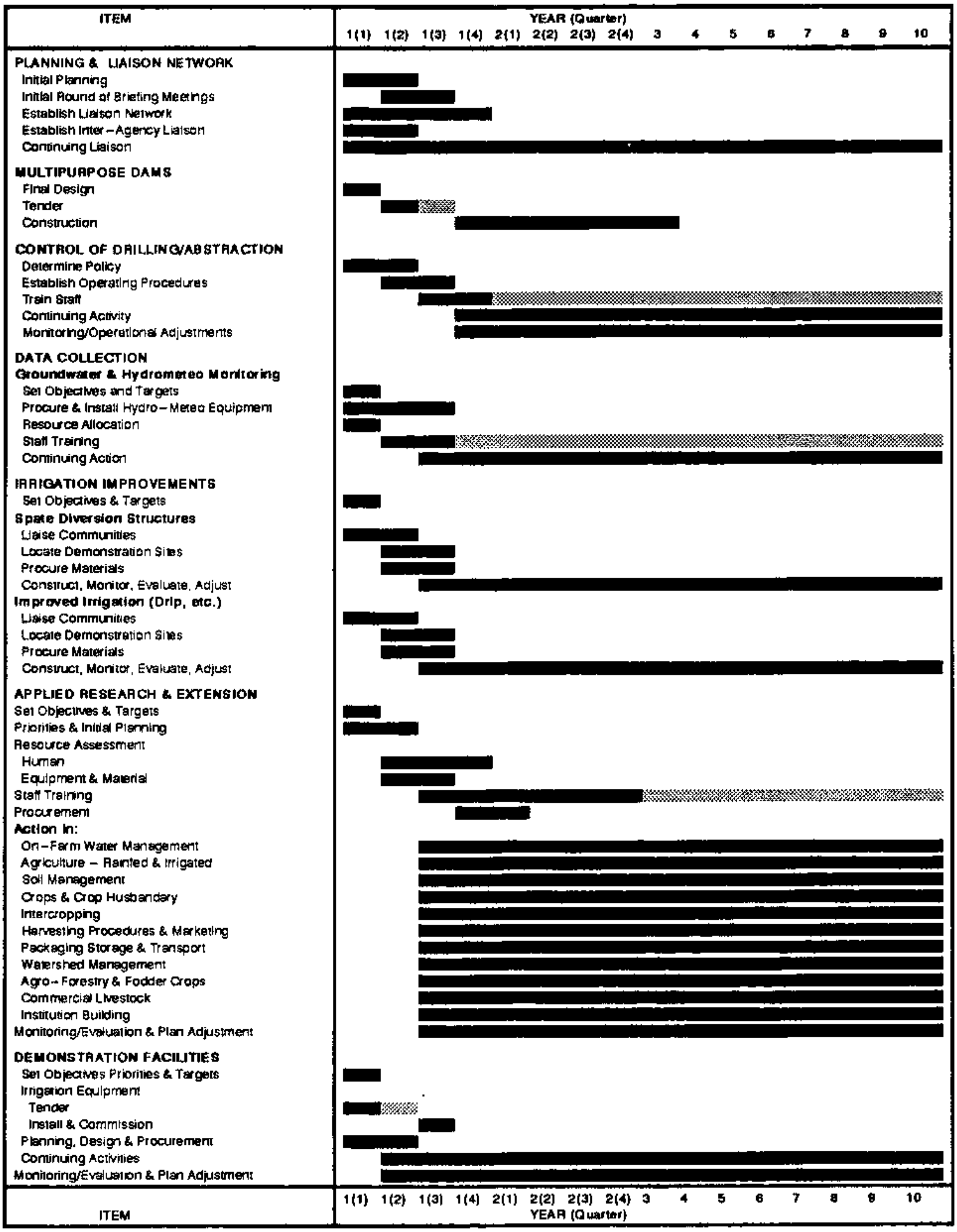
Fig S.6 *Regional Plan of Action/Implementation Schedule*



1 INTRODUCTION

1.1 BACKGROUND

1.1.1 The NORADEP Project

The Northern Region Agricultural Development Project (NORADEP), funded by the World Bank and executed by the Sana'a Sa'dah Hajjah Agricultural and Rural Development Authority (SSHARDA) has as its objectives:

- The increase of agricultural productivity and farmers' incomes by the provision of improved agricultural services, the promotion of better management of land and water resources and manpower, and the improvement of irrigation and agricultural practices.

- The improvement of health and nutrition standards through the provision of development opportunities for rural women.

The project is one means by which the Government intends to achieve its priority objective of accelerated development of the Northern Region, both for socio-political reasons and to ensure more balanced development in the country.

The major components of the project are the provision of comprehensive regional agricultural services; the enhancement of agricultural credit facilities; irrigation development through the construction of multi-purpose dams; and technical assistance and training.

This report, covering the Sa'dah Plain Target Area, has been prepared as part of the Technical Assistance for Engineering Services to the NORADEP project funded by UNDP (YEM/87/015). It is one of seven Target Area Water Management Plans, from which a Regional Water Management Plan has been formulated.

1.1.2 Technical Secretariat - High Water Council

From January 1989 the Technical Secretariat of the High Water Council (TS-HWC) has carried out work on a wide range of subjects related to water planning and management, culminating in the publication of a final report: *Water Resources Management and Economic Development* (10 Volumes), December 1992. The report sets out very clearly the need for, and the actions necessary to achieve, effective water management in the national context. Foremost among these are needs for data and the development of the institutional and human resources to use the data.

A national water resources management programme can only be established on the basis of assessments of individual water management units, from which the overall technical picture can be assembled and policy decisions made. The Target Areas, defined for the NORADEP project on the basis of their agricultural potential, comprise such units, and are therefore an integral part of the national planning process. Although the data assembled for the Target Areas is limited in absolute terms, it compares very favourably in quality and quantity with data available elsewhere in Yemen, and can be used as a model for future programmes to gather basic data.

1.2 THE STUDY AREA

The Sa'dah Plain is situated in the Central Highlands of Yemen in the centre of Sa'dah Province some 250 km on the asphalt road north of Sana'a (Fig. 1.1). The alluvial plain covers an area of about 213 km^2, and has a surrounding catchment of hills and mountains of about 937 km^2. The plain is 30 km long in a northwest/southeast direction and its width varies from 7.5 km in the northwest to 16 km in the southeast.

The main road from Sana'a to the north passes through the plain. The most important towns are Sa'dah in the southeast, At Talh in the centre and Dayan and Majz in the northwest. Several wadi channels enter and cross the plain; Wadi Marwan is the effective outlet for surface water and leaves the plain north of Sa'dah town, joining Wadi Najran across the border. Fig. 1.2 is a map of the Target Area.

Topographic elevations in the plain range from 2050 m at the northwest margin of the plain down to 1840 m near Wadi Marwan in the northeast. The surrounding mountains reach altitudes of up to 2750 m at the west side of the plain, where Amran Limestone and Wajid Sandstone outcrop, ie. about 800 m above average plain level. At the southern, eastern and northern borders granites, limestones, sandstones and metamorphic rocks rise 100 to 400 m above the plain.

1.3 ISSUES AND PRIORITIES

1.3.1 Water Management Issues

The principal issues that must be addressed in the context of water management in the Sa'dah Plain are:

- The conflict between the encouragement of increased agricultural production and long-term resource sustainability - particularly of groundwater.

- The effect of changes in agricultural practices on the quantity and quality of land and water resources, and the environment generally.

- The implications of the increase in farmers' incomes, and thus living standards, on water resources. There are obvious interactions with public water supply and sanitation, but the general provision of infrastructure and services falls outside the scope of this report, though not outside the responsibilities of SSHARDA.

- Equity: there is currently a considerable gap between the living standards of the richer and poorer farmers. This will always exist, but water management interventions may well tend to exacerbate the situation and the matter of equity would as a result have to enter into the planning process.

- The effects on the allocation of water resources of any development of industry in the Target Area.

Fig. 1.1 *Location Plan*

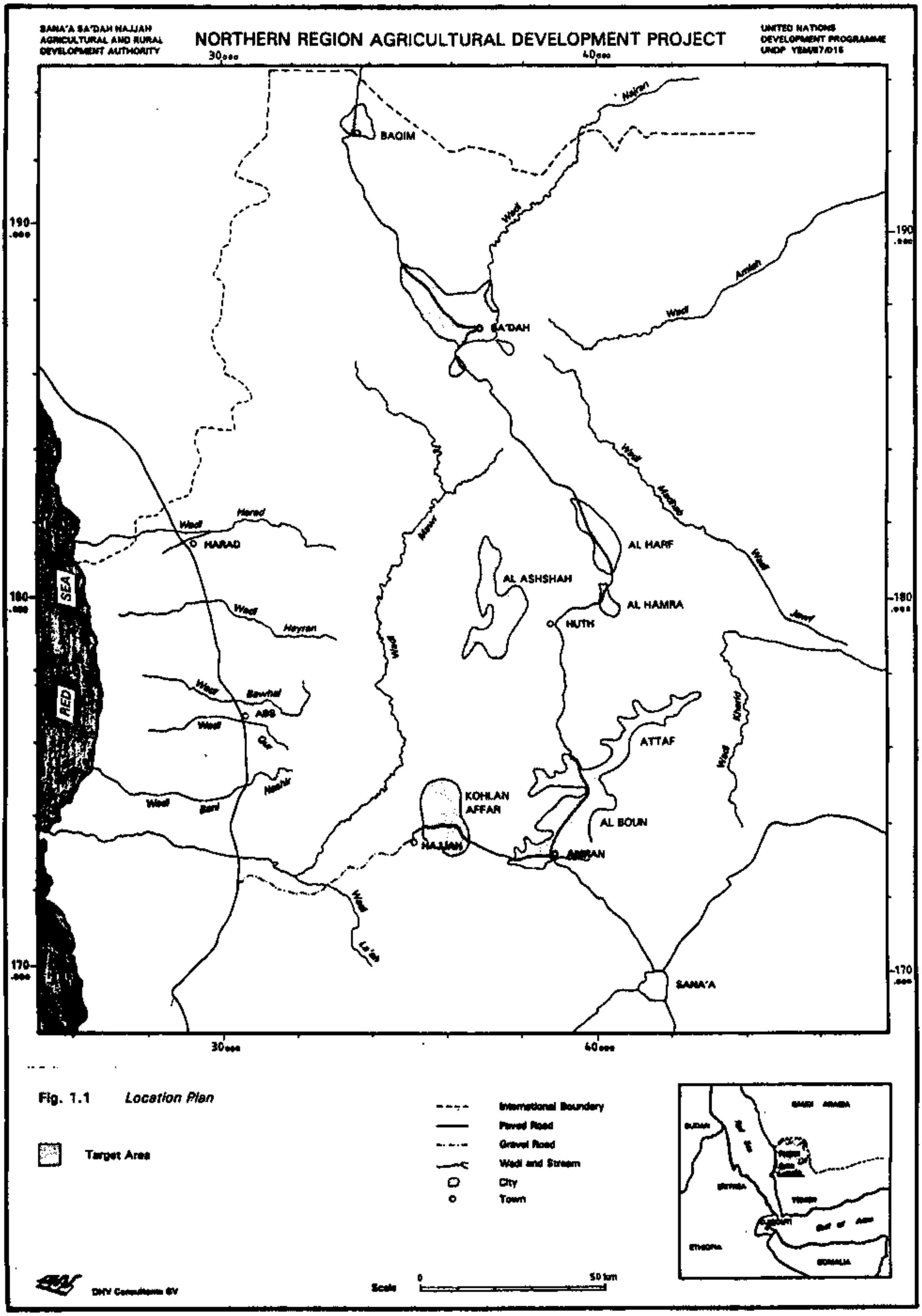
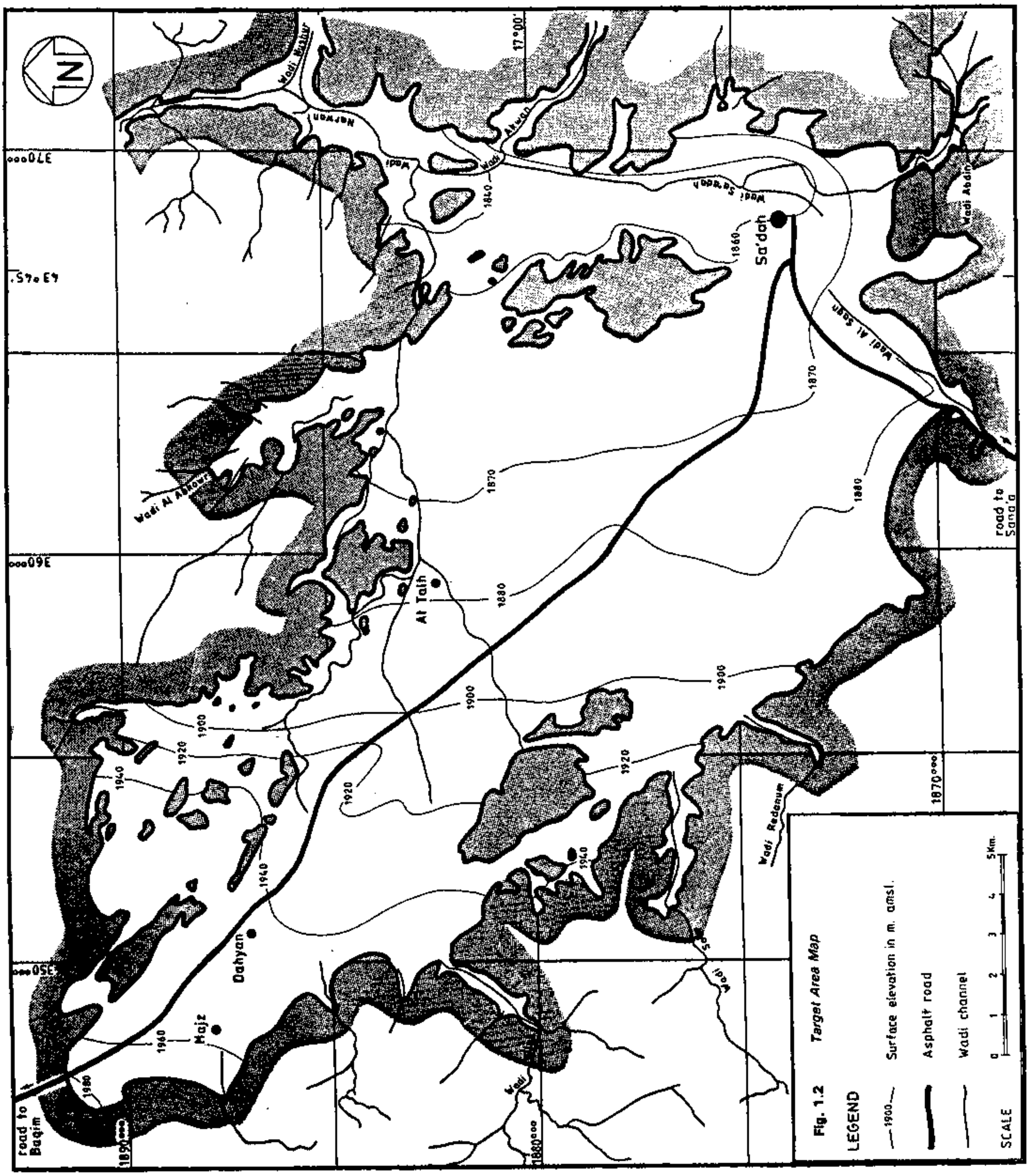


Fig. 1.2 *Target Area Map*



1.3.2 Report Priorities

The major concern with respect to water resources in the Sa'dah Plain is the excessive pumping of groundwater, which has resulted in a decline in the water table of some 40 m between 1983 and 1992. It is estimated that current abstraction of groundwater exceeds recharge by some 400%. Therefore, groundwater is the main focus of this report.

However, particularly around the edges of the plain where wadis debouch onto the alluvial soils, surface water remains an important resource. During the last twenty years or so, this surface water has become more difficult to control and utilise; floods have become more flashy and peak flows higher as a result of degradation in the catchments caused by changes in the traditional land use patterns. Erosion of wadi terraces has occurred and valuable land resources are being lost in locations where it might be possible to gainfully use spatewater in conjunction with groundwater to achieve a greater overall water use efficiency. On the other hand, in some cases, the better solution from an analytical point of view would be to allow the wadi flows to recharge the aquifer, from which more efficient use could be made of the water. Each case has to be treated on its merits.

Another approach to the use of surface water, which can have advantages in particular physical conditions, is the multi-purpose dam, which serves both to store flood water so that it can be used over a longer period than during the traditional spate - and so more efficiently - and to encourage infiltration into the shallow wadi-bed aquifer, again for planned use at a later stage. However, careful economic analysis is required to justify the construction of such dams.

1.4 REPORT OBJECTIVES

The longterm objective of the water management planning process must be to attain the optimum sustainable physical and economic use of available water resources for agricultural and domestic purposes; also industrial use where applicable. Such a widely based objective is entirely theoretical in the current context of national planning, resource and institutional constraints, and the severe lack of detailed data. However, there is an increasingly urgent national need for action to control the over-exploitation of groundwater for agriculture at the same time as maintaining or increasing the existing standard of living of the rural population.

Therefore, this report concentrates on intermediate objectives which are achievable with the resources available to SSHARDA and other relevant institutions, were those resources to be applied in the appropriate way. These intermediate objectives, combining practical initiatives to rationalise water use with the gathering of the detailed data essential for comprehensive planning, can be summarised as follows:

- Reduction of groundwater abstraction, while maintaining farmers' income levels, by applying controls on exploitation, increasing returns to water, and educing reliance on groundwater.

- Establishment of the human, physical and data resource base for longterm planning and action. This will necessitate accurately targeted training at all staff levels coupled with objective driven management and the provision of the resources required to achieve the objectives; monitoring of ground and surface water and climatic data; and carefully planned and executed applied research and extension.

These objectives, the issues they raise, and the means of achieving them are discussed in detail in Section 7, but it is essential to set them out clearly here, at the beginning of the report, in order that the basis of the report is understood by the reader from the outset.

1.5 REPORT LAYOUT

Each of the Target Area reports is designed as a tool for line management who will have to implement the plan and contains:

- A summary
- An introduction (Section 1) which sets out the background to the report, the general issues that have to be addressed and the report; report objectives; and national context within which the report is set.
- Section 2, a summary of the water resources of the Target Area.
- Section 3, which covers the major points brought out by the SONDEO (Rapid Rural Appraisal Survey).
- Section 4, a review of the current management of water and agriculture, which extends the basic data presented in Sections 2 and 3.
- Section 5, which contains a detailed discussion of the problems, solutions, actions, and constraints involved in the planning process.
- Section 6, an analysis of the current financial status in the Target Area (from the farmers point of view) and outline projects of the effect of plan implementation.
- Section 7, which contains the recommended Target Area Water Management Plan, and includes a tentative implementation programme.

The Target Area Water Management Plans are combined into a Regional Water Management Plan, the purpose of which is to summarise for senior management and policy makers the individual detailed Target Area Plans, bringing out the differences between the Target Area, and recommending priorities for implementation. These priorities are then assembled into a tentative regional implementation programme, supported by an outline overall budget. Funding possibilities are then reviewed briefly.

1.6 BACKGROUND STUDIES AND DATA COLLECTION

The report draws on data contained principally in the following specialist study reports, compiled by the Technical Assistance Team, supported by SSHARDA counterparts and assistants. The NORADEP Report Number (see References) is given in brackets.

- Agro-Economic and Sociological Sondeo Study (3 Volumes), August 1993 (13).
- Groundwater Resources in the Sa'dah Plain, August 1993 (8).
- Mapping and Evaluation of Groundwater in the Wajid Sandstone of the Sa'dah Region, April 1993 (10).
- Water Balances in the NORADEP Region, July 1993 (1).
- Reconnaissance Study for the Selection of Small Dams (51 sites), August 1993 (16).

A basic physical and socio-economic framework for the planning process was established by the completion of a well inventory, which incorporates investigations into cropping patterns, and a rapid rural appraisal survey (SONDEO). During the well inventory comprehensive details were taken of 563 wells, and the locations of a further 1648 were accurately recorded. In addition an assessment was made of surface water runoff, though data is scanty and unreliable. A generalised water balance was compiled.

The SONDEO survey involved visits to 57 individual farming families in 52 villages throughout the Target Area; group discussions involving four "key farmers", and discussions with others present at qat sessions; and other personnel engaged in agricultural development, officials of the Co-operative Agricultural and Credit Bank (CACB), members of two LCCDs, the SSHARDA branch manager, the head of the agricultural co-operative and the Deputy Governor.

A number of farms throughout the NORADEP region, state and private, were assessed for their suitability as demonstration farms. Soil surveys were carried out on four of these (Al Boun, Al Batana, Al Magash in the Sa'dah Plain and Bani Qais), and designs for the installation of modern irrigation have been prepared.

1.7 THE NATIONAL CONTEXT

1.7.1 Planning Background

At unification it was agreed that operation of the development plans of PDRY and YAR should be extended while a new First Five-Year Development Plan is prepared for ROY; this should come into force in 1994/95.

Objectives
For the agricultural sector the objectives were similar in both countries; those of YAR were to raise agriculture's share in GDP through increasing efficiency of agricultural production and support services; increase crop and livestock production to satisfy domestic demands and to expand exports; focus on self sufficiency and food security; to develop the skills and capacities of farmers and to modernize technical

operations;optimize resource utilization and to limit expansion in qat production; foster public, private and cooperative sectors as a means of increasing production; and ensure supplies of adequate raw materials for agricultural processing industries.

Strategy
In order to meet these objectives the strategy was to raise farmers' knowledge by developing the administrative and technical aspects of research, extension, demonstration and information/audio visual services; improve varieties and expand production and supplies of seeds and seedlings; provide adequate supplies of inputs (fertilizers, chemicals and machinery) for ensuring increased production; expand forest planting and provide special incentives for sand dune stabilization; encourage animal breeding to increase meat, dairy and egg production; and tighten quarantine controls; expand pasture production and protect rangelands; rationalize irrigation water utilization, organize well drilling and improve standards of water management; establish a network of marketing facilities, expand wholesale markets and market regulation, build cold stores, encourage the private sector, and ban importation of fruits and vegetables; and stimulate the operations of private cooperatives.

Thus, a suitable framework exists within which a water management plan, in conjunction with complementary agricultural environmental and institutional initiatives, could have a positive effect on the development of agriculture.

1.7.2 Agriculture in the Economy

Agriculture is a major sector, employing about 58 percent of the labour force. In the period 1986 to 1989, agriculture contributed 28 percent and 16 percent respectively to the YAR and PDRY economies. For the decade to 1991 it is estimated that the annual growth rate for agriculture was 2.2 percent, while population grew at 3.0 percent. From 1990 there was a slowdown even from this low level of growth as supplies were disrupted by the Gulf War and farmers began to feel the impact of macroeconomic imbalances in the form of unfavourable terms of trade for cereals and input supplies.

Overall agricultural output (excluding qat), at about YR 20 000 million (Projected, 1991), accounts for just over 20 percent of GDP. By adding qat total (projected) GDP for 1991 would rise by more than 35 percent. Qat occupies some 25 percent of the controlled irrigation area and provides employment for some 500,000 people (16 percent of the working population). The official policy towards qat is to restrict cultivation to low potential areas. However, in practice due to its profitability and widespread consumption, nothing has been done to restrict production.

Crop Production
Among the subsectors, conventional crop production is the most significant, accounting for almost 75 percent of the total agricultural GDP (excluding qat), followed by livestock (about 20 percent); fisheries and forestry each contribute less than five percent.

The estimated crop production breakdown is: cereals and by-products 47 percent; tree crops (coffee, fruit, etc.) 12 percent; vegetables 8 percent; forage 20 percent; and other crops 13 percent. In addition to the conventional agricultural crops, although not included in the national accounts statistics, it is estimated that qat (occupying 80 000 ha, output of some 280,000 tons) has an added value of more than YR 34 000 million.

Livestock
Livestock is an important resource with considerable potential for expansion, consisting largely of nomadic/sedentary sheep and goats production. A modern poultry industry has developed since 1975.

Fuelwood
Rangelands cover some 15% of the territory. In the past, Yemen had significant forest cover but due to uncontrolled felling and lack of a national forestry policy, woodlands is being consumed for domestic fuel faster than it is replaced.

Output and Yields
During the two decades 1970-1990 the area planted to wheat and millet increased by 230 percent and 250 percent, respectively, while the sorghum area decreased by 250 percent. Traditional cash crops of cotton and coffee have declined in the last decade. Production of vegetables, fruit and forage increased significantly, and output of qat increased dramatically. Despite considerable Government investments, yields of most crops have not changed significantly since 1970, reflecting the low availability of inputs and the lack of real impact by research and extension on modernising farm technology.

Food Balance
In the north, the self-sufficiency ratio for food declined from 80 percent in 1975 to 52 percent in 1990.

1.7.3 Population

An estimated 7.3 million people (63 percent of the total population) live in rural areas and some 1.8 million people work and depend directly on agriculture (equivalent to 58 percent of the total labour force). Demographic analyses indicate that 37 percent of the rural population is under 20 years of age and a further 20 percent is between 20 and 30 years. The rapid population growth rate raises a massive challenge on three levels: national food production, employment opportunities, and environmental protection.

1.7.4 Resource Base

Yemen enjoys resources and a climate more suited to diversified agriculture than most other countries in the Arabian Peninsula. In the highlands and on the escarpments, there are about one million hectares of rainfed arable land; approximately half of this area is developed as terraces. Irrigated land totals some 320 000 ha, 60% from spate flows, and 40% from groundwater.

However, more than half of the geographic area is arid or semiarid rangelands. Deforestation and neglected maintenance of the traditional water harvesting terraces threaten the basis of rainfed agriculture and increase the risk of erosion. The potential for livestock development has also been neglected.

Groundwater extraction has increased dramatically in recent years. Aquifer levels are declining in most watersheds (the drops range from 1 to 6 m per annum) and the incidence of salt water intrusion is increasing in some coastal areas. Spring-fed irrigation has reduced significantly as groundwater tables have dropped. It is estimated that current withdrawals of water for all purposes are 138 percent of renewed resources and, despite recent discoveries of new groundwater sources, this means that water reserves are being "mined". Some 90% of total withdrawals are for agriculture.

The threat to sustainable agriculture from the eroding resources base is great. Yet, in the near to medium-term, agriculture is likely to remain an important sector, especially in view of the limited known oil and mineral reserves and the restricted potential for industrial development.

1.7.5 Constraints

Economic and Strategic

Several aspects of a macroeconomic policy are constraining growth of the agriculture sector: the continuing unrealistic official exchange rate has distorted prices of imported food, while foreign exchange rationing, together with licensing procedures, has reduced importation of inputs and equipment; constraints on the Government's recurrent budgets have restricted the recruitment of trained personnel, limited field operations and starved projects of operational funds; the resource base is vulnerable and there is no real national policy or practice on conservation, particularly of water and woodlands; Government's interventions have not been guided by any very clear objectives, and the tools for supporting policy makers (statistics, economic analysis) are weak; and, by maintaining food self-sufficiency as a central development objective (as opposed to food security), the Government has promoted unbalanced development in which irrigated (low value) cereals have an exaggerated place.

Institutional and Technical

A number of institutional and technical constraints have held up agricultural development. Among the most important are excessive centralisation and bureaucratic inefficiencies in MAWR, which have seriously delayed project implementation and restricted potential output from development investments; an overambitious agronomic research programme with inadequate attention to technological initiatives (water management and appropriate mechanisation), farming systems analyses, and outreach for solving farmers' problems; limitations in field extension services (and few incentives) and messages which inadequately address target group requirements; insufficient technical training for extension staff and farmers; very little attention to irrigation neglect of the potentially important livestock sector; and persistent shortages of inputs, particularly for crop production.

1.8 GENERAL APPROACH TO PLANNING

1.8.1 Definition of Water Management

It is generally recognised that water resources are severely limited: they are not adequate for current requirements, and groundwater - the main source for irrigation -

is being mined at an alarming rate. On the other hand, soils though under threat from erosion, are not a constraint on development. Soil, water, vegetation and forestry cover are interdependent, requiring an integrated conservation policy, and therefore water management cannot be dealt with in isolation because:

- Physically it is related to soils, farming systems, cultivation techniques, agricultural inputs and livestock.
- Institutionally it is affected by land ownership/tenure patterns, water rights and the relevant legislation, extension services, credit and marketing, education, local and national government and other agencies with responsibilities in the sector.

Any water management plan must take account of all these inter-related factors. Unless it does so it will not even be implemented, let alone succeed.

For the purposes of this report water management is defined as all the processes that can be used to conserve, develop and harness water for agricultural and rural development purposes, from the time rain falls, to the drainage of surplus and wasted water, including abstraction, conveyance, on-farm-water-management, agricultural techniques and watershed management.

1.8.2 Responsibilities of SSHARDA

The water management plan in this overall sense must be understood, accepted and endorsed by farmers individually and collectively. Only then will they be motivated to ensure - through pressures on local, district, provincial and national administrations, and other institutions such as SSHARDA who have the responsibility and authority - that the plan is implemented, and continuously adapted to changing circumstances.

SSHARDA, as the organisation with overall responsibility for agricultural and rural development, must ensure first of all that its function is understood by everyone, that it is open to suggestions and criticisms and responds in a positive manner. Most importantly it must base its work on what is already known and understood by farmers, and not attempt to impose solutions from outside.

The SONDEO studies reveal that many farmers do not have the necessary knowledge in some areas of their activities, or are working on erroneous assumptions. In the correction of these basic deficiencies SSHARDA must take extreme care that the extension message is put across in an appropriate and positive way, so encouraging farmers to seek further information, and to take part in work to modify and improve water management and farming practices in general.

1.8.3 Technical Assistance Studies

Within the constraints of resources and time on the technical assistance studies it has only been possible to take a reasonably quantitative approach to the analysis of the most important issue, that of groundwater. Other issues have been dealt with in a qualitative way, although the more important topics have been broadly quantified where possible, with data from other recent and relevant studies where no other is available.

In the event this approach has proved to be justified since it is at the level of individual farmers and farmers' groups that action must initially be concentrated. Here the SONDEO studies have demonstrated clearly that so much has to be done to improve basic water management practices that it would be totally inappropriate - not to say wasteful of time and resources - to attempt any quantitative analysis of farming systems at this stage. It is far more important to commence without delay the work needed to increase water use efficiency through improvements in irrigation techniques and farming practices.

Nevertheless, the comprehensive groundwater database that has already been established, and the valuable findings of the SONDEO survey, should be maintained and extended as a basis for long term monitoring.

2 WATER RESOURCES

2.1 BACKGROUND

2.1.1 Climate

The climate in the Sa'dah Plain is classified (Koppen) as mountainous semi-arid. The natural vegetation is of the briar, succulent, savannah type but as a consequence of intensive grazing little of the grassland is left. The result is the desert-like appearance of the non-cultivated parts of the plain.

Average monthly temperatures range from 13°C in January to 25°C in July; average annual temperature is 19.3°C.

Rainfall is sporadic and scanty and storms are usually short, intense and local. Therefore, there is a large variation in annual rainfall. Data from four rainfall stations in and near the plain have been analysed: Al Muthef (7.5 km southeast of Majz), Al Gudami (12 km north of Sa'dah town), Al Dumeid (5 km southeast of Dayan) and Sa'dah town (Salam hospital). The data from these stations differ immensely, despite the small distance between them. For example, the mean annual precipitation in Al Muthef, measured during the period 1983-1990, is double that at Al Gudami (200 and 103 mm respectively). Averaging the data of these stations gives a mean annual rainfall of 136 mm. This preliminary estimate of the yearly rainfall has been assigned to 1992 to enable the calculation of the volume of the yearly total rainfall on the plain. Rainfall distribution is variable but in general there are two peaks, the periods March-May and July-August. The wettest month is April.

Evaporation far exceeds the precipitation during most of the year. Pan evaporation was measured by the German-Yemeni Plant Protection Project in 1976 at about 2800 mm per year (Class A). Daily figures in the driest months were 10 mm and 5-6 mm in the wettest months. ETO (Penman) is about 2280 mm.

2.1.2 Geology

At the end of the Cretaceous and during the Tertiary regional block faulting and volcanic activity occurred in association with the Red Sea rift. The Sa'dah Plain originated as a graben (sunken area created by down faulting) which has since been filled by alluvial deposits comprising gravels, sands, silts, clays and loess varying in thickness from 10 m at the borders to about 50 m in the central part of the plain and which is underlain by the Wajid Sandstone of Cambrian to Permian age. Volcanic activity during the Tertiary left alkali basalt, rhyolites and pyroclastic basaltic rocks, locally interbedded with clastic wadi alluvial deposits, in several parts of the plain.

The Sa'dah Plain is bordered by the Jurassic limestone of the Amran Series at the southeast and northwest margins, which rest upon the calcareous sandstones of the Kohlan Group and in some areas directly upon the Precambrian Basement. The Wajid Sandstone outcrops north and east of the plain.

2.3 GROUNDWATER

2.3.1 Hydrogeology

Alluvium
Alluvium in wadi beds may function as a temporary perched aquifer and where saturated it represents a relatively good one. However, in most of the Sa'dah Plain the alluvium is situated above the water table and is therefore not saturated, but does serve as a medium to hold surface and rain water while it percolates into the underlying sandstone.

Amran Limestone
The Amran Series, principally composed of limestone, and marls with some shales, is generally considered a poor aquifer; higher permeabilities are only encountered in fractured zones.

Wajid Sandstone
The Wajid Sandstone was investigated as part of the NORADEP Project (NORADEP Report 10). It dominates in the extreme northern part of Yemen and constitutes the main aquifer in all the alluvial plains in the north. In the Sa'dah Plain all groundwater is derived from the Wajid Sandstone. Its thickness to the underlying impermeable Precambrian basement rocks varies as a consequence of tectonic block-faulting, ranging from 100-150 m locally in the north and up to 600-650 m in the central and eastern parts of the plain (WRAY 3, Yominco-TNO, 1985).

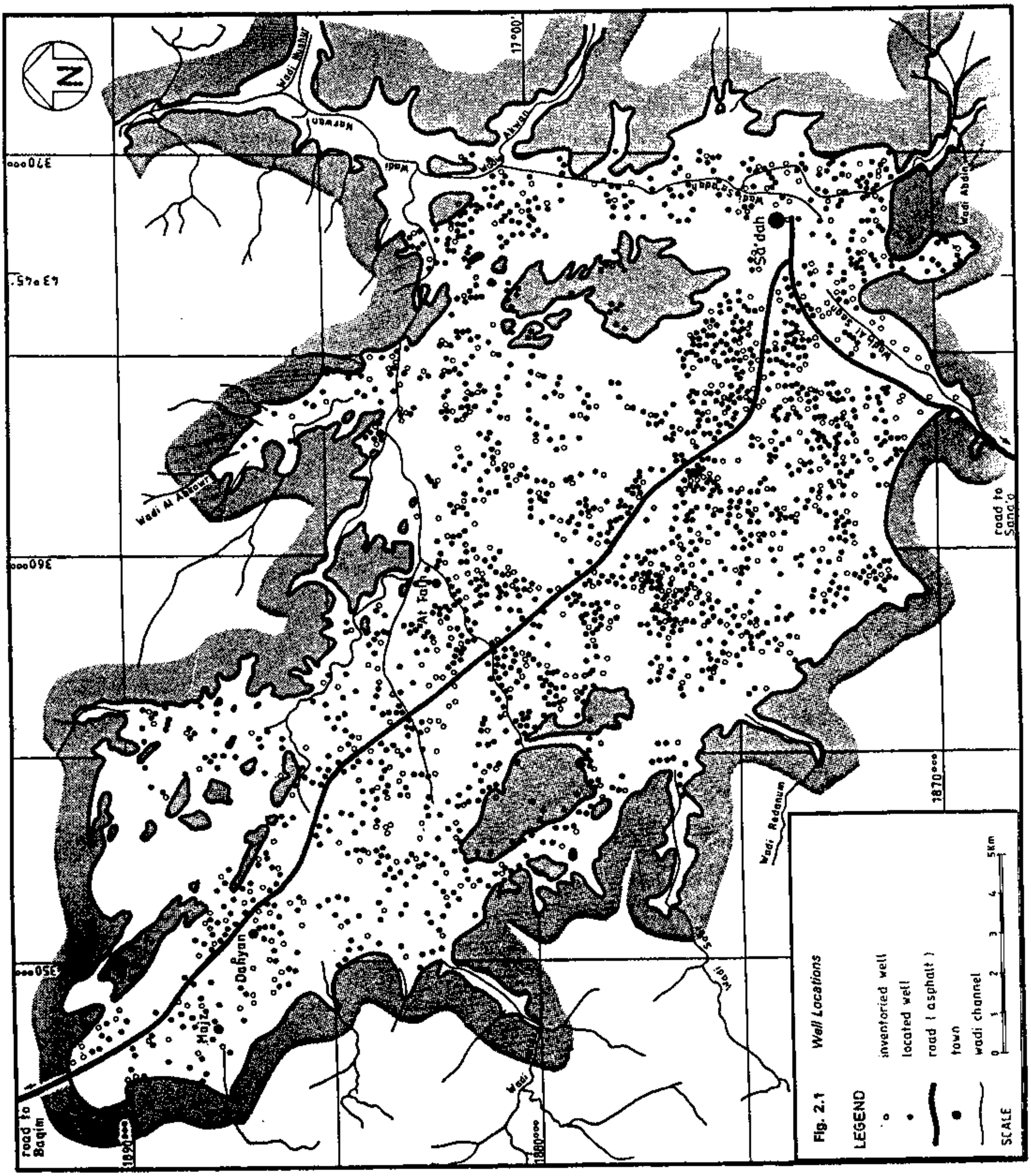
The WRAY study revealed the following hydraulic properties obtained from aquifer tests in the Sa'dah Plain: average porosity varying from 0.05 to 0.15, average specific yield (effective porosity) of about 0.075, permeabilities ranging from 0.1 to 0.3 m/day and transmissivity values varying from 20 to 100 m^2/day. These hydraulic capacities classify the Wajid Sandstone as a moderate aquifer.

2.3.2 Well Inventory

During the last decade several water resources studies have been carried out in the Sa'dah Plain. Therefore, the approach adopted for this study was to prepare an updated well inventory. A sample of about 25% of all the wells in the Sa'dah Plain was taken. At these selected well sites complete interviews with the farmers were carried out and all measurements taken. For the remaining 75% of the wells, only the locations were plotted on the map. This process resulted in the location of a total of 2211 wells in the Sa'dah Plain. Fig. 2.1 shows the location of all the wells visited for this study.

Serious groundwater development in the Sa'dah Plain started only in the late 1970s, about 15 years later than in the Amran Valley. Most wells were drilled in the period from 1984 to 1986, when 813 wells were completed. After 1986 drilling decreased significantly (from 287 wells in 1986 to 124 in 1991). 50% of all wells were drilled after 1985; the average age is 8 years. The oldest dates from 1920 and is the only operational shallow dug well in the plain.

Fig. 2.1 *Well Locations*



2.3.3 Distribution and Number of Wells

Well densities are particularly high east, south and west of Sa'dah Town. It was assumed that about 90% of all existing wells were spotted and that the remaining 10% are evenly distributed over the clusters of boreholes in the area, ie. a total of about 2457 wells (in the first half of 1992), which is more than twice the number of wells (1175) located during the well inventory taken for WRAY 3 in 1982/1983. The total number of operational wells in 1992 in the Sa'dah Plain was taken to be 2330, on the assumption that 5% of the estimated total were not operational.

2.3.4 Well Characteristics

Construction
93% of the surveyed wells were boreholes, while 7% were dug wells deepened by drilling. During the WRAY-3 well inventory 93 shallow dug wells were located of which one now remains. 12.8% of the boreholes had been deepened once, twice or even three times. The drilling method used was predominantly cable-tool. Practically all thė boreholes were cased through the alluvium, but were generally unlined in the Wajid Sandstone, and with a diameter of 200 mm.

Depth
Borehole depths ranged from 60 m to 300 m, although most (65%) are between 150 m and 225 m. Only one was deeper than 300 m. The average depth was 174 m. Depth to water ranged from 40 m to 80 m. Average aquifer penetration in the Sa'dah Plain was the highest in the NORADEP Project. Water column heights ranged from 9 m to 250 m; the average aquifer penetration was 113 m. If the groundwater level were to drop 30 m over the whole plain, then only 3% of the boreholes would dry up.

Pumping Equipment
In all the boreholes of the survey sample water was pumped by vertical turbine (lineshaft) pumps coupled via crossed webbing belts to diesel engines. Neither electro-submersible nor centrifugal pumps were observed in the area. There was a very high level of standardisation in engine and pumping equipment: 95% of all the turbine pumps were supplied by two manufacturers; 91% of the engines were of one make.

Yield
Well discharge rates in the Sa'dah Plain are very low. The mean value from this survey was 3.3 l/s, half that determined in 1985 by the WRAY-3 Survey (6.7 l/s); minimum and maximum discharge rates were 0.75 l/s and 9.38 l/s; most (91%) ranged from 1 l/s to 5 l/s. On the Baqim Plain similarly equipped boreholes in the Wajid Sandstone yield an average of 6.5 l/s, but there groundwater levels are higher.

In 89 wells both the static and dynamic water levels could be measured. Specific discharge values (discharge/drawdown) were very low and ranged from 0.05 to 2.5 l/s/m with a mean of 0.5 l/s/m (cf. Baqim Plain: mean 2.1 l/s). The higher the specific discharge the better are the water transmission characteristics of the aquifer. Low specific discharge values dominated in the centre of the plain, while higher values were found in an area east of Sa'dah Town.

2.3.5 Cost of Construction and Equipment

Borehole construction costs in Sa'dah Plain were relatively low because drilling was mostly by the cheaper cable tool method, and over most of their depth the boreholes were not cased or screened. Costs ranged from YR 15 000 to YR 270 000 (a deep well of 140 m drilled in 1985); median well costs were YR 50 000. (All at current prices, ie. those at the time of construction, which ranged from 1970 to 1992).

Pumping equipment costs had a much larger variation: from YR 10 000 to YR 720 000, and a median of YR 60 000. A major contributing factor to this was the variation in the equipment and installations costed. The pump and engine was always included; the pumphouse, reservoir and piped water distribution network may also have been allowed for.

2.3.6 Abstraction

Operating Practice
The average farmer in the Sa'dah Plain pumped groundwater for 8 to 11 hours per day, throughout the year, averaging 9.8 hours per day 26 days a month.

Volume Pumped
At 405 wells the discharge was measured, from which the total abstraction in 1992 was estimated as 80 Mcm, a mean volume per well of 34,500 m^3. During the WRAY-3 well inventory (1985) 1065 wells were responsible for an annual abstraction of 50.8 Mcm, a mean volume per well of 47,700 m^3.

Just as in several other plains in the NORADEP Project region the rate of increase of the yearly abstracted volume has clearly diminished since 1987. A (very rough) estimate of all the groundwater pumped in the Sa'dah Plain, using figures from 1970 (when abstraction became significant) up to 1992, gave about 694 Mcm. Expressed in terms of lost aquifer, the volume pumped during these 12 years corresponds to a lost saturated aquifer thickness of 30 metres, extending over the whole Sa'dah Plain.

2.3.7 Water Levels

Depth to Groundwater
Over most of the Sa'dah plain the depth to water level ranged from 40 m to 80 m below ground level (bgl). Lower water levels were observed in an area west of Sa'dah Town where Wadi Redanum debouches onto the plain (more than 90 m bgl) and between the villages of Al Talh and Dahyan (more than 80 m bgl). These seemed to be depressions in the water table caused by excessive pumping. Relatively high water levels were found downstream of where several wadis debouch onto the plain (less than 40 m bgl), although these levels were probably those of temporary perched aquifers.

Piezometric Levels
Piezometric levels drop from 1970 m amsl in the northwest margin of the plain to 1790 m where the groundwater leaves the plain through Wadi Marwan in the northeast, an average hydraulic gradient of 0.007. The general groundwater flow is directed towards the southeast in the western half of the plain and to the northeast in the eastern half.

Reduction Over Time
A comparison was made between the results of the WRAY-3 well inventory and the survey carried out for this study. A map indicating the decline in water level during the period from 1983 to 1992 was prepared (Fig. 2.2). During this nine year period a mean groundwater level decline of about 40 m occurred in most of the Sa'dah Plain. Most effected is an area of about 70 km^2 in the southeast part of the plain, west, north and south of Sa'dah Town. Here the drop of the water level was more than 40 m throughout, but in some places more than 55 m.

In 1991 average water level declined by 5.6 m. If this were to continue, over 50% of the wells would be dry by the year 2015. This is illustrated in Fig. 8.1.

2.3.8 Water Quality

The minimum value of the groundwater electrical conductivity (EC) was 296 microSiemens/cm, the maximum 4100 and the mean 953. 84% of all measurements were between 400 and 1200. Fig. 2.3 shows the variation over the Sa'dah Plain. The WRAY-3 well inventory showed a pattern of moderate salinity with the bulk of the values below 750 microSiemens/cm. Thus, there has been a serious deterioration of the general water quality over the last nine years. In the region south of the road from Sa'dah town to Baqim, large areas now show EC values of more than 1000 microSiemens/cm, with some above 1500. North of this road in general there is not a significant increase in electrical conductivity, except in the north-western part of the plain. The most critical area extends along wadi Sa'dah, east of Sa'dah Town. Here excessively high values of EC have been measured in several wells: about 1500 to 4100 twice that measured nine years before.

Salinity is not correlated with depth or relative permeability, though there is some evidence that high EC is associated with specific highly mineralised aquifer horizons.

2.3.9 Water Use

Extrapolation from data collected on visits to 510 farms gave a total area of land associated with wells of 7,881 ha, of which 2,308 ha was fallow, giving a command area of about 5573 ha, or 2.4 ha per well. The mean annual gross application was 2974 mm, which at an estimated overall irrigation efficiency of 41% gave a net application of 1227 mm, to which must be added the average net contributions from spate and rainfall of 22 mm and 138 mm. Thus, groundwater provided about 88% of crop water requirements on farms which had access to a well.

Of the 80 Mcm annual groundwater abstraction over 77 Mcm (96%) is used for irrigation, and the balance for domestic purposes and livestock.

2.3.10 Cost of Pumping

Estimates based on the data gathered during the well inventory gave a total average pumping cost of YR 4.64/m^3, broken down as shown below.

Cost Components	YR/m^3
Annual Cost of Well and Equipment (79%) Operation and Maintenance (9%) Diesel (12%)	3.65 0.41 0.58

Thus, the average gross irrigation water application of 2974 mm in 1992 would have cost YR 108 551, had the farmer taken the full financial cost.

As water levels decrease, the cost of pumping increases; by 2010 the cost per cubic metre pumped would have increased by 250% (Fig. 8.2)

2.4 WATER BALANCE

A water balance is one of the tools required for water resources management. From the different components and their interactions, and the impact of human interference, water resources development and planning activities can be carried out.

The 213 km^2 alluvial Sa'dah plain is surrounded by a 937 km^2 mountainous area with slightly higher rains than the plain itself (175 mm). The RC of this area is in the order of 12%. This rather high RC figure was taken because the runoff generating area directly surrounds the plain, keeping transmission losses relatively low. The runoff is used in part directly for irrigation; the remaining flow recharges the aquifers below the wadi beds and the plain. Aquifer recharge also takes place through rainfall; this is estimated at 5.5% of the rain falling on the plain or 1.7 Mcm, (the remainder evaporates.

A water balance was calculated for the combined unsaturated and saturated zone, represented by the unsaturated alluvium and sandstone and the saturated sandstone respectively. The area used for the calculation of the water balance was the Sa'dah Plain as defined approximately by the boundaries of the alluvial fill and, therefore, corresponding with the plain boundaries as shown in the figures. The results are given in Table 2.1.

Table 2.1 *Water Balance for 1992 (Mcm)*

INFLOW		OUTFLOW	
Net Rainfall Infiltration	1.7	Evapotranspiration from Groundwater Irrigation	36.1
Net Wadi Surface Water Infiltration & Foothill Runoff	4.9	Subsurface Groundwater Outflow	Nil
Subsurface Groundwater Inflow: Wadi Fills	0.5	Change in Storage: Unsaturated + Saturated Zones	-28.9
Bedrock	Nil		
Total Inflow	7.2	Total Outflow	7.2

Thus, annual groundwater abstraction is more than four times the recharge.

Fig. 2.2 *Decline of Water Level 1983 to 1992*

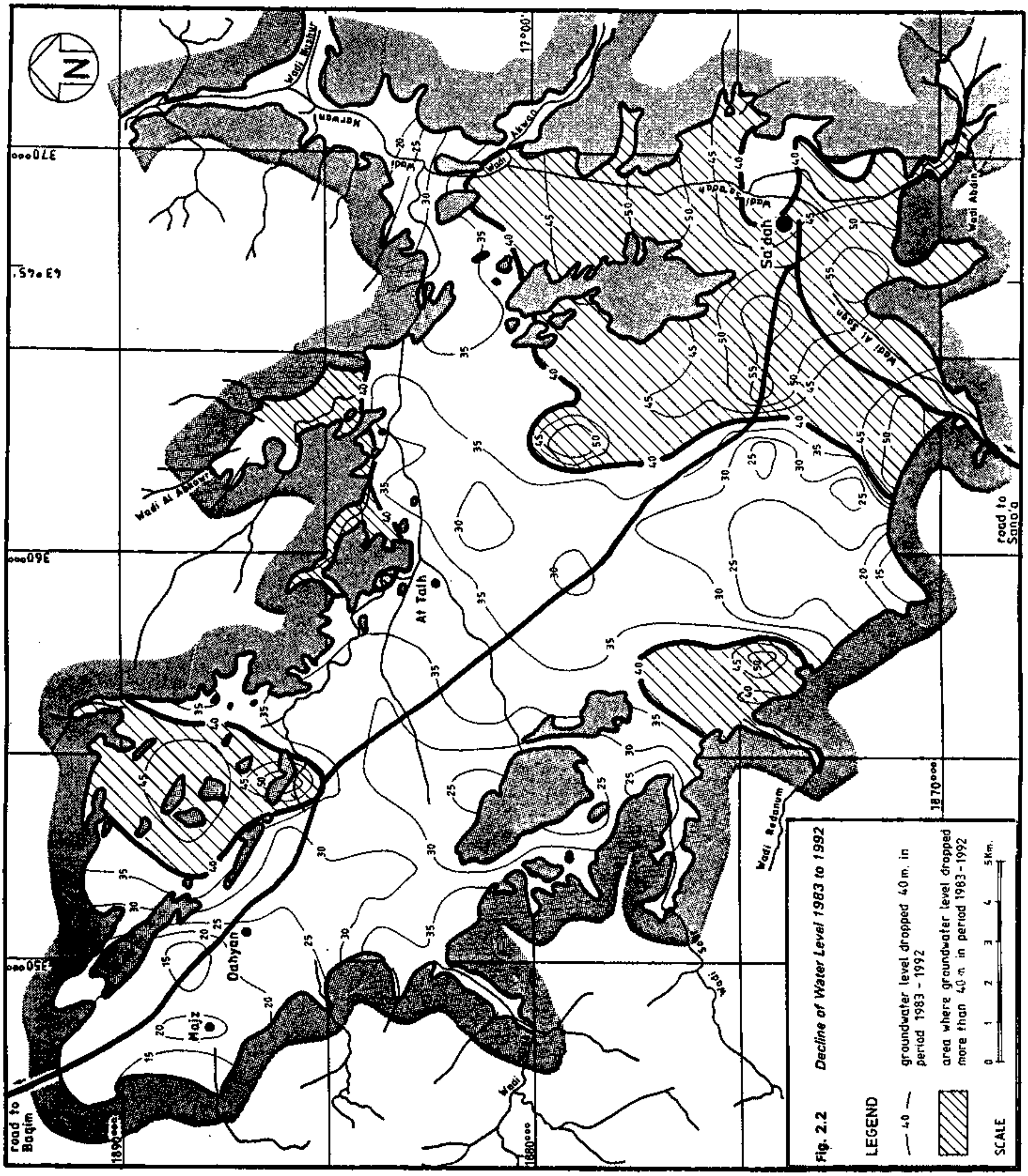
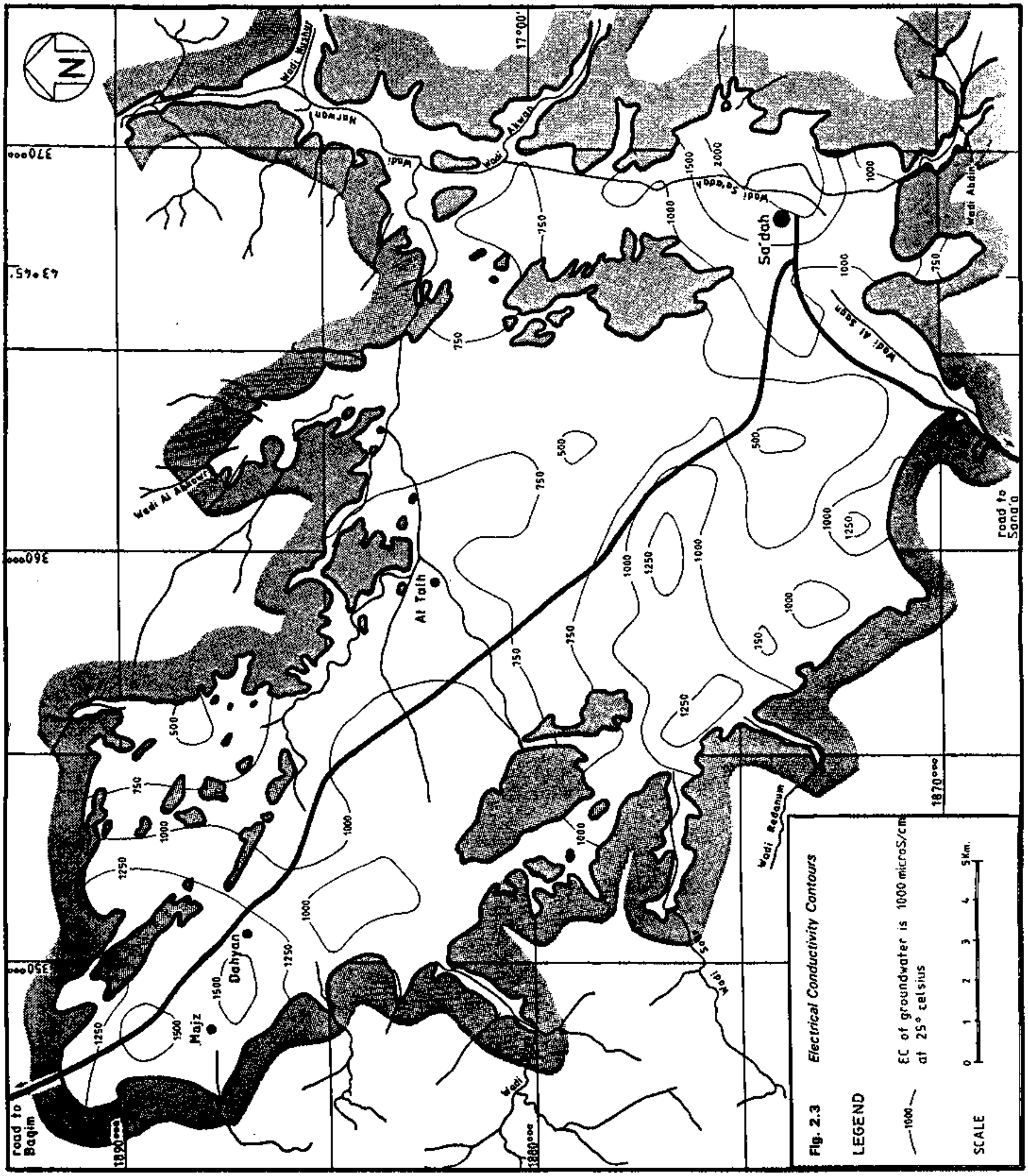


Fig. 2.3 *Electrical Conductivity Contours*



3 SOCIAL, AGRICULTURAL AND INSTITUTIONAL ENVIRONMENT

3.1 TARGET AREA

The Target Area comprises the Sa'dah Plain and the surrounding foothills, an area of some 38 000 ha of which 24 000 ha is cultivated and 18 000 ha is entirely or partly under groundwater irrigation. There are a number of wadis flowing through the plain, from which a large area can be irrigated by spate. From the 1986 Census there are some 157 villages in the Target Area, where about 112,000 people live, 25,000 in the main town of Sa'dah. Using a population growth rate of 3.3% pa, these figures would be 136 000 and 30 000 for 1992.

The Target Area is covered by four Districts, within the administration of Sa'dah Province, and by the four corresponding Local Co-operative Councils for Development (LCCD). The operations of the Ministry of Agriculture and Water Resources (MAWR) and of SSHARDA are integrated at provincial level. SSHARDA operates through a number of Block Centres. The Target Area is covered by the Block Centre at Al Magash, and agricultural extension services are run through offices at sub-block level in Majz, Bani Moath, Damage and Al Taweelah. The livestock/veterinary service (administratively independent) and the engineering and maintenance services are based at SSHARDA branch level

3.2 SONDEO SURVEY

SONDEO is a rapid rural appraisal technique which is designed to collect qualitative data from informal, semi-directed discussions between individual or small groups of farmers and an interdisciplinary team of researchers. Informal-random and purpose sampling techniques are used, with topic guidelines rather than questionnaires, to ensure that all necessary subject areas are covered. The survey is covered by NORADEP Report 13 (3 volumes).

3.3 FARM SIZE

The farm size distribution demonstrated by the survey is shown below.

Table 3.1 *Distribution of Farm Holding Size*

Holding Size (ha)	% Total
< 1	22
1 to 2	30
2 to 4	28
4 to 6	15
> 6	5
Total	100

3.4 LAND TENURE AND FARMING SYSTEMS

3.4.1 Land Tenure

With the increase in groundwater irrigation there has been a general movement of people from villages in the foothills to the plain, mostly in the last ten years.

Sharecropping in several different forms takes place both as a means by which landless people can earn a living and of extending the area cultivated by a farmer and/or his extended family. The sharecropping arrangements in the Target Area are different to those in the rest of the northern region. Leasehold is not used in the Target Area as a form of tenure.

A major problem is that of population pressure and diminishing farm size. As a consequence of Islamic inheritance laws the ownership of land tends to be fragmented. Most farms are individually owned holdings of scattered plots, the boundaries of which are well documented.

3.4.2 Farming Systems

Farming systems in the Target Area are moving from the Smallholder Mixed Farming type (subsistence) to the more market orientated Irrigated Smallholder (Beets, 1990). Currently all farms are operated as a mixture of the two systems. Only a very few farmers work the subsistence system, relying solely on rainfall for the cultivation of their lands. Again, less than a quarter of the farmers are completely reliant on groundwater irrigation. More than two thirds use a mixture of the two systems.

3.4.3 Crops Grown

The few farmers depending entirely on rainfall and runoff grow one crop of sorghum inter-cropped with cowpea. The majority, who have access to groundwater, grow rainfed and irrigated summer crops and irrigated winter cereals in addition to perennial cash crops.

3.5 WATER RIGHTS

Water from wells constructed by two or more farmers is distributed in proportion to their individual contributions to the construction cost.

Spate water is allocated on the general principle "The Highest is the First", under which water is allowed to flow to downstream farmers only when the upstream farmers have (within reason) irrigated their fields fully. The allocation is supervised by a *Wakil*, and is usually varied for the second and subsequent spates to take account of the moisture status of the upstream fields and to introduce some equity between upstream and downstream farmers.

Ownership of the yield of runoff harvesting systems is subject to generally accepted traditional rights. Others have no right to surplus flows without the owners permission.

Disputes on water are settled within the traditional setting of tribal customary law. The law is administered by the *Wakil* or a council of village sheiksh who live in the area and belong to the tribes of the litigators.

3.6 HIRED LABOUR

Only during sowing and harvesting is outside labour sometimes used, at YR100 to 200/day plus food. Payment is sometimes made in kind. Many farmers with permanent crops hire labour on a monthly basis at YR 3 000 per month plus food. Women from landless or poor families who live in the area, or who come from other parts of Yemen, also work as labourers, for five hours a day rather than the eight hours of the men, and for a lesser wage. During the peak seasons farmers assist each other in the traditional fashion without payment.

3.7 INPUTS

Fertilisers and agri-chemicals are sometimes in short supply but are generally available from shops in Baqim, Sa'dah and other market places, due to the proximity of the border. One serious problem with imported materials is that they are often beyond their expiry date. This is particularly true of pesticides. Very few farmers use only chemical fertiliser; most combine it with manure from cattle, goats, sheep and poultry. Neither farmers nor traders are aware of the correct method or quantity of application, or of the potential hazards to the environment and health. Chemical fertilisers are frequently applied in excessive quantities.

3.8 MECHANISATION

More than half the farmers own a tractor and equipment, and tractors including driver and fuel, are available for rent at rates of YR 1200 to 1500/ha (ploughing) and YR 800/ha (cultivation). The majority of farmers use tractors for ploughing, levelling and threshing, in combination with animal power and hand labour for other operations. In some cases farmers, individually or as a group, own machinery and equipment and hire tractors to operate it; farmers also rent equipment from each other. However, it must be pointed out that the tractors and equipment used are often not appropriate to local conditions.

3.9 FINANCE AND CREDIT

No problems are reported by the farmers with financing except that CACB procedures are cumbersome, and therefore expensive, not least in terms of time; some are not interested in credit for religious reasons. The traditional sources of finance are relatives, affluent farmers, traders or businessmen. The most common is supplier credit, usually consisting of a down payment and repayment over one or two years. Many farmers who have worked abroad, or who have been involved in cross-border trade, have saved enough to be able to finance their own operation.

3.10 MARKETING

Marketing is a major problem for perishable and non-perishable produce, except for qat where an efficient system of distribution has been in existence for very many years. Storage of potatoes and grain crops is feasible, but there are no storage or processing facilities for the perishable crops and no information on market trends and price movements. Fruit, qat, livestock and surpluses of grain and vegetables are sold in the markets on the trunk road and in Sa'dah. Fruit and qat are also sold through wholesale traders into the Sana'a markets. The area is famous for its grapes and pomegranates, but overproduction has resulted in lower prices, losses and the grubbing of vines and trees, to be replaced with citrus and apple. Most farmers do not know when to harvest, how to grade or how to package and transport fruit in such a way that it will fetch the highest price and be competitive on the export market.

The farmers are concerned at the lack of marketing infrastructure and knowledge in the area; also that the authorities do not appreciate the magnitude of likely future problems. Many farmers have planted fruit trees which will come into full production in a few years time. No market or storage facilities have been developed, nor are any initiatives contemplated by the Government or private enterprise. Some suggest that they should organise themselves into fruit growers associations or co-operatives to get a better grip on the market; to commence the building of storage, packing and transport facilities; and to start, in collaboration with private entrepreneurs, a fruit processing enterprise (jams and juices) to absorb and add value to the anticipated surpluses of production in the Sa'dah basin.

3.11 FARMERS' ASSOCIATIONS

Farmers are very interested in establishing genuine farmers' associations, but do not know how to go about it; they have negative experiences with an existing co-operative. However, in 1991 a wheat growing co-operative was established in Baqim with the aim of encouraging farmers to grow more and better wheat crops, and to increase yields. The CACB provides credit to the co-operative, which distributes the funds to the members. The farmers have elected their own board of directors, which is not dominated by outside interests or particular individuals or interest groups. It also provides fertiliser, improved seeds, pesticides, machinery and equipment. The Government, through MAWR, provides inputs at discounted prices, which benefits the farmers directly.

3.12 PRIVATE ENTERPRISE

Private enterprise plays an essential role in the provision of services and agricultural inputs, but prices are high and credit expensive. No extension services are offered.

3.13 EXTENSION AND VETERINARY SERVICES

Agricultural extension in the target area is administered through four offices under the technical supervision of the block centre. No agricultural or irrigation extension is carried out by the private sector. The farmers noted that the extension services suffer from inadequate staffing and lack of transport; despite this they feel that they get benefit and can rely on advice or agricultural inputs from the Block Centre.

Veterinary services are administered centrally from Sana'a, under technical assistance; activities are limited to collection of statistics on diseases and immunisation campaigns and treatments. Farmers very much appreciate the level of service provided; veterinary assistants and doctors visit regularly and are available on demand.

3.14 LIVESTOCK

Livestock, largely sheep and goats, are a major source of cash within the farming system. Livestock husbandry is becoming more difficult because of the decrease in grazing and higher fodder prices, which particularly affects cattle. Three quarters of the farmers keep cattle for home needs and more than half have oxen for use in cultivation; few have donkeys or camels. The livestock are fed on crop residues and fodder crops, and the goats and sheep browse and graze, to provide meat and milk for the family and some for sale. Sheep and goat meat fetches high prices (up to YR100/kg live weight).

3.15 WOMEN IN AGRICULTURE

Women play a major role in the agricultural activities of the family, but have no access to extension services and are not involved formally in the decision making process on the farm. Besides all the household chores - cooking, cleaning, fetching water and fuelwood - she has to assist in crop and animal husbandry. A few women make an income from goats or poultry, or from a small village shop. Although women are often involved full-time in agriculture and livestock there are no women extension workers and so women are not able to benefit from the extension service.

3.16 THE FAMILY AND EMPLOYMENT

About one third of farmers live in extended family units, containing up to 20 or 40 members, from three generations. Usually the ownership of the land is not divided and the family cultivates as a group with the father as the head and the eldest son as his right hand and successor. One third of farmers live in nuclear families and have only small holdings; another one third live in extended two generation families where the eldest son cultivates the land with his brothers and sisters.

Family size is large - an average of nine children - because of the need for farm labour. Many families still have one member working abroad or elsewhere in Yemen. The head of the household is the oldest male, who is responsible for organisation of the daily operations on the farm; the women have no role in this. Unemployment has been increasing as workers return from abroad, and the price of labour has been reduced as a result. Two thirds of the farmers have only agriculture as their source of income. One third earn extra income through trade or business in local markets, or by providing transport. The great majority of the farmers interviewed wanted their sons to work in agriculture and to take over from them. There is conflict between this view and that of not wishing to do anything about falling groundwater levels.

3.17 LOCAL LEADERSHIP

The sheiks, and the leadership in the villages, do not generally play any part in agricultural development or water management although some run demonstration plots on their farms. These sheiks are often in a position to arrange for the necessary inputs or facilitate farmers' efforts to make contacts or receive advice on the crops grown on the demonstration plots by using their network of relations. Some sheiks in the Target Area are members of the local LCCD. They can play an important role in water management, if they are respected by their constituency.

3.18 LOCAL COUNCIL FOR CO-OPERATIVE DEVELOPMENT

Each district has a LCCD; for every 500 inhabitants a representative is directly elected by the villagers for a five year term of office. Village representatives elect an executive council of 5,7 or 9 members; also a chairman, general secretary and treasurer for a period of 4 years. The responsibilities of the LCCDs encompass rural development services such as roads, health centres, schools, drinking water supply and electricity. The LCCDs no longer play a significant role in agricultural development or water management. The farmers want them to become involved again in solving problems.

3.19 GOVERNMENT INSTITUTIONS

Farmers see government as playing a very limited role in the improvement of agriculture. No major contributions have been experienced by most farmers.

SSHARDA and Water Management
Farmers are not aware of SSHARDA's activities in water management. Neither do they know of the NORADEP Project.

3.20 PUBLIC SERVICES

Farmers are particularly concerned about the shortage of health and drinking water services; also the lack of female education opportunities and the low rate of female literacy - at the same time not recognising the very heavy workload of the women!

3.20.1 Health

Health care facilities are non-existent in the villages. In Sa'dah there are two hospitals and in Dahyan one health centre; another is under construction. Four of the larger villages have private clinics operated by a doctor and some nurses. Farmers complain that these clinics are very expensive. However, Government clinics suffer from staff absence and lack of medicines.

3.20.2 Education

Primary education is not compulsory by law. Nearly all boys go to primary school in Sa'dah; in the villages only about three quarters. Not all villages in the Target Area have primary schools, which are distributed so that they are within half an hour's walk for all children, although some ride donkeys to school. In Sa'dah a significant number of girls go to separate primary schools, but in the villages only a few attend. The level of illiteracy among women of all ages is still very high. Secondary education facilities only exist in Sa'dah. One third of the boys will continue their education here on academic or technical courses and many try to continue to a professional level. The problem is finance; one farmer has opened a small shop in Sa'dah for his sons to operate so that they can earn their living costs and go to school. Farmers would like more secondary schools.

3.20.3 Electricity, Water Supply and Sanitation

Only Sa'dah and the surrounding villages have a public electricity supply.

Piped water is also only available in Sa'dah and the surrounding villages, at a price of YR 20/m^3. All villages have some form of drinking water supply, based on a tubewell and a privately owned generator.

Only Sa'dah has a public sanitation system. About one third of village houses have pour-flush latrines, the remaining two thirds have the traditional hole in the wall with direct outlet to the street or garden. In the foothills and the mountains people go to the fields.

3.20.4 Postal Services, Shops and Trade

With the exception of a post office in Sa'dah there are no formal postal services in the area.

In each village of more than 15 houses there is a retail shop selling foodstuffs, and other daily necessities. Restaurants can only be found in the towns and the larger villages along the trunk road.

Blacksmiths, carpenters, plumbers, electricians, masons, motor mechanics, etc. have workshops in the larger villages throughout the area.

3.21 ECOLOGICAL CONSIDERATIONS

Ecological damage is on the increase; farmers are partly aware of this but do not see the need for preventative or ameliorative measures.

3.21.1 Soil Erosion

Soil erosion is very severe in many parts of the Target Area. Wadi spates have damaged fields and washed topsoil away; in some areas mountain slopes have no vegetation and the uncontrolled runoff damages the fields below. The Sa'dah plain is an open area where there are practically no trees left; high winds blow away much of the topsoil. Terraces have been abandoned as farmers have moved to the plain; the retaining walls are breaking down and topsoil is being washed away.

3.21.2 Wood Cutting

Trees are still the main source of energy and are cut indiscriminately, without any replacement planting. Only a few farmers grow trees, next to their houses as shade

4 CURRENT MANAGEMENT OF WATER USE AND AGRICULTURE

4.1 WATER SOURCES AND ALLOCATION

4.1.1 Background

The data in this section is drawn from the SONDEO and Well Inventory Surveys and has been collated and arranged to form the basis for the discussion of water management problems in Section 5.

4.1.2 General

SONDEO Survey
10 to 15 years ago farmers relied entirely on rainfall, water harvesting and wadi spates (**Sayl**). Table 4.1 shows the situation as determined from the SONDEO interviews with 57 farmers. Half of the farmers now rely on groundwater to supplement rainfall, and there is a clear division between them and the remainder who still use the traditional water resources. There seems at the moment to be little attempt to use these traditional sources conjuctively with groundwater.

Table 4.1 *Sources of Water for Agriculture*

WATER SOURCE	% of Total Area
Rain Only	30
Runoff and Rain	5
Spate and Rain	15
Groundwater and Rain	50
Total	100

Farmers expressed interest in irrigation dams, but few appreciate the advantages or disadvantages, and have not yet discussed the potential effects on traditional water rights.

Well Inventory
The well inventory survey, which by definition covered only those farms where groundwater is used for irrigation, showed that the average area associated with each well is 3.4 ha, but that only 2.4 ha is commanded by groundwater, the remainder being left fallow. The smallest plot is 0.5 ha, while the largest is 50 ha. 74% of farmers have an area less than 4 ha. The smallest irrigated plot is 0.04 ha and the largest 12.5 ha. Most irrigated farms (88%) have a total commanded area less than 4 ha.

4.1.3 Spate (*Sayl*) Management

Water management of the *Sayl* is organised through a centuries-old system. Flood water is allocated to the farmers whose lands border the wadi on the basis of an

Islamic legal principle of watering the higher fields before the lower fields. Only farmers whose plots of land border the wadi, and those who have the traditional water rights benefit from the *sayl*. The water rights are always attached to the ownership of the land; water rights cannot be alienated by sale or through inheritance from the land to which they are attached.

Floods are diverted by means of earth and stone dams constructed in the wadi to divert part of the flow into a main channel, which is then divided into secondary, tertiary and sometimes quarternary branches or distribution channels before the water reaches the cultivated plots. A farmer starts the irrigation of his fields by constructing an earth bund in the branch channel nearest his land to divert the water into his land, from where it is directed to each field in turn. When a field has received sufficient water, the bund between it and the next field is breached to allow the water to flow through.

The irrigation operation by the farmers and the proper allocation of the available flood water is supervised by an elected and authorized representative of the farmers. The role of this representative, the *wakil* is to supervise the distribution of the water allocation, day and night, at the time of the *sayl*. He is responsible for maintaining the rules of distribution and assessing the labour duties for the maintenance of the main and branch channels. He should be neutral person and not a member of the local farmers irrigation association; usually he is appointed from another part of the wadi. Every diversion channel has its own *wakil* and if he loses the trust of the farmers he can be replaced.

The lack of weirs and spate breakers in the area is a problem in that uncontrolled floods cause floods soil erosion, damaging the fields and making maintenance necessary and repair operations after each flood season.

4.1.4 Micro-Catchments (*hudban*)

Only farmers owning plots of land which are situated near the foothills benefit from the run off from the *hudban*. These catchment areas are owned by a family or clan, and the water rights can traditionally only be held by them. Other farmers will own the right to use the trees, and yet others the grazing rights, on the same area of land.

4.1.5 Tubewells

Ownership
One third of the boreholes in the target area are individually owned and two thirds are shared. Up to thirteen farmers may share one well in order to spread the investment costs, but usually only two to four farmers have a share.

Water Sharing
Water sharing will only take place when a farmer has excess water which he cannot use. There are two types of such farmers. In the Target Area four types of water sharing approaches were observed.

- Water is shared only by the joint owners.

- The farmer makes water exchange arrangements with other deepwell owners.
- The water is shared on the basis of water sharecropping arrangements.
- The water is sold to neighbouring farmers or to a truck driver, who will sell to qat and fruit growers, or for drinking water.

One advantage to the sharing of wells is that the process allows farmers, who individually could not afford a borehole, to have access to groundwater-perhaps not enough to irrigate all their land, but sufficient to enable them to grow more crops than they otherwise could.

The main disadvantage observed is that the water allocation rotation (once every eight days for a well owned equally by eight farmers for example) tends to be rigidly applied, without regard to the needs of the crop. In such circumstances irrigation scheduling is far from efficient, water is waste and crop yields reduced.

Water sharing without payment is rare and happens only when a pump breaks down within the family or with good friends, based on mutual understanding and trust that the favour will be returned.

4.2 IRRIGATION

4.2.1 Water Conveyance

Lined channels are rarely used in the Target Areas; the most common methods used to convey water from the well to the field edge are: PVC pipes, hand dug earthen channels, galvanized steel pipes, and Lay-flat plastic tubing for distribution from the steel pipe mains to the farm plots.

More than half of the farmers interviewed had installed piped distribution systems at a cost of about YR 200/m, including transporation and installation, which was mostly done by the farmers themselves. Due to the irregular shape and small size of the plots the piping system for one well can total 4 km in length.

4.2.2 Water Application

Table 4.2, which is based on SONDEO data, gives general information on irrigation methods and water application intervals. During crop establishment the intervals shown would be shortened. However, if they are truly representative, these intervals are for all crops except qat far too long. The soil would not be able to store sufficient water from one irrigation to avoid severe moisture stress. For example in July, vegetables should be irrigated every one to two days, and grapes about once in ten days.

Table 4.2 *General Irrigation Details*

PERENNIAL CROPS	IRRIGATION		ANNUAL CROPS	IRRIGATION	
	Method	Interval (days)		Method	Interval (days)
Grape	Furrow	15	Sorghum	Basin	10
Pomegranate	Furrow	15	Wheat	Basin	15
Orange	Furrow	15	Barley	Basin	10
Other fruit	Furrow	15	Pulses	Basin	15
Alfalfa	Basin	15	Potato	Furrow	10
Qat	Furrow	10	Tomato	Furrow	10

4.3 CROPPING

4.3.1 Cropping Pattern

Fig. 4.1 shows the range of crops grown in the Target Area, in the form of a cropping calendar assembled from data gathered during the SONDEO and well inventory surveys. Some other crops are cultivated, but on a very small scale. From the SONDEO interviews the percentages of total land area under different crops were estimated (Table 4.3).

Fig 4.1 *General Cropping Calender*

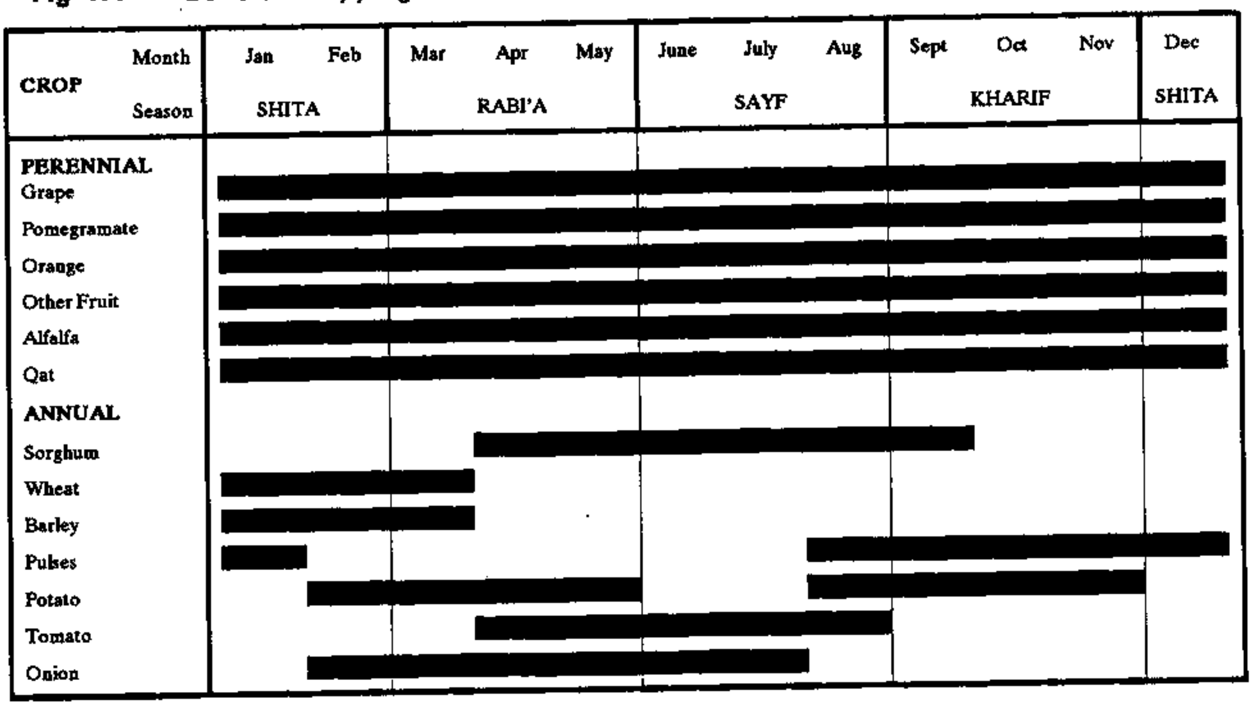


Table 4.3 *Cropped Areas*

PERENNIAL CROPS	% of Total Area	ANNUAL CROPS	% of Total Area
Grape	6	Sorghum	19
Pomegranate	4	Wheat	12
Orange	7	Barley	7
Other fruit	8	Pulses and	
Alfalfa	4	Vegetables	4
Qat	4	Sum	42
Sum	33	Fallow Land	25

Cropping is concentrated heavily on the staple grains and cash crops - fruits and qat. The only exception to this is alfalfa, which is grown for stockfeed. The percentage of groundwater irrigated farms on which each crop is grown is shown in Table 4.4.

Vegetables, in particular onion, tomato and potato are grown on up to 10% of the farms, but there are virtually no pulses cultivated. Over half the farmers used 10% or less of their land for qat, but about a third had between 10% and 30% of their holding under the crop.

Table 4.4 *Crop Distribution*

CROP	% of FARMS
Sorghum	94%
Wheat	92%
Pomegranate	68%
Barley	67%
Alfalfa	62%
Grape	59%
Qat	44%
Peach	31%
Apple	29%
Fig	11%
Apricot	10%

4.3.2 Use of Inputs

About a fifth of the farmers did not use any form of fertiliser; another tenth used only manure; but the remaining used either a combination of manure and chemical fertiliser, or chemical fertiliser only. Fertiliser application rates were relatively high, frequently higher than recommended.

Half the farmers used pesticides, and about one fifth used improved wheat and vegetable seeds.

4.3.3 Mechanisation and Cultivation

Less than a tenth of farmers rely completely on animal power; a further fifth use only machinery. The others use a combination of animal draft and machinery, increasingly small-scale equipment better suited to the plot sizes, some of which is manufactured/adapted in Sa'dah town.

Some farmers are attempting to conserve water by applying the appropriate (simple) techniques to grape cultivation, and by using minimum tillage methods in their cereal cultivations.

4.3.4 Crop Yields

From the SONDEO findings annual budgets for typical small, medium and large farming families were prepared. These are given in full in Annex 1 and discussed in more detail in Section 6. They should not be taken as definitive, but are nonetheless an extremely valuable guide to the financial status of farmers in the Target Area.

The typical crop yields shown in Table 4.5 are drawn from these budgets. In some instances the yield levels appear to be a little higher than is in fact probable, but there is a universal tendency among farmers to exaggerate their production. Even so, in all cases, the yields reported are lower than potential.

Table 4.5 *Typical Crop Yields*

CROP	YIELD t/ha
IRRIGATED	
Grape	12.0
Citrus	25.0
Qat	2.0
Alfalfa	40.0
Wheat	3.5
Barley	3.0
Sorghum	4.0
Tomato	24.0
SPATE/RAINFED	
Sorghum	2.0

4.4 CROP WATER USE

4.4.1 Crop Water Requirements

Neither the SONDEO survey nor the Well Inventory were designed to provide information from which crop water requirements could be calculated precisely. The necessary climatic and agricultural research data is not available in the necessary detail, in any case. However, using calculations carried out by Chaudry *et al* with the FAO CROP WAT Program (TS-HWC, 1992) an estimate of the overall monthly and daily crop evapotranspiration was been prepared, based on the range of crops grown in the Sa'dah Plain. This is shown in Table 4.6. Average ETc per day ranges from about 2.4 mm in March to over 6.0 mm in June and July, with an annual average of 4.0 mm/day.

4.4.2 Area Irrigated by Groundwater

As a result of the Well Inventory survey it was estimated that three are some 2330 wells in the TA, with which 7881 ha of land are associated - 5573 ha commanded by irrigation and 2308 ha fallow for lack of sufficient water. It should be noted that this fallow area (44% of the commanded area) is for groundwater irrigated farms only and cannot be compared with the 25% fallow land estimated for all farms (Table 4.3). The land area would be divided into more than 2330 individual holdings, since wells are often owned in partnership by more than one farmer.

From the evidence gathered during the SONDEO survey, backed up by the experience of agricultural extension staff, it is clear that:

- Not all of the area commanded by groundwater is irrigated at any one time, because not enough water is pumped to meet crop water requirements.

- Farmers' irrigation scheduling is not optimum.

- Water conveynance and application is not efficient: there is seepage from unlined conveyance canals (about 50% of the water is conveyed in pipes from pump to field-edge); land levelling is poor; the layout of basins, borders and furrows is not always ideal; and farmers tend to apply more water than the crop actually requires, leading to excessive deep percolation.

All the matters discussed above have been taken into account in the compilation of Table 4.7, in which the volume of water abstracted in 1991 is balanced with domestic and irrigation usage, and the return flow to the aquifer through deep percolation. On the conservative assumption that sufficient water is applied to cover the full annual crop ETc, the maximum area of commanded land that could have been irrigated was 2606 ha, ie. less than 50 percent. The main reason for this is the low overall irrigation efficiency (about 41 percent), a result of the water conveyance and application problems summarised above.

It should be noted that surface runoff from irrigated areas due to inefficient water application is not specifically accounted for. In comparison with seepage losses, runoff is likely to be insignificant at the level of accuracy of the estimates presented in the table.

Table 4.6 *General Crop Water Requirement*

CROP	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	ANNUAL
	SHITA		RABI'A			SAYF			KHARIF			SHITA	
Grape	26	29	32	39	83	140	160	140	160	136	90	58	1093
Other Fruits	69	34	48	51	79	144	160	159	182	159	122	90	1297
Alfalfa	76	127	128	138	179	209	190	160	182	159	137	107	1792
Qat	40	59	64	69	89	105	95	80	91	80	63	54	889
Sorghum				42	145	294	249	84					814
Wheat	138	152	53								44	133	520
Barley	138	151	73								47	130	539
Vegetables	68	90	112	157	180	180	225	225	225	180	90	68	1800
SUM	555	642	510	496	755	1072	1079	848	840	714	593	640	
Average ETc per Month (mm)	79	92	73	83	126	179	180	141	168	143	85	91	1439
Average ETc per Crop–Day (mm)	2.6	3.1	2.4	2.8	4.2	6.0	6.0	4.7	5.6	4.8	2.8	3.0	4.0

Table 4.7 *Groundwater Use in 1992*

Total Groundwater Abstracted (Mcm)	80.3
Domestic Water Use (Mcm)	2.8
Irrigation Water Use (Mcm)	77.5
Commanded Area (ha) (1)	5573
Average Area Irrigated (ha) (2)	2460
Gross Irrigation Application (mm)	3150
Total Efficiency (%) (2)	41.3
Irrigation Water Losses (mm)	1851
Aquifer Recharge (Mcm)	45.5
Net Irrigation Application (mm)	1300
Effective Rain (mm) (3)	138
Effective Spate (mm)	22
Total Effective Water (mm)	1460
Annual Crop ET (ETc - mm)	1460

Note:
1) Table 5.1
2) Adjusted to achieve balance between ETc and Total Effective Water
3) Conveyance Efficiency 75 % (>50% piped)
Application Efficiency 55 % (Poor levelling)
Total Efficiency 41.3%
4) Based on data from Al Muthef, Gudami, Sa'dah, Dumeid (USBR Method)

4.5 LIVESTOCK

Sheep and goats are the major livestock, followed by cattle (Table 4.8). The average flock size of sheep/goats ranges from 10 to 24 head per farm; the average farm household keeps about three cattle (cows and oxen). Very few farmers keep camels and donkeys. Some farmers own beehives.

Livestock management is traditional and at subsistence level. Cereal stalks and residues in addition to a green ration of alfalfa and barley are the main fodder sources. Sheep and goats are fed on crop residues or left to graze the grass and shrubs of the adjacent rangelands. Cattle are kept in a compound on crop stalks, barley and alfalfa. Signs of phosphorous deficiency in cattle were reported by many farmers, variously attributed by AREA and others to phosphorous-deficient fodder because of calcareous soils, and to inhibition of phosphorous absorption by cattle fed on green barley fodder.

Table 4.8 *General Details of Livestock*

Animal	No. of Farmers Interviewed	%	Heads/Farm
Sheep	13	24	14
Goats	2	4	10
Sheep & Goats	35	65	24
Cattle	33	61	3
Donkeys	5	9	1
Camels	1	2	1

5 PROBLEMS, SOLUTIONS, ACTIONS AND CONSTRAINTS

5.1 THE PROBLEMS

The major water management problems presented and discussed below can be identified from the quantitative and qualitative data summarised in Sections 2, 3 and 4. All must be addressed by the Water Management Plan. The problems, with their general effects on the management of water, are summarised in Tables 5.1, 5.2 and 5.3, which also contain summaries of the solutions proposed and the actions needed to achieve the solutions.

5.1.1 Problems Directly Related to Water

Excessive Abstraction of Groundwater
Over 95% of the water pumped is used for irrigation, the remainder for domestic and livestock purposes; there is negligible commercial or industrial use. Current groundwater abstraction is estimated to be more than four time the recharge, and the mean groundwater has declined by about 40 m between 1983 and 1992 (Section 2.3.7). In 1991 it fell by some 5.6 m. If abstraction were to continue at this rate about 50% of the boreholes would be dry before the year 2015, when the average water table would be about 190 m below ground level.

The immediate effects are felt in the form of increased production costs, initially as higher pumping costs coupled with reduced discharge, and eventually as the expense involved in purchasing more powerful pumping equipment and/or deepening/replacing the borehole; provision of domestic water also becomes more expensive. Without positive action to reduce abstraction substantially living standards generally will decrease, with the poorer sections of the community being particularly affected. Eventually the aquifer will be unusable, except for (very expensive) domestic water supply.

Increasing Water Supply
In 1992 the average EC of the groundwater was 953 microS/cm, a level at which some restriction on its use for irrigation has to be taken into account. Significant areas show EC values of 1000 to 1500 microS/cm and more. Nine years ago most of the area had EC levels below 750 microS/cm. The data available does not allow definition of the cause of this increasing salinity, but it is clearly associated with the decline in water level.

There must already be some reduction in crop yields as a result of the increased salinity, and in places these will have become quite significant. Soils will eventually become salinised, leading to further yield reductions. Fortunately the current inefficiencies in water conveyance and application are likely thus far to have minimised any salinisation, by allowing sufficient water to be applied to leach out the salts. However, as irrigation is improved allowances for the application of additional water (of the order of 15% for water of EC 1500 microS/cm to maintain the yield of grape) will have to be made, so reducing the cost savings from the improved irrigation and requiring a still higher level of management. In the long term salts leached from the soil profile into the aquifer will further increase groundwater salinity levels.

Inefficient Water Conveyance and Application
The overall efficiency of irrigation including scheduling (see below) was estimated at about 41%, ie. 59% of the water pumped does not contribute to plant growth (except as described above by leaching out salts from the soils). The fact that most of this water will percolate back to the aquifer is not relevant in the context of farmers' finances: the effective overall average cost of water because of these inefficiencies is increased from YR 4.6 to YR 11.2/m^3.

Inefficient Irrigation Scheduling
Because the inefficient scheduling of irrigation contributes to overall irrigation inefficiency it also has adverse effects on the cost of production, not only in the form of increased pumping costs but in the wastage of inputs, particularly fertiliser which may not reach the plant roots at the right time. The excessive application of water also contributes to this waste by washing fertilisers through the soil profile before they can be effective.

A major cause of poor scheduling is the rigid application of the rules covering the distribution of water from shared wells under which each shareholder takes water on a given day regardless of whether his crops need water at that time or whether another shareholder's crops are suffering from moisture stress.

Inefficient Use of Spate
Traditional techniques of spate management, though relatively efficient from the water use point of view, can be improved upon by the introduction of modern materials and construction methods (such as gabion boxes for small weirs and deflectors) in order to save labour and decrease the risk of structural damage which would lead to the "loss" of water down the wadi.

At the moment there is little conjunctive use of spate and groundwater for irrigation, and as a result water use efficiency is reduced. In most cases spate water would be more effective (and equitably) employed by spreading it over a larger area than is traditional and then using groundwater as required to meet subsequent crop water requirement. Such an approach is no more than an extension of the improvement of scheduling and application discussed above for groundwater application.

Multipurpose dams can also have a bearing on the efficient use of spate flows, again if appropriate in conjunction with groundwater, by allowing the water to be used in a fully controlled way. However, the cost of the dam, the loss of water to evaporation and any negative effects on farmers downstream with water rights have to be very carefully considered.

Aquifer Pollution
There is currently no reason to think that the aquifer is polluted or indeed is in immediate danger of pollution, except in so far as increasing salinity could be regarded as a form of pollution. However, two potential causes of pollution are sufficiently important to be discussed here.

Table 5.1 *Problems Directly Related to Water*

PROBLEMS & EFFECTS	SOLUTIONS	ACTIONS
Excessive Extraction	Control Drilling & Abstraction	Define & Monitor the Problem
Increased Agricultural Costs	Appropriate Licenses & Taxes	Maintain & Improve Well Inventory
Pumping	Improve On–Farm–Water–Management	Early Display & Use of Results for Staff Training & Extension
Well Deepening & New Equipment	More Shared Wells	Collect, Process, Publish & Early Display of Meteo Data
Domestic Water Supply Problems	Increase Returns to Water	Introduce & Enforce Legislation
Decreasing Standard of Living	Reduce Area Groundwater Irrigated Cereals	Research & Extension/Monitor & Evaluate Results
Eventual (Economic) Aquifer Depletion	Diversification of Farm Activities	Train Staff
Increasing Water Salinity	Control Drilling & Abstraction	Define & Monitor the Problem
Yield Reductions & Soil Damage	Improve On–Farm–Water–Management	Analyse Implications/Define Strategy
Increased Water Use & Cost	Introduce Tolerant Varieties	Research & Extension/Monitor & Evaluate Results
Higher Level Management Required		Train Staff
Inefficient Water Conveyance & Application	Maximise Piped Conveyance	Define Irrigation Strategy & Implement
Higher Production Costs	Improve On–Farm–Water–Management	Research & Extension/Monitor & Evaluate Results
Wasted Water	Introduce Modern Irrigation Methods	Distribute, Sell, Install Pipes & Hoses
		Promote Modern Irrigation Methods
		Train Staff
Inefficient Irrigation Scheduling	Improve Farmers' Knowledge	Define Irrigation Requirements & Refine by Research
Increased Costs of Water & Labour		Research & Extension/Monitor & Evaluate Results
Wasted Inputs		Optimise Use of Shared Wells
		Train Staff
Inefficient Use of Spate	Improve Spate Management	Define Problem & Strategy
Sub–Optimal Production	Construction/Upgrading of Diversion Structures	Use Improved Seeds/More Inputs
Greater Use of Groundwater	Enhance Returns to Water	Rationalise Water Application
	Conjunctive Use of Groundwater	Train Staff
Aquifer Pollution (Potential?)	None Yet Required	Monitor

The first is the leaching of agri-chemicals (fertilisers, herbicides and pesticides) from the soil into the groundwater. There is evidence of the use of fertilisers at rates above those recommended which, combined with excessive applications of irrigation water, would eventually lead to accumulation of certain compounds in the groundwater. The same would apply to non-organic herbicides and pesticides, though these are probably not used in excessive quantities.

The second is the possible effects of seepage from the septic tanks and soakaways used for the disposal of domestic waste water and sewage. In this case most of the potential pollutants are organic, as are some agri-chemicals, and therefore subject to natural processes of degradation and attenuation in the alluvium above the aquifer and in the unsaturated section of the aquifer itself. The total depth of this unsaturated zone is between 60 and 80 metres over most of the Plain. Thus, except for the area around Sa'dah Town where there is a high concentration of population, there is generally little risk of pollution.

5.1.2 Problems Affecting Water Use Efficiency

Water use efficiency in this context is directed at obtaining the maximum return per unit volume of water abstracted and used and so includes much more than efficient irrigation conveyance and application. Any matter that has an effect on the efficiency of water use must be taken account of in the planning process. Those upon which SSHARDA can have influence, or where they have direct responsibilities, are reviewed in this section.

Coverage of Extension Services

Without comprehensive and efficient extension services there cannot be efficient use of water. Extension advice, based on sound applied research, is essential for every aspect of agricultural production: land preparation; selection of crop varieties and planting time; crop water requirements; irrigation scheduling, water conveyance and application; irrigation methods; crop and livestock husbandry; and harvesting, storage and packaging.

Though better than in most other Target Areas, provision of extension services is far from adequate and almost entirely absent in the case of women, who make major contributions throughout the agricultural economy.

Access to Credit

Without easy access to reasonably priced finance it is not realistic to expect farmers to improve water use efficiency. However, compared with some of the other Target Areas, farmers in the Sa'dah Plain seem to be reasonably satisfied with the availability of credit. Nevertheless, CACB procedures are cumbersome, slow (and thus expensive), and CACB credit is not available to the smaller farmers. This has two effects: those farmers most in need of finance to improve their farming and increase the standard of living of their families are disadvantaged; and existing inequities are exacerbated.

Table 5.2 *Problems Affecting Water Use Efficiency*

PROBLEMS & EFFECTS	SOLUTIONS	ACTIONS
Coverage of Extension Services Lack of Advice Inefficient Operations Little Impact on Women	Widen Scope & Improve Provide Research Data & Appropriate Messages Provide Multi-Media Support	Provide Adequate Resources Research to Improve Backup Particular Emphasis on Women Monitor Results/Adjust Approach Train Staff
Access to Credit Disincentive to Invest Reduced Efficiency	Widen Eligibility for Credit Simplify Procedures & Reduce Costs Credit Only to Improve Water Use Efficiency	Modify Legislation (If Necessary) Improve CACB Management Train Staff
Input Availability & Use Unbalanced, Not Optimum Reduced Yield	Improve Supply Position Research & Extension	Define Needs – Type & Quantity Involve Private Sector & Farmers' Associations Train Staff
Cropping Balance Cereals give Low Return to Water (Overproduction of High Value Crops would Reduce Prices)	Improve Returns to Water Rationalsie Cropping Patterns & Timing Introduce Modern Techniques	On-Farm-Water-Management (Table 5.1) Marketing (Table 5.3) Research & Extension/Monitor & Evaluate Results Train Staff
Land Tenure (Sharecropping) Discourages Investment & Care of Land	Establish Equitable Tenancy Agreements	Legislation & Enforcement Local Leadership
Land Fragmentation Inefficient Water Distribution & Use (Other Inefficiencies Also)	Encourage Rational Land Use	Local Leadership & Extension Messages

Input Availability and Use
The availability of the right inputs at the right time in the required quantities is essential. The provision of advice on the optimum use of all inputs one of SSHARDA's responsibilities, through extension. There are currently major shortfalls in the supply of inputs and advice as to their best use.

Cropping Balance
Farmers using groundwater to produce cereal crops are already incurring a massive financial loss (see Section 6.5). There may well be arguments (in the national interest) for encouraging the farmer to subsidise the consumer; also (because he and his family prefer the taste) for the farmer to invest in producing his own food staples. However, from a financial point of view it makes no sense to grow cereals when much better returns to water can be obtained from higher value crops, though often still at an overall financial loss. From the national point of view, in the context of the extremely severe shortage of water and depletion of water resources, there is an imperative need to promote major developments in both cropping and downstream value-adding activities.

The opportunity should be taken to make use of traditional crop varieties and husbandry techniques in research and extension programmes to maximise rain/runoff-fed yields.

Land Tenure (Sharecropping) and Land Fragmentation
Current sharecropping arrangements, though subject to a long tradition, do not encourage the tenant to invest in improving agricultural efficiency. The fragmentation of land, brought about mainly by the inheritance laws, results in inefficient water distribution and use; and in the poor use of resources generally.

5.1.3 Problems Affecting Agricultural Productivity

Although the problems discussed below do not have any direct connection with water resources or water use they do have a profound affect on productivity and therefore on the returns to water. As such they must be covered by the planning process.

Appropriate Mechanisation
There are individual plots in the Sa'dah Plain Target Area which are large enough to make the use of small standard four-wheel tractors for land preparation, etc. reasonably efficient, but only on the basis of shared ownership or hire. However, in general miniature four-wheeled tractors or single-axle machines would be more appropriate. Indeed Sa'dah is the only Target Area where some machines of this type are to be found, together with small static threshing machines which are vastly more efficient than the traditional hand or animal methods, and the use of motor vehicles with or without special attachments on their wheels.

Much scope remains for the introduction of suitable machinery and appropriate equipment, eg. tined cultivators rather than disc harrows, which are entirely unsuitable to the Sa'dah Plain soils and cause enormous damage leading to further productivity reductions.

Table 5.3 *Problems Affecting Agricultural Productivity*

PROBLEMS & EFFECTS	SOLUTIONS	ACTIONS
LACK OF:		
Appropriate Mechanisation Wasted Resources Reduced Yields	Introduce Properly Sized Machinery & Appropriate Implements	Research & Extension Liase with Private Sector/Local Manufacturers Encourage Shared Use Train Staff
Marketing Wasted Production Resources Reduced Income Wasted Export Opportunities	Gather Market Information Export Research – Crop & Trade Train Farmers & Involve Private Sector	Determine Requirements/Monitor & Evaluate Results Research & Monitor Markets Inform Farmers through Associations Diversification into High Value Non–Perishable Crops Establishment of Processing Facilities (Private Sector) Train Staff
Farmers' Associations (Production & Purchasing) Lower Producer Prices Higher Expenditure Potential Markets Not Exploited	Establish Appropriate Institutions	Determine Reqirements Local Leader/Farmer Liaison Guide Implementation/Monitor & Evaluate Results Train Staff
Watershed Management Loss of Agricultural Resources Potential Income Generating Activities Not Exploited	Repair & Maintain Terraces Establish Fuelwood Enterprises Encourage Advances in Livestock Management	Research & Extension into Fuelwood & Pasture Demonstrate Cash Benefits of Fuelwood & more Intensive Livestock Train Staff
Involved Local Leadership Sub–Optimal Community Involvement	Establish Means of Regular Interaction	Senior Level SSHARDA Involvement Define Strategy/Monitor & Evaluate Results

Marketing
Only for qat, the most valuable of the crops grown, does a full marketing system exist, ie. one that covers the whole process from correct selection, harvesting and packing of the crop through wholesale and transport, to the delivery of the product fresh and undamaged to retail outlets. Gross margins on qat are high; they would be much reduced if it were treated in the same way through the marketing cycle as are the other perishable crops. Fruits and vegetables are wasted, as are the resources used to produce them, incomes are reduced and potential export opportunities are foregone.

Farmers' Associations (Production and Purchasing)
Production and marketing decisions are hindered by lack of a marketing infrastructure; production itself is made more difficult by irregular supplies and shortages of vital inputs. There are no Farmers' Associations set up in such a way (involving the private sector) as to overcome these, and other problems.

Watershed Management
With the growth in groundwater irrigated agriculture traditional land management has been neglected; the population has doubled in the last 20 years and so the demand for firewood and range for livestock has also increased. The result is increasingly severe watershed degradation and loss of the natural resource base. 90% of the domestic energy used in Yemen is obtained from wood, the supply of which is being rapidly exhausted.

Properly structured watershed management, in addition to conserving soil and surface water resources for present and future use, has the potential to provide opportunities for income generation which would help to take the unsustainable pressure off groundwater.

Involved Local Leadership
Farmers feel that their local leadership is not sufficiently involved or committed to development. It may be that the farmers hope that more involvement by the leadership would mean less work for them. This would not be the case, but it is beyond dispute that successful development in all sectors requires balanced contributions from all members of the community.

5.2 SOLUTIONS

5.2.1 Recommended Solutions

The recommended solutions to the problems set out above are clearly shown in Tables 5.1, 5.2 and 5.3. Solutions to several of the problems overlap or are complementary. As a result it is possible to summarise the solutions as follows:

- Involvement of local and community leaders: success in this will make other solutions much easier to achieve.

- Control and reduction of abstraction, the feasibility of which will depend on the level of farmers' knowledge.

- Improvement and expansion of the extension and research services in order to help farmers increase their knowledge.
- Improvement of farmers knowledge of on-farm and spate water management, crop husbandry, appropriate mechanisation, marketing, and the diversification opportunities provided by investment in watershed management.
- Introduction of appropriate modern irrigation methods and equipment.
- Reduction (to zero, as soon as possible) of the area of low value (cereal) crops under groundwater irrigation.
- Simplification and increase access to credit.
- Establishment of equitable and rational land tenure/ownership.
- Formation of appropriate farmers associations for production and purchasing.
- Involvement of private sector where appropriate.

5.2.2 Other Solutions Considered

Before it was decided which solutions should be recommended other possibilities were considered for certain problems. These are described below.

Irrigation Water Supply
Transfer of groundwater from adjacent catchments was dismissed at an early stage in view of the already excessive cost of supply from the Sa'dah Plain aquifer (Section 6.5). The only possibly viable transfer would be of surface water, but a suitable source is not available. With the general shortage of water resources in Yemen proposals to transfer water, especially for irrigation, would in any case meet with very powerful resistance.

Another superficially attractive option is the reuse of waste water. However, since over 95% of groundwater is used for irrigation and there is no waterborne sewerage system, except a small one for Sa'dah, in the Target Area to provide a source of wastewater, this was also excluded from further consideration.

The last option considered was the pumping groundwater from beneath areas of non-agricultural land for transfer to irrigated land. This would be expensive and might also give rise to disputes over water rights. In the Sa'dah Plain the density of boreholes is relatively very high, but there are locations where such an approach could be technically feasible. However, the potential cost and the lack of detailed data on aquifer properties disqualifies this option from immediate consideration, though it would be worth reviewing at a future date.

Increasing Water Salinity
In areas with water of very high salinity it may eventually become financially as well as technically feasible to mix water pumped from boreholes in less affected areas, eg.

the non-agricultural areas considered above as sources for additional irrigation water; for the immediate future, however, it must be ruled out for the same reasons.

Provision of Extension
In certain circumstances it could be advantageous to provide extension advice through contracts with private sector organisations. However, in Yemen there are not enough skilled and experienced personnel currently available to staff government institutions with responsibility for providing extension services, and so the option was not considered further. Nonetheless, once SSHARDA have established a sufficiently positive record in extension and research activities to justify the charging of fees for the provision of advice to farmers, this option may well be worth analysing in more detail as a means of financing enhanced services.

5.3 THE ACTIONS NECESSARY

The actions necessary to reach the recommended solutions fall into some seven general categories, for all of which adequate resources must be provided (Tables 5.1, 5.2 and 5.3).

- Involvement of local leadership, community groups and the private sector; and encouragement of Farmers' Association to promote efficiencies of scale.
- Staff training: extension, research and credit.
- Introduction and enforcement of legislation to control groundwater abstraction, watershed management, and rationalise sharecropping.
- Collection, analysis and publication of data.
- Expansion of the applied research and extension programmes, and monitoring and evaluation of the results to ensure the work develops in line with farmers' needs, including suitable diversification of farming activities.
- Introduction of modern irrigation systems.
- Simplification and the widening of access to credit.

Detailed Action Lists for use in the planning of implementation are included as Annex 2.

These cover data collection and publication, extension, and applied/adaptive research, assistance to farmers in procurement of modern irrigation systems through CACB and will be referred to as appropriate in the discussions that follow.

5.3.1 Involvement of Local Leadership and Communities

Close liaison between SSHARDA and local leadership, perhaps via the LCCDs, and farming communities is fundamental to the success of all activities within the Water Management Plan short, medium and long term.

It cannot be emphasised too strongly that the only hope for success for the plan is to ensure from the very beginning that all actions are farmer-centred, for if the detailed plans are not accepted by farmers they will not work. Farmer-centred does not mean that farmers' requirements should be met without question, but that they must be actively involved from the outset in the planning process, so that they will accept the final decisions.

The setting up of the institutional framework to involve the farmers and their community leaders will be extremely time-consuming, but without it the technical components of the plan cannot succeed.

Farmers on the Sa'dah Plain seem keen to adopt improvement in agriculture and water management. One of the first priorities is to establish links with communities at a very early stage so that their needs can be built into the initial detailed implementation plans.

5.3.2 Staff Training

It must be emphasised that an essential prerequisite to all of the actions discussed below is an extensive and comprehensive programme of staff training. Staff at all levels will require training, in the form of courses locally run, regionally based or overseas, and on job under the supervision of a suitably qualified and experienced manager. Training is not a one-off exercise; regular updating and upgrading is essential and as time goes on more of the training can take place in-house.

It is recognised that a training programme has been an integral part of the NORADEP Project since it began. However, as is pointed out above, training needs and provision should be kept under constant review in order to that changes made necessary by the way in which the project develops can be introduced. The detailed multi-sectoral planning process that will be required as the first activity in the implementation of the Water Management Plan provides an ideal opportunity to review, and if found necessary, to re-direct the current training programme and extend it in line with the needs of the plan.

Training should cover at least the following subjects:

- For Senior and Middle Management
  - General management
  - Project management
  - Programme administration
  - Water resources
  - Research/extension management
  - Monitoring and evaluation

- At Supervisory Level
  - Programme execution/administration
  - Water resources management
  - Practical research/extension
  - Credit provision
  - Rainfed agriculture

- Irrigation agronomy/engineering
- Women's development
- Appropriate mechanisation
- Animal husbandry
- Horticulture

■ For Field Staff (Extension Agents and Subject Matter Specialists)
  - General crop cultivation (Irrigated and rainfed).
  - Extension and dissemination techniques.
  - Women's development.
  - Credit provision to small farmers.

5.3.3 Legislation

Groundwater
Detailed legislation to control the drilling of wells and abstraction of groundwater is currently under discussion by a government committee with the brief to combine draft laws prepared by MAWR and MOMR. Meanwhile a government decree giving interim powers to the MAWR or authorities delegated by the Ministry, with the force of a by-law, is in effect. The decree covers the three parties likely to be involved with the drilling of a borehole:

■ The Well Owner, who cannot contract for the drilling of a well until he has the approval of MAWR or its agent. This approval depends on a thorough analysis of the hydrogeology, proposed well depth, pump type and other specifications, and the location of the proposed well in relation to existing boreholes. One of the conditions for obtaining the licence is that the owner should undertake that the borehole will not be used to irrigate qat.

■ The Drilling Contractor, who must be licensed as competent and whose equipment is subject to inspection and approval. He cannot commence drilling until the owner has obtained permission for the well.

■ The Pump Supplier, who must not sell any equipment to the owner that does not meet the specifications set by MAWR or its agent. Equipment cannot be supplied until the owner has a licence for the well.

In the NORADEP region SSHARDA is to implement the decree, in combination with the relevant extension activities.

Thus the necessary powers to control groundwater abstraction already exist, and are in the process of being expanded and reinforced. However, the powers are not currently being used.

Watershed Management
The natural resources of the watershed - soil, trees, vegetation - are just as vital to the long term interests of Yemen as are water resources; indeed, they are linked with water resources. Because of changes in traditional landuse, which have taken place for perfectly valid reasons, there has been land degradation, increasingly rapid runoff and more destructive wadi spates, which erode valuable arable land. Excessive

cutting of fuelwood contributes to the process, as do overgrazing and neglect of terraces.

It is not realistic to think that this process can be reversed without a combination of legislation and incentives, together with research and extension work to demonstrate that viable income generating activities are feasible in the watershed areas to provide farmers with an opportunity to diversify their activities profitably. Examples of such diversifications are discussed in Sections 6.4.

Land Tenure

Existing sharecropping arrangements, though sanctioned and supported by tradition, and capable of pragmative modification as has successfully been demonstrated within the NORADEP region during the recent years of low rainfall, are not conducive to the improvement of water use efficiency or longterm sustainability of land resources.

Sharécropping is much less wide spread in the Sa'dah Plain than in other Target Areas. However, the principle remains that a tenant with an unwritten agreement for a year at a time for the use of a plot of land, and who will receive between 25% and 50% of the proceeds from the crops he grows, has no incentives to take care of the land, invest in it and to seek to maximise the efficiency of production.

It is not in the interests of the landlord or the tenant, still less of the economy as a whole, that this situation should continue. Legislation to ensure equitable and sustainable use of sharecropped land is essential.

5.3.4 Data Collection and Publication

Groundwater

Extensive well inventory data was collected as part of the technical assistance studies and is presented in the Groundwater Resources Report (NORADEP Report 8). The most important data in the context of this plan are those concerning:

- Groundwater level, its geographic variation and changes over time.
- Well yields and their variation over time and space.
- Water salinity and its variation.
- The water balance.

These are the major parameters required to monitor the abstraction control component of the plan, and should be the focus of the groundwater monitoring activities detailed in Annex. They are all fully illustrated in the form of contour maps, cross-sections, (which are particularly revealing) frequency distributions and tables in the Groundwater Resources Report, and some are reproduced in Section 2.3 of this report. The maps and cross sections are by far the most appropriate way of displaying the information for the purposes of training staff and conveying extension messages to farmers. They are cheap and quick to produce and update and have maximum impact in the eyes of the non-specialist.

The well inventory provides a very sound basis for future work, but it also illustrated just how complex is the aquifer system of the Sa'dah Plain. It will be a very long time before there is enough information for a meaningful model of the aquifers to be made. Meanwhile work must concentrate on regular updating of data on the leading parameters listed above, and **most importantly on the rapid processing, publishing and dissemination of the data.**

A major additional advantage of regular monitoring is the contacts between SSHARDA staff and farmers.

Hydro-Meteorological Information

As part of the technical assistance studies the need for hydro-meteo data collection, for the enhancement of the national database, was examined; a specification for suitable equipment for data collection and processing was prepared. At the time of writing this report the equipment was yet to be procured.

Though the collection and automatic electronic logging of such data is vital for national planning purposes, the time that necessarily elapses between gathering the data and publishing it reduces its use in the field.

Therefore, raingauges and Class A Evaporation Pans must be installed at all research and demonstration facilities, at each SSHARDA Branch and Block Office, and on the farms of reliable farmers, to give a reasonably uniform coverage of the area. The data can be displayed simply in graphical form and used in crop research, for the training of staff and farmers, and the development of extension messages.

5.3.5 Applied Research and Extension

Applied research and extension cannot practically be separated since they are part of a continuous cycle: extension identifies a problem, to which research is applied, and the solution is used as an extension message. Furthermore, applied research is carried out partly at a central location, partly on farms, so as to ensure that it is relevant and contributing to the solution of problems and to development generally.

Because there are bound to be false starts and blind alleys in research and extension work (as in any other) a continual process must take place of objective setting/review of progress against objectives, introduction of changed external factors, setting of revised objectives, etc, ie. the process of monitoring and evaluation.

This section of the report deals with research and extension together and differentiation is only made where necessary.

A comprehensive plan and monitoring system to permit modifications to be made as experience gained is essential to any research programme. In this case research must concentrate on practical applications for existing farming systems and potential diversifications. It should be carried out at central locations (SSHARDA demonstration farms) and on selected private farms of different types and sizes. Effort must be invested in building up and maintaining contacts with other organisations performing similar work in similar ecological zones outside the

NORADEP region in order to avoid the waste of resources resulting from duplication of work, and to promote cross fertilisation of ideas.

The wide range of activities that will have to be the subject of properly planned and directed research is shown in Annex 2. The main topics are:

- Farming Systems.
- On-Farm-Water-Management.
- Soil Management.
- Crops, including fodder crops and intercropping.
- Agro-Forestry.
- Livestock.

Unless the farming systems of the area are completely understood the most appropriate interventions cannot be determined and extension resources will be wasted.

Farming Systems
Farming systems in the Target Area vary from the subsistence oriented rainfed and spate irrigated cultivation of staple grains around the edge of the plain, to the growing of fruits and qat for sale and grain for consumption under groundwater irrigation (which comprises the major part of the agricultural activity) to the recently observed (August 1993) introduction of polythene tunnels for the intensive cultivation of vegetables using drip irrigation and the most up-to-date techniques. The systems are perhaps not so complex as those in other Target Areas but they require investigation in order to be properly understood. The level of appropriate mechanisation is higher here than elsewhere in the NORADEP region and this too must be taken into account.

On-Farm Water Management
OFWM covers water management at farm level, from the source (spate flow, harvested water or groundwater) to the plant roots, including irrigation scheduling, water conveyance, application and irrigation management, and then finally drainage to ensure that neither the crop nor the soil are damaged by excess water.

Some of the major problems experienced in Sa'dah during this process are discussed in Section 5.1.1. However, the whole range of activities which constitute OFWM (summarised in Annex 2) must be integrated into a research programme directed at improving water management across the spectrum of farming systems.

An obvious first step is to establish crop water requirements, yield response to water and to salinity in order that traditional irrigation can be improved - by introducing piped conveyance, improving land preparation and applying water more efficiently. These measures could reduce the water abstraction by about 25% while crop yields increase. The introduction of intermediate and advanced irrigation, eg. microtube-bubbler drip and sprinkler, would save a further 15% of water (Section 6.3.2).

Relevant and useful work has, for example, recently been completed, as part of the Rada Integrated Rural Development Project in Al Bayda Province, into both microtube-bubbler irrigation, and the supplementary irrigation of sorghum which demonstrated that farmers normal practice of nine irrigations was excessive and that reducing to five timely irrigations may even give a higher yield.

These subjects are both discussed, in more detail in Section 5.3.6 and demonstrate that it is imperative to take account of relevant research work done elsewhere and to maintain close liaison with other researchers.

Soil Management
Most of the soils in the Sa'dah Plain are weak and require careful management; all the soils would benefit from a higher organic matter content. While it is clear from first principles that cultivation should be with tined implements only, since discs would further weaken the soil, detailed applications have to be developed. Some farmers already use minimum tillage techniques. An examination and optimisation of these, combined with work on mulching and the best fertiliser combination of organic and chemical must be carried out. Many farmers apply more chemical fertiliser than is recommended. Recommendations must be supported with solid evidence. Work on soil management will be very much interconnected with that on OFWM described above.

An increase in organic matter content would also improve soil structure. The introduction of pulses (legumes) to the area would serve this purpose as well as providing "free" nitrogen and expanding the diet of farming families. Pulses are a part of the cropping pattern in other Target Areas and there is no reason, why they should not become so in Sa'dah, given the correct interventions by SSHARDA staff.

Crops
Crop varieties and cropping patterns well suited to traditional water management practices are well established, and a relatively high proportion of farmers are using improved seeds to take advantage of the availability of groundwater irrigation. There remains, however, much work yet to be done to optimise the potential of this assured source of water, and to test and introduce varieties and techniques to extend harvesting periods and so reduce the current cycle of shortage and glut on the markets, reduce wastage and increase incomes.

The most important factor in crop research, as in all other research sectors, is to maximise the (financial) returns to water by correct selection of varieties, cropping patterns and mixes and the optimum use of inputs. Work on fodder crops - improvement of the traditional sorghum and alfalfa, together with trials on other high yielding alternatives, eg. Napier Grass, Stylo or Leucaena (cross-over with agro-forestry), must be undertaken.

One of the major problems in the development of the agricultural sector is the lack of potential export crops. In the highland plains such as Sa'dah any export would almost certainly have to be high value, low buck and non-perishable. Grape, dried as raisin, is the only product that approaches these criteria, but lack of marketing infrastructure and awareness currently precludes exploitation of this potential opportunity. However, suitable liaison between private sector marketers and the research and extension services-to tighten up on quality control would be essential to the development of such trade.

Other, longer-term, possibilities for export include essential oils (such as geranium and rosemary), and dried herbs. These also would require collaboration between the private and government sectors to combine the agronomic, processing and marketing components.

With the current lack of research resources and the extremely urgent need to work on the improvement of basic techniques and knowledge any such work cannot be contemplated in the near future. However, if the most is to be made in the future of agricultural potential, these and other ideas should be entered into longterm plans.

Harvesting, Packaging and Storage
These are the crucial early stages of the sales component of the marketing process, and the relevant knowledge and techniques are currently sadly lacking (except for qat) in even this relatively advanced Target Area. There is little that is area or even country specific in the methods required and so the extension process will simply be the training of extension staff to deliver the necessary message to farmers.

Agro-Forestry
Agro-forestry should be an integral part of the soil management, cropping and livestock systems and research work on it must be carried out accordingly. It has the potential to contribute significantly to the improvement of soils (through mulching and the addition of organic sources of nitrogen); to crop yields and returns to water (by maximising land utilisation and provision of nitrogen); and to the more intensive rearing of livestock (through the rehabilitation of overgrazed rangelands and as a source of high-nutrient feed).

In addition it would contribute to land and water conservation in the watershed: physically by helping to prevent soil erosion and the destruction of terraces and natural woodlands; and financially by providing alternative sources of income through intensification of the livestock sector and establishment of a sustainable fuelwood industry (Section 6.4.1).

Important and significant research work has been carried out into agro-forestry (including the intercropping of trees with fodder crops) within water harvesting (runoff) systems, which are very well understood by Yemeni farmers. The decline of these traditional land use systems is responsible for land degradation in the Sa'dah Plain catchment. Adaption of the methods developed elsewhere would contribute to rehabilitation and conservation of the environment as well as widening the income generating options in the agricultural sector.

Livestock
The livestock sub-sector is operated entirely on a subsistence basis, in spite of the fact that production in Yemen, particularly of sheep and goats, does not meet market requirements and so large scale imports (US $ 43 million in 1990) are required. In

addition the local product has the advantage of taste-preference and therefore commands a premium price. Thus, there is a major opportunity for diversification into the more intensive rearing of small ruminants. As an indication of the potential for development, one million sheep/goats were imported in 1990, at which time the national herd was estimated to be of the order of seven million head.

In combination with the agronomic research into fodder crops and agro-forestry systems outlined above, input will also be required from livestock specialists into the appropriate breeds and breeding practices, the formulation of feeds and the need for smallscale feed production operations, and the optimum husbandry and marketing methods.

5.3.6 Modern Irrigation Systems

Although the evaluation, promotion and introduction of modern irrigation systems really falls under the heading of the previous section, it is dealt with separately because it is so crucial to the saving and management of water. The subject was briefly mentioned in Section 5.3.3 under OFWM, and the financial aspects are dealt with in Section 6.3.2.

Provision is made under the NORADEP project for installation of modern irrigation equipment at the SSHARDA farm at Magash (drip) north of Sa'dah Town, and at a privately owned farm in the Target Area (drip and sprinkler). (NORADEP Reports 24, 25 and 26 cover this). The intention is that these installations should be used for extension and demonstration purposes to interested farmers as well as to increase irrigation efficiency and financial returns on the farms where they are installed. In the extension/demonstration role, care will have to be taken to ensure that farmers are not put off by the scale of the installations (20 ha at Al Magash) and go away believing that, if they themselves do not have an equally large area, they cannot consider installing modern irrigation. (This matter is dealt with below).

Piped Conveyance
Loss of pumped water by infiltration, and thus waste of money (and the proportion of the water that evaporates), is usually considerable. In an unlined earth canal through loamy sand soil losses are likely to be about 0.1% per metre, ie. 10% of the water running in a 100 m long canal and 50% in a 500 m long canal.

For surface irrigation, piped conveyance of the water from the pump to the field edge provides a ready solution to this problem. About 50% of the farmers in the Sa'dah Plain use some form of piped conveyance: buried PVC with screw-plug outlets, or systems of above ground piping and lay-flat hose. The Al Magash farm has a good example of the former system. Installation costs are in the order of YR 35 000/ha for a rigid pipe system, and layflat PVC hose is about YR 2500 for a 50 m roll (75 mm diameter).

There should be little problem demonstrating to farmers the benefits of installing some form of piped conveyance.

It should be noted that lining earth canals with cement mortar is an alternative to piped conveyance, but is usually more costly.

Improved Surface Irrigation
The layout, land grading and smoothing of surface irrigated plots frequently leaves much to be desired. Rectification of these problems is a matter for the extension officer under the guidance of an irrigation specialist as necessary. Designs will have to take account of the natural gradients, soil types, irrigation method, ie. basin, border or furrow, and the flow available. If the flow is not sufficient to permit efficient irrigation, eg. on a light, permeable soil, then consideration must be given to the provision of sufficient storage to enable the optimum lead stream to be supplied.

The application of water to furrows is straight forward, given that they are correctly designed. However, the even spreading of water into a basin or onto the upper edge of a border strip can cause problems. One method worth consideration and development by research and extension staff is a locally fabricated variation on the gated pipe. PVC pipe of different diameters is readily available, together with all the necessary fittings. Trials using different flows at varying pressures, with pipes of different lengths and with holes at a range of centres would quickly result in a set of useful recommendations for transfer to farmers.

Sprinkler Irrigation
Sprinkler irrigation can be used for field crops - cereals and fodder - and for vegetables. One of the disadvantages for the farmers in the Sa'dah Plain of using sprinkler rather than surface irrigation for cereals is the cost. As will be seen in Section 6.5 cereals are already grown at a financial loss (in real terms). A sprinkler system would almost certainly require a higher pressure (35 m) than is available from the borehole pump and so extra energy costs would be incurred in addition to the capital cost.

The overall efficiency of a sprinkler system would be about 75%, against that of a properly designed furrow or border strip layout of at least 65%, ie. there would be about 15% saving in water and, therefore, from a water management point of view its use would be worthwhile.

Drip Irrigation
Drip is suitable for vegetables, fruit trees and qat, all higher or high value crops and therefore grown at less of a real financial loss, or a positive financial gross margin. The capital cost would be about the same as that of sprinkler and the additional pumping energy requirement about 20% less. Overall efficiency is about 85%, giving a minimum 30% saving on water use over surface methods.

Microtube-Bubbler Irrigation
This is a relatively low cost system, suitable for the irrigation of fruit trees and perhaps some vegetables, developed under the Rada Integrated Rural Development Project in Al Bayda Province. It has potential application throughout Yemen. A full description is given in Annex 3, which is taken from the Project Technical Note No. 50 - the Final Report of the Extension Advisor - but the most important features are listed below.

- All necessary materials are available in Yemen.

- Negligible infield energy consumption.

- Low maintenance requirements.

- Simple operation.

The system is based on the delivery by gravity of water, directly from the well pump or if necessary from an elevated storage tank, through PVC pipes to polyethylene lateral pipes which run alongside the rows of trees. From each lateral small diameter (3 to 4 mm internal) microtubes carry water into a circular furrow around each tree.

The system received an extremely enthusiastic reception from farmers in the Rada IRDP area and demand for it exceeded the Project's capacity to provide installation services (farmers pay for all materials).

It is clear that the microtube bubbler system has tremendous potential for use in the Target Area and the liaison should be established immediately with RIRDP staff with a view to establishing trials in the NORADEP region.

Demonstration and Promotion
The irrigation installation proposed for SSHARDA's Al Magash demonstration farm (NORADEP Report 21), consisting of 20 ha of drip, is on too large a scale to be relevant to the majority of farmers. The opportunity should be taken, during the planning of demonstration facilities at Magash, to include provision, for example, of the more appropriately sized installations described below, which are likely to be appropriate for the requirements of other demonstration farms in the NORADEP area.

Outline Costs
In order that up-to-date prices could be used in the cost/benefit calculations (Section 6.3.2), guideline quotations for small scale sprinkler and drip installations were obtained from a well known international supplier of irrigation equipment in the United Kingdom. These, with the outline specifications are contained in Annex 4. The cost of supply and installation of the microtube-bubbler equipment was based on Annex 3, with a generous allowance made for the purchase and erection of a header tank. Indicative costs for the supply and installation of one hectare of each of the systems are tabulated below.

Table 5.4 *Indicative Costs of Modern Irrigation Equipment*

Type	Operating Head (m)	Cost (YR'000/ha)
Sprinkler	36	165
Drip	29	175
Microtube-Bubbler	2 (max)	125

5.3.7 Access to Credit

Ready availability of credit at reasonable rates of interest with minimum formality is essential if farmers are to use water more efficiently by investing in modern irrigation methods and agricultural practices, and in additional to diversify their activities into areas that require initial capital investments.

Credit is not currently available from CACB to all categories of farmer and one of the first actions that must be undertaken is to explore, through liaison with local and community leaders, farmers associations, the CACB and SSHARDA, ways and means of giving all farmers access to credit for viable approved investments. Group loans or loans guaranteed through a farmers' association may be one solution, depending to what extent CACB rules can reasonably be modified while still maintaining a fair lending margin. The availability of funds at concessionary rates for on-lending for specific purposes would also be worth exploring.

Training and early administrative changes within CACB are necessary to reduce its operating costs and make it more responsive to the needs of its customers. The bank will have to ensure that its staff can travel without delay to where they may be needed to assess eligibility for a loan. Equally, extension staff must be trained to assist farmers in preparing loan applications.

5.4 CONSTRAINTS

There exist a large number of constraints which will inhibit the actions discussed in Section 5.3 - severely in many cases. For the purposes of this report these constraints have been divided into three groups, Socio-economic, Technical, and Institutional, though there are inevitably linkages and cross-overs between the groups.

5.4.1 Socio-Economic Constraints

The background to the socio-economic factors that are likely to constrain development is given in Section 3. Thus it is only necessary here to list the major points, as follows:

- The need for farmers to feed their families, which inhibits the move away from traditional, less water efficient techniques.
- Women's ambiguous status as major contributors to the rural economy who are excluded from a formal role in planning and decision making, and have restricted access to education and virtually no exposure to extension services. In Sa'dah this constraint will take a long time to overcome.
- The subsistence level of livestock husbandry, to which the status of women, who are mainly responsible for livestock within the family farming unit, makes a major contribution.
- Traditional sharecropping practices, which have the effect of actively discouraging efficient use of resources, and thus lead to reduced income for both landowner and tenant in addition to land degradation.

- Traditional practices of "harvesting" fuelwood by lopping are falling away because of increasing pressure on a dwindling resource, and trees are being felled. No thought is given to growing trees in woodlots.

- There is minimal awareness of the ecological damage being caused by indiscriminate fuelwood cutting, by overgrazing or the abandonment (for sound agricultural reasons), of terrace cultivation and no acceptance of the need for changes in current practices in their own interest and those of their children.

5.4.2 Technical Constraints

A universal lack of sufficient education, with women particularly badly affected, is the major factor governing the technical constraints to development, which can be summarised as:

- Farmers do not recognise the right of government to interfere with their perceived groundwater rights, which are an extension of the traditional rights attaching to surface and shallow well water.

- Farmers are not aware of the true costs of groundwater irrigation and so continue to irrigate low value crops at an effective financial loss.

- Insufficient numbers of adequately educated (and experienced) SSHARDA research and extension staff.

- Lack of knowledge among farmers, which is compounded by the limited support available from the extension services.

- The incidence of new plant diseases of which there is no remedies have not been found. A particular example, and a very important one in view of the total investment made in the crop, is a disease of orange trees which currently (August 1993) seems to be affecting orchards in Sa'dah Plain, and for which extension staff have no answers.

5.4.3 Institutional Constraints

These too have been effectively covered above and, as is unfortunately so often the case, they are the main factor inhibiting development. In summary, they are:

- SSHARDA's role in water management and agricultural development is not understood by the community.

- SSHARDA's willingness and ability to enforce current and future legislation to control groundwater abstraction. (Until their role and authority are understood it will be difficult for SSHARDA to be effective).

- Local and community leadership and the LCCDs are not involved in water management and agricultural development. Farmers say they want such involvement and SSHARDA must act as a catalyst for it. (This would logically be part of the public relations exercise needed to establish SSHARDA's role, duties, responsibilities and authority in the minds of the farming community).

- A lack of Farmers' Associations to promote and encourage joint activity in the general interest of all, particularly in the securing of inputs and establishing and expanding a marketing strategy.

- Associated with the last point is the lack of constructive involvement by the private sector in the development process. Input supplies are erratic, sometimes of doubtful quality and often expensive; marketing standards require much improvement. It is in traders' interest as well as farmers' to play an active part in development.

- The inability to deliver credit efficiently to all farmers with a justified requirement for funds.

- A shortage of trained and experienced staff in research and extension particularly women, and in livestock husbandry.

- Lack of provision for adequate resources needed to deliver extension services.

- Farmers see the Magash demonstration farm as too large to be relevant to their needs. While this may not in fact be so, its very extent (20 ha) is intimidating. Specific areas dedicated to demonstration and extension should be set aside, perhaps near the farm entrance.

6 FINANCIAL CONSIDERATIONS

6.1 INTRODUCTION

Unless the objectives of a Water Management Plan can be demonstrated as financially acceptable to farmers, there can be no hope of implementing it. This is particularly the case in the Sa'dah Target Area where the community has a history of strong-minded independent action. This section contains outline analyses of the subjects that are likely to be most critical in gaining acceptance of a plan: the cost of pumping water, and the effect on farm family budgets in the context of a population growing at over 3% per year.

Diversification away from traditional agricultural activities will become increasingly necessary to maintain real incomes. This also must be shown to be financially attractive as well as compatible with accepted farming patterns if it is to be taken up by farmers. Thus, the broad implications are examined of the introduction of agro-forestry for fuelwood, stockfeed and soil improvement and of the intensification of small livestock rearing. In addition to increasing income these activities would have positive environmental effects; also, since they are at present largely in the domain of women's responsibilities, they will serve to encourage a wider overall role for women in the farming community.

Finally, while it is not appropriate in this report, which is directed to pragmatic solutions for extremely pressing water management problems, to attempt detailed financial analysis (for which in any case data is not available), still less are economic analyses possible or justified. However, Section 6.6 contains discussion of some of the economic impacts of the current situation in the Target Area, and of possible actions undertaken within the plan.

6.2 COST OF GROUNDWATER

Average groundwater level in the Sa'dah Plain declined by 5.6 metres in 1991. If that rate of decline were to continue 50% of the boreholes in the Target Area would be dry by the year 2015 (Section 2.3.7 and Fig. 8.1). The financial implications for the farmers are twofold:

- The cost of pumping, ie. the running costs (diesel plus operation and maintenance), will increase approximately in proportion to the fall in water level.

- Farmers will have to deepen and/or replace their boreholes and install more powerful pumping equipment.

The SONDEO Survey showed that farmers make no allowance in the costing of their operations for the capital cost of the borehole and pumping equipment. Pumping costs reported by farmers corresponded, crop-for-crop, almost exactly with the running costs calculated from a consideration of average depth to water, average well discharge, and the estimated gross irrigation water application. No allowance was made in their thinking for the cost of the capital invested, which is in fact over three and a half times the running costs (YR 3.65/m^3 and YR 0.99/m^3, in 1991). The implications of this on the cost of crop production are examined in Section 6.5 and shown in Fig. 8.3, but the fact is that, while gross margins seem reasonable, they are far from sufficient to cover the capital costs, and provide a profit margin. The projected increase in cost of water is shown in Table 6.1, and illustrated in Fig. 8.2.

Table 6.1. *Groundwater Cost Over Time*

YEAR	Cost of Pumping (YR/m^3)				
	O&M	Diesel	Sum Running Cost	Capital Cost	Total
1991	0.41	0.58	0.99	3.65	4.64
1992	0.46	0.65	1.11	3.89	4.99
1993	0.51	0.72	1.23	4.12	5.35
1994	0.56	0.78	1.34	4.36	5.70
1995	0.61	0.85	1.46	4.59	6.05
1996	0.75	1.04	1.79	5.12	6.90
2000	0.88	1.23	2.11	5.64	7.75
2005	1.11	1.58	2.69	6.78	9.47
2010	1.37	1.96	3.33	7.95	11.28
NOTE	Assuming consistent average decline of 5.6 m per year in groundwater level.				

In addition to facing steadily increasing running costs which will erode financial returns, the farmers in due course will have to raise a large amount of capital to replace wells and pumpsets. The availability of capital would have been less of a problem when most of the boreholes in the Sa'dah Plain were drilled, because remittances from family members working outside Yemen would then have been regular and substantial. Today and in the future, however, unless additional income from off-farm employment or business is available, farmers are likely to have to raise commercial credit to fund replacements. In the financial scenario outlined above such credit would not be viable, and so would not be offered.

Therefore, it is very much in farmers' interests to reduce the volume of water pumped in order to reduce the overall decline in margins and to delay for as long as possible the problem of finding new capital to invest for which the full commercial price would have to be paid.

6.3 FARM FAMILY FINANCE

6.3.1 Family Budgets

From the data gathered in the SONDEO survey family budgets were compiled for typical small, medium and large irrigated farming enterprises, as follows:

Small
- Farm area 0.75 ha, fully under irrigation
- Family of 6 persons, of whom 3 work fully or partly on the farm
- 20 sheep and goats and 3 cattle

Medium
- Farm area 2.5 ha: 1.5 ha fully under irrigation; 1.0 ha rainfed
- Family of 9 persons, of whom 5 work fully or partly on the farm
- 30 sheep and goats and 5 cattle

Large
- Farm area 5.5 ha: 4.0 ha fully under irrigation; 1.5 ha rainfed
- Family of 12 persons, of whom 8 work fully or partly on the farm
- 50 sheep and goats, 6 cattle and 3 camels
- Farmer has loans

The budgets are contained in Annex 1.

It must be understood that these budgets were assembled from Rapid Rural Appraisal data and, therefore, have no statistical validity. However, they give a more than adequate general picture of the situation on groundwater irrigated farms in the Target Area and are an excellent basis for the discussion which follows; and, indeed, for the more detailed work which will have to be carried out in the early stages of the Water Management Plan.

The budgets were assembled for use in demonstrating the effects of interventions in water management on groundwater irrigated farms, and so the farmers who rely on rainfall and spate are not represented.

The budgets comprise three tables:

- Cropping Plan and Income, which shows the areas under different crops, the yields, market values and gross income.

- Operating and Production Costs, where the unit costs of various operations from land preparation to marketing are extended into total production costs by individual crop.

- Family Cost/Benefit Account, where income from other sources is added to the gross crop income to give the total gross income, and from which production costs are deducted to arrive at the gross benefit. Finally taxes and the costs of capital are deducted to give the net benefit. A proportion of this benefit will be taken in cash from marketed goods the remainder as produce consumed by the family. Note that the gross benefit calculation referred to above excludes the capital cost component of groundwater abstraction. The implications of this are examined in Table 6.4.

The tables of Operating and Production Costs clearly show the high proportion of the total represented by pump running costs (Irrigation).

Sources of income, other than from the arable/horticultural farming enterprise, are livestock (for all three families), casual labour for the small farm, a business for the medium and large farms, and from outside employment for the large farm family.

Only the large farm has a commercial loan, in addition to informal credit (from family or trader). The small and medium farms have just informal credits. It should be noted that a completely unrealistic allowance for servicing the capital invested in the borehole and pumpset and other major equipment is shown as "Depreciation" under Operating and Production Costs. If the true costs of capital were deducted from the Gross Benefit, Net Benefits in nearly all cases would be negative (Table 6.4).

It is almost certain that operating costs having inputs from major items of machinery or equipment owned by the farmer, eg. tractors, ploughs, threshing machines, do not include allowances for the cost of capital. Inclusion of these would further reduce the real net benefit.

The overall returns to labour, excluding income from employment off the farm and casual labour, are tabulated below.

Table 6.2 *Farm Family Returns to Labour (YR/day)*

FARM	NET BENEFIT LESS NON-FARM INCOME	FAMILY LABOUR DAYS	BENEFIT PER DAY
Small	49 000	640	77
Medium	129 000	1260	102
Large	202 000	2160	93

Thus, returns are broadly comparable to what could be earned for casual labour, and so do not provide any incentive to remain in farming if other opportunities for paid employment arise.

6.3.2 Cost Benefit Analyses

The farm family budgets discussed in Section 6.3.1 were used as a basis for comparative cost/benefit analyses over a 20 year period, being taken as the starting position in Year 1. The analyses are in Annex 1.

Each analysis contains four tables, showing:

- Crop Areas and Yields
- Crop Production, Value and Gross Income
- Crop Production Costs
- Family Cost/Benefit Account

Yields, though perhaps questionable in some cases, were generally accepted. The calculated running costs for groundwater pumping were used, rather than those derived from the SONDEO, which at the order of accuracy of the analyses had little overall impact on the results. The nominal sum shown in the Farm Family Budgets for depreciation was moved to the Cost/Benefit Account, where it was assumed to represent the capital charges for major equipment, and the rate of *Zakat* was standardised at 10% of gross benefit. This ignored the fact that some of the benefit would have been taken in kind; but "Other Taxes" were adjusted to keep the total tax payments unchanged. The treatment of irrigation costs is described below.

Cost/benefit analyses (at 1991 prices) were carried out for three cases:

- Base Case, for which the only change over time from the adjusted family budget was in the treatment of irrigation water costs. These were divided into two components, running costs and labour. Running costs were taken from Table 6.1, and labour was calculated as a proportion of running costs from SONDEO returns. Yields, and thus income, and all other production costs remained as for Year 1.

- Case 1, for which it was assumed that extension interventions led to increased yields, and that these were aided by increased expenditure on inputs. It was also assumed that piped conveyance was installed throughout the remainder of the farm areas (from a base of about 50%). The costs of the pipes were assumed to be covered by a five year loan at a subsidised interest rate of 5%. As a result of the increased irrigation efficiency the costs of irrigation water were reduced.

- Case 2, for which it was assumed that yields would remain the same as in Case 1 but that water use would be further reduced by the installation of drip irrigation for suitable crops grape, citrus, qat and tomato. Purchase of the drip equipment was again assumed to be on a five year subsidised loan, and allowances were made in the Production Costs tables for operation and maintenance of the equipment.

A summary of the net benefits is given below (Table 6.3), and shown in Fig. 6.1, (Base case and Case 2), which includes bars showing population growth at 3% per year.

The effect of the steadily increasing cost of water in the Base Case is clearly demonstrated: farming on this basis would become untenable sometime after Year 10 for the small and medium farmers, and after 20 for the large farmers; and probably even earlier if boreholes and/or pumpsets have to be replaced.

Case 1, where some 27% less water is used than in the Base Case, shows an increase in benefit, but one that would not, except for the large farm, keep up with the projected growth in population of over 3% per year. This growth rate would double the population in 20 years.

Case 2 (35% to 43% less water) achieves "population parity" for the large farm and approaches it for the medium farm, but the small farm is no better off than under Case 1.

Fig. 6.1 *Effect of Water Cost Increases on Farm Incomes*
Legend Base-Current yields/irrigation
Case 2 - Improved yields/some modern irrigation

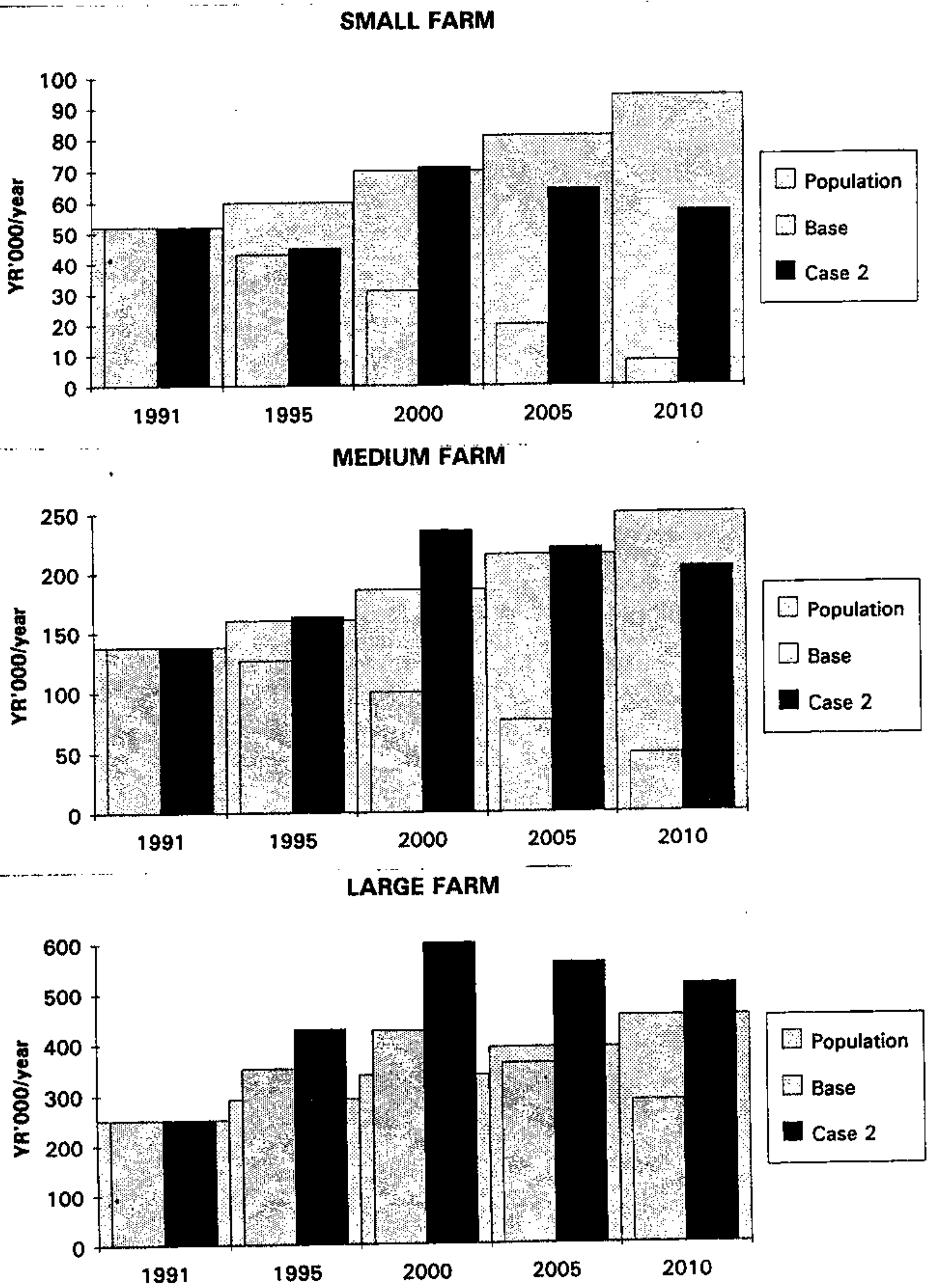


Table 6.3 *Farm Family Net Benefit Projections*

FARM	NET BENEFIT (YR '000)					Year 20 Year 1 (%)
	1	5	10	15	20	
Small						
Base Case	52	45	33	22	10	19
Case 1	52	600	76	68	59	113
Case 2	52	47	73	66	59	113
Medium						
Base Case	138	127	100	76	49	35
Case 1	138	223	259	242	222	161
Case 2	138	163	235	220	204	148
Large						
Base Case	251	351	426	360	286	114
Case 1	251	576	658	610	556	221
Case 2	251	428	600	560	516	205

Thus it has been demonstrated that, given appropriate extension interventions, production and incomes can be maintained while reducing the volume of water used. However, it is clear that additional income/production would have to be obtained from the improvement of rainfed agriculture and/or diversification. In addition some way will have to be found to cushion the effects on the smaller farmers of reducing living standards.

It is also clear that improving water use efficiency will not on its own make a worthwhile impact on the overall water balance.

To indicate the real financial position of the farms, the effect of the capital cost of water abstraction, for Case 2 only, is shown in Table 6.4.

Table 6.4 *Farm Family Real Net Benefit (YR'000)*

FARM	Year 1	5	10	15	20
Small					
Net Benefit	52	47	73	66	59
Irrig. Capital Cost	77	67	93	118	144
Real Benefit	(25)	(20)	(20)	(52)	(85)
Medium					
Net Benefit	138	163	235	220	204
Irrig. Capital Cost	150	138	189	234	285
Real Benefit	(12)	25	46	(14)	(81)
Large					
Net Benefit	251	428	600	560	516
Irrig. Capital Cost	419	378	522	647	791
Real Benefit	(168)	50	78	(87)	(275)

6.4 POTENTIAL DIVERSIFICATIONS

It was demonstrated in Section 6.3.2, in general terms, that unless crop returns to water can be improved by unrealistically high margins, farm family benefits will fall to a level at which the farming unit can no longer be maintained. If this breakdown of the agricultural economy is to be prevented then farmers will have to diversify their activities. To be successful such diversifications will have to build on existing knowledge and tradition, **and to be demonstrably profitable**. Even so much promotion and extension will be essential to convince the farming community of the need for diversification and the benefits to be gained. Focused demonstration activities run by SSHARDA, or suitable progressive farmers, would be necessary.

Not only should diversifications be acceptable and profitable for the farmer, they should be at least environmentally neutral (preferably positive), and contribute to the overall good of the country's economy. The two potential diversifications discussed briefly below - fuelwood and commercial small livestock rearing - fulfil both these criteria, and in addition address the imperative need to improve the quality of women's contribution to the farming system and their authority within it.

Other feasible diversifications and value-adding activities, which would require the involvement of Farmers' Associations and the Private Sector in unison, could be the storage of perishable produce, and its processing. These are long term possibilities, which should be examined when the plan is well into implementation, and are not discussed in this report.

6.4.1 Fuelwood

There is no forestry or fuelwood policy in Yemen.

Fuelwood provides about 90% of household energy and at the current rate of cutting there is a severe risk that all trees in Yemen will have been cut down by the year 2000. Although there is a transition to bottled gas and kerosene for cooking, it is likely that at least half of the population will continue to rely on fuelwood while it is still available.

The SONDEO Survey report records that natural rangelands, including Acacia species, which are cut for fuelwood, covers about 10% of the Sa'dah Target Area. However, this resource is being rapidly depleted without any attempt at replacement.

A socio-economic study on forestry development funded by the Overseas Development Administration of the United Kingdom in 1989, concluded that:

- Considerable potential exists for agro-forestry development, though competition for water resources will require strong extension efforts to convince farmers of the benefits of cultivating wood trees.
- Tree planting could be accelerated through training and extension linked to demonstrations of trees as a cash crop.
- Established farmers are more amenable to this type of long term development.

A preliminary budget for groundwater irrigated fuelwood production (Table 6.5) indicates the potential gross benefits from growing fuelwood would be over YR 250 000/ha/year once full production had been established in the fifth year after planting, excluding family labour.

Table 6.5 *Fuelwood Preliminary Annual Production Budget (YR/ha)(1)*

ITEM	Unit	Quantity	Rate	Sum	Total
INCOME(2)					
Fuelwood	tonne	200	1 500	300 000	300 000
PRODUCTION COSTS(3)					
Seedlings	nr	450	5	2 250	
Planting & Watering	day	310	100	3 000	
Weeding & Felling	day	5	100	500	
Irrigation Water(4)	m^3	12 000	1	12 000	
Inputs	LS		5 000	5 000	
Marketing	LS		10 000	10 000	32 750
GROSS BENEFIT					
(at full production)					267 250

Note
(1) Adapted from World Bank, 1993
(2) 1200 trees/ha; 3 year rotation from Year 5 for 5 years, ie. trees/ha/year at 0.5 t/tree
(3) Excluding family labour
(4) Running costs

This gross benefit compares very favourably with other high value crops grown in the Target Area (Table 6.6 and Fig. 8.4). It should be noted that, although fuelwood shows a gross benefit about two thirds of that for citrus, the value of citrus is likely to reduce sharply when the recent new plantings come into full production in the next five years. A 20% decrease in the value of citrus would reduce the gross benefit to YR 296 000 per ha. The market for fuelwood is far more robust.

There is also very great potential for growing fuelwood on terraces and other runoff collecting areas. This would have the advantages of saving groundwater, returning abandoned terraces to profitable use and thereby arresting land degradation.

In climatic conditions similar to those in the Target Area (Average annual rainfall 115 mm and ETO 2350 mm; cf. Sa'dah: 150 mm and 2280 mm), experiments completed in December 1988 gave yields of over 20 t/ha for *acacia salicina* and over 25 t/ha for *Eucalyptus occidentalis* after three years of growth at densities of 1250 trees/ha. Soil water balance studies during the growing season suggested that water from upper soil layers could be used by annual crops without affecting growth of the trees. Thus it is probable that, for example, fodder crops could be grown between the trees. This would have the advantage of suppressing weed growth, providing additional cash benefits and, if the fodder crop were a legume, of reducing the need to apply nitrogen fertiliser to the trees.

Table 6.6 *Comparative Crop Gross Benefits (YR '000/ha)*

CROP	Yield(1) (t/ha)	Value	Income	Production Cost	Gross Benefit
Citrus	25.0	20.0	500	104	396
Qat	2.0	220.0	440	109	331
Tomato(2)	24.0	15.0	360	63	297
Fuelwood	200.0	1.5	300	33	267
Grape	12.0	15.0	180	104	76
Alfalfa	40.0	1.5	60	44	16
Sorghum(3)	4.0	12.4	50	37	13
Wheat(3)	3.5	11.4	40	28	12

Notes
(1) Year 1 Yields
(2) "Mid-season" price: Ranges from YR 5 to YR 60/kg
(3) Including stover/straw

There is every reason for SSHARDA, in liaison with relevant agencies, to initiate production trials immediately with different tree varieties, and under both irrigated and runoff conditions, in order to confirm the apparent potential. As well as being essential to promote the concept of fuelwood farming to the community the trials, and any subsequent commercial development, would provide a useful source of finance to fund SSHARDA's other operations.

6.4.2 Intensification of Livestock

Since 1980 imports of cattle have increased by ten times, and of small ruminants by three times, despite the market premium on local produce, and the potential for regional exports. Livestock productivity is low in comparison with regional and East African countries. In addition to the economic implications the import of live animals, which originate mainly from Africa, carries a risk of the import of contagious diseases.

It is believed that the livestock population is static or diminishing, particularly in the NORADEP area. Even so, hides and skins are the third largest agricultural export commodity in Yemen, though the potential quality of the products is halved by poor handling and preserving practices.

There is obviously very great potential for the intensification of livestock rearing (for meat and dairy products), but the realisation of this potential is subject to a number of important issues and constraints that will take considerable time to resolve. These include:

- Increasing scarcity of labour, with more children attending school.
- Scarcity of fodder and competition for the water needed to grow it.
- Shortage of other feeds.

- Degradation of rangelands.

- Poor productivity of traditional breeds.

Before a livestock intensification policy can be developed much work will be required to upgrade breeds and produce commercial breeding stock for farmers; to increase the efficiency of forage production and conservation; to develop labour-saving husbandry techniques; and to encourage the setting up of small scale facilities for feed production and the processing and marketing of animal products.

6.5 THE REAL COST OF CROP PRODUCTION

Farmers' failure to include the real cost of groundwater in their crop costings, and the problems that will arise in the future because of this, were discussed in Section 6.2. The effect on the returns from crop production was examined over a 20 year period for a typical range of the crops grown under irrigation in the Target Area: sorghum, wheat, grape, alfalfa, qat, citrus and tomato. Annex 5 contains the full calculations, which are summarised for the Base Case in Table 6.7, and illustrated in Fig. 8.4.

Table 6.7 *Effect of Production Cost Increases on Margins (YR'000/ha)*

CROP Value	Citrus 500			Qat 440			Tomato 360		
YEAR	GM	IC	NM	GM	IC	NM	GM	IC	NM
1	402.2	104.8	297.4	344.6	68.6	276.0	300.9	56.7	244.2
5	388.7	131.7	257.0	335.8	86.3	249.5	293.6	71.3	222.3
10	370.0	161.9	208.1	323.5	106.0	217.5	283.5	87.7	195.8
15	353.4	194.6	158.8	312.6	127.5	185.1	274.5	105.4	169.1
20	335.0	228.2	106.8	300.6	149.5	151.1	264.5	123.6	140.9
CROP Value	Grape 180			Sorghum 50			Wheat 40		
YEAR	GM	IC	NM	GM	IC	NM	GM	IC	NM
1	83.3	86.9	(3.6)	16.0	64.7	(48.7)	15.2	44.2	(29.0)
5	72.2	109.2	(37.0)	7.6	81.4	(73.8)	9.5	55.5	(46.0)
10	56.7	134.2	(77.5)	(3.9)	100.0	(103.9)	1.7	68.2	(66.5)
15	42.9	161.4	(118.5)	(14.2)	120.2	(134.4)	(5.3)	82.0	(87.3)
20	27.6	189.2	(161.6)	(25.5)	140.9	(166.4)	(13.1)	96.2	(109.3)

Key
GM – Gross Margin, including irrigation running costs
IC – Cost of servicing irrigation capital investment
NM – Net Margin

Calculations were carried out for the Base Case and Cases 1 and 2 as appropriate (Section 6.3.2), on a per hectare basis. Production costs were divided into two components, pump running costs (O&M plus diesel) and other costs. Subtracting the total production costs from the crop value gave the gross margin; and subtraction of the annual capital charges for the borehole and pumpset gave the net margin. These figures ignore the effect of other capital items, which are in any case likely to be small in comparison with that of the borehole and pumpset, but give a very good general indication of the critical role that groundwater abstraction plays in the farming economy.

Real net margins on sorghum and wheat are already severely negative; between Year 5 and 10 even the gross margin, which is the value used by farmers, approaches zero. For grape the situation is slightly better, but net margins are still negative throughout the 20 year period. Citrus, qat and tomato maintain positive net margins throughout, but the values in Year 20 are respectively 36%, 55% and 58% of those in Year 1.

6.6 ECONOMIC IMPLICATIONS

It is not the purpose of this report to present an economic analysis of the effects of a Water Management Plan and, indeed, there is not yet sufficient detailed data available. However, some general comments would be appropriate; these follow.

6.6.1 Farmgate Prices and Costs

In their 1993 Agricultural Sector Study the World Bank published estimated farmgate prices for a number of different imported commodities as part of the financial and economic analysis. These have been used in the compilation of Table 6.8 and Fig. 8.5, in which the price of imports at farmgate are compared with the cost of producing the same crops on-farm.

Table 6.8 *Farmgate Price/Cost Comparison (YR'000/tonne)*

CROP	IMPORTED PRICE (1)	COST OF PRODUCTION (2)					
		Base Case		Case 1		Case 2	
		A	B	A	B	A	B
Sorghum	6.0	10.5	30.8	8.0	21.2	--	--
Wheat	7.8	8.7	24.6	6.3	16.0	--	--
Citrus	19.0	4.5	9.7	3.5	6.9	4.2	7.0
Tomato(3)	8.3	1.6	4.6	1.2	3.1	1.5	3.0

Note
(1) Adapted from World Bank, 1993 (ER $1 = YR 30)
(2) A - Includes irrigation running costs only; B - Includes irrigation capital costs also
(3) Price for vegetables

Imported sorghum is substantially cheaper than that produced under irrigation in all cases. Imported wheat is much cheaper than locally produced under irrigation if the full cost of water is used, but of the same order (YR 8000/t) if the cost of capital is ignored. Locally produced oranges and tomatoes are much cheaper than imported produce in all cases.

Therefore, from the national point of view as well as that of the farmers, the cultivation of staple grains under irrigation should be phased out and replaced with high value crops for local sale and export. The corollary of this is that the production efficiency of cereals under rainfed and spate must be increased.

6.6.2 Rural Employment

With the return of migrant workers as a result of the Gulf crisis there is currently no shortage of adult male labour. However, with the increasing tendency for children to go to school and continuing pressures on women with respect to their many duties, the labour force available in two vital sectors of the farm economy - fuelwood and livestock - is shrinking. Thus, it is probably not the total labour resource that may be a constraint on development, but its distribution over traditionally allocated tasks. Given a partial reallocation of tasks and/or diversion of activity to more labour intensive farming patterns, eg. rain/runoff-fed/spate irrigated cereals and fuelwood cultivation, increased rural employment may be achievable.

However, the return to labour will have to be calculated over the entire farm family enterprise, not judged on the basis of returns from individual crops or activities. In order to determine the likely opportunities for additional employment, much more detail is required of the farming systems existing in the Target Area than can be obtained from the SONDEO.

6.6.3 Sustainability of Groundwater Resources

Abstraction at the current rate of four times annual recharge is not sustainable, physically or financially, regardless of which crops are grown.

This is without doubt the most important economic factor that has to be taken into account. The effects on agriculture have been discussed at some length elsewhere in this report, the effect on other economic developments cannot be ignored. The most important of these are domestic water supply and sources of water for any future industrial developments in the area, eg. factories to process agricultural produce.

6.6.4 Environment

The effects on the environment of the changes in land use patterns over the last twenty years, and of current activities in the rural economy, have also been discussed above, as have the likely medium term adverse outcomes and measures necessary to arrest and reverse the process. As far as possible only such measures as would show a positive return to farmers investment have been considered. However, it must be acknowledged that some costs to the economy - perhaps in the form of temporarily subsidised credit and tax relief - may be necessary to prompt farmers to make the initial investment within the required timeframe.

Other less profitable but also essential interventions may need longer term/higher financial inputs. One means of creating the necessary resources would be for SSHARDA to take part in profit-making enterprises with the intention of raising finance without recourse to central funds. Community fund-raising against specific objectives, eg. establishment/maintenance of woodlots or terraces, might in the future become feasible if SSHARDA's links with the community are properly developed.

6.6.5 Equity

One of the objectives of economic development is to achieve a reasonable degree of equity in conditions and standards of living. Insofar as it may well be necessary to provide extra incentives to poorer (subsistence oriented) farmers in order to encourage them to change and develop their farming system, an additional burden will be placed on the economy.

7 RECOMMENDED WATER MANAGEMENT PLAN

At this stage it is appropriate to review the main points made so far in the report, before moving on select the major problems and issues that will have to be addressed and re-state the planning objectives. This process leads naturally to the recommendations for a Water Management Plan, and the basic requirements for implementation. (Implementation is dealt with in more detail in the Regional Water Management Plan - NORADEP Report 15).

7.1 STUDY REVIEW

The context into which this report must fit is set out in the first section, together with the definition of water management used for the purposes of the report and the general approach to the work. In Sections 2 and 3 the findings of the comprehensive studies on water resources and socio-economics, carried out to form the basis for the planning process, are summarised. The current status of water and agricultural management is examined in Section 4, which leads in Section 5 to a comprehensive assessment with respect to water management of the problems revealed by the studies, the solutions available, the action necessary and the constraints on such actions. Section 6 contains a discussion of some of the financial considerations affecting the planning process, and touches on broader economic issues.

7.2 THE PLANNING PROCESS

7.2.1 General

Water Management Planning in general has to take place on three levels, the national, regional and local. In this case the local dimension is described by the Target Area concept and the region is the NORADEP area. At national level the perspective tends to be strategic, built upon detailed data supplied from regional and local sources. The Target Area, subject of this report, must be looked at pragmatically, for it is here that the basic data is gathered and the overall success or failure of planning initiatives are decided. In the Target Area the plan meets the water users and impinges on their established water use patterns. If it has not been developed in negotiation with them it will not work; it cannot be imposed by force.

The NORADEP Regional Water Management Plan (NORADEP Report 15) is based on six Target Area plans (Reports 16 to 21) and the Tihama Wadi Development Study (Reports 29 and 30). In it priorities among the Target Areas are determined and regional objectives set out. It is essentially a business plan for one sector of SSHARDA's responsibilities, against which achievements should be measured.

7.2.2 Major Problems and Issues

The full range of water management problems, is discussed at some length in Section 5. Many of the problems and resulting issues are related or interact in some way;

some are more important than others (critical in the case of over-abstraction of groundwater). In order to achieve a plan of manageable dimensions only the most important subjects have been selected for listing here, as follows:

- Excessive abstraction of groundwater.
- Poor on-farm-water-management and crop husbandry.
- Sub-optimal coverage by Extension Services.
- Selective and cumbersome credit procedures.
- Total lack of watershed management.
- Inadequate local leadership and community involvement.

The list has been chosen in such a way that the lesser problems are all associated in some way with one of those listed, and will therefore be addressed and assigned the appropriate priority.

It is on their success in solving these problems that SSHARDA's performance must be judged.

7.2.3 Target Area Planning Objectives

In view of the wide range and absolutely basic nature of the problems and issues listed above, great care must be taken to select objectives that address the most urgent and critical of the problems and are achievable with SSHARDA's current and foreseeable level of resources. Hence, two objectives have been set:

- Reduction of groundwater abstraction while maintaining farmers income levels.
- Establishment of the human, physical and data resources base for longterm planning and action.

The first objective addresses the most pressing physical priority, the decline in groundwater levels, while acknowledging the importance of acceptance by farmers. The second addresses the need to build up institutional capabilities in order properly to plan and execute the development process. Medium and long term achievement of the first objective will not be possible unless the requirements of the second are met.

7.2.4 Planning Data

This report contains all the data necessary for quite detailed planning, and is effectively a planning/implementation manual. However, the reports upon which it is based must be referred to as necessary.

7.3. PLAN OF ACTION

To achieve these general objectives a number of activities will have to be carried out in parallel. This process is illustrated in Fig. 7.1 - General Plan of Action and Implementation Programme. In this report only the planning framework can be established; detailed activities must be determined after appropriate analysis within SSHARDA.

7.3.1 Preliminary Procedures

Before any action is taken **it is essential to set up the planning and liaison network**, which will control all other activities. This network will commence in the SSHARDA planning department with decisions by senior management as to the allocation of resources, setting of general operational objectives and overall budgets; and the best way of establishing workable liaison groups with local leadership (say, via LCCDs) and communities. Initial approaches to LCCDs will in any case have to be made at senior level. No contentious action, such as implementation of the decree to control drilling and abstraction, should be taken before local and community leadership have been briefed and appropriate procedures agreed.

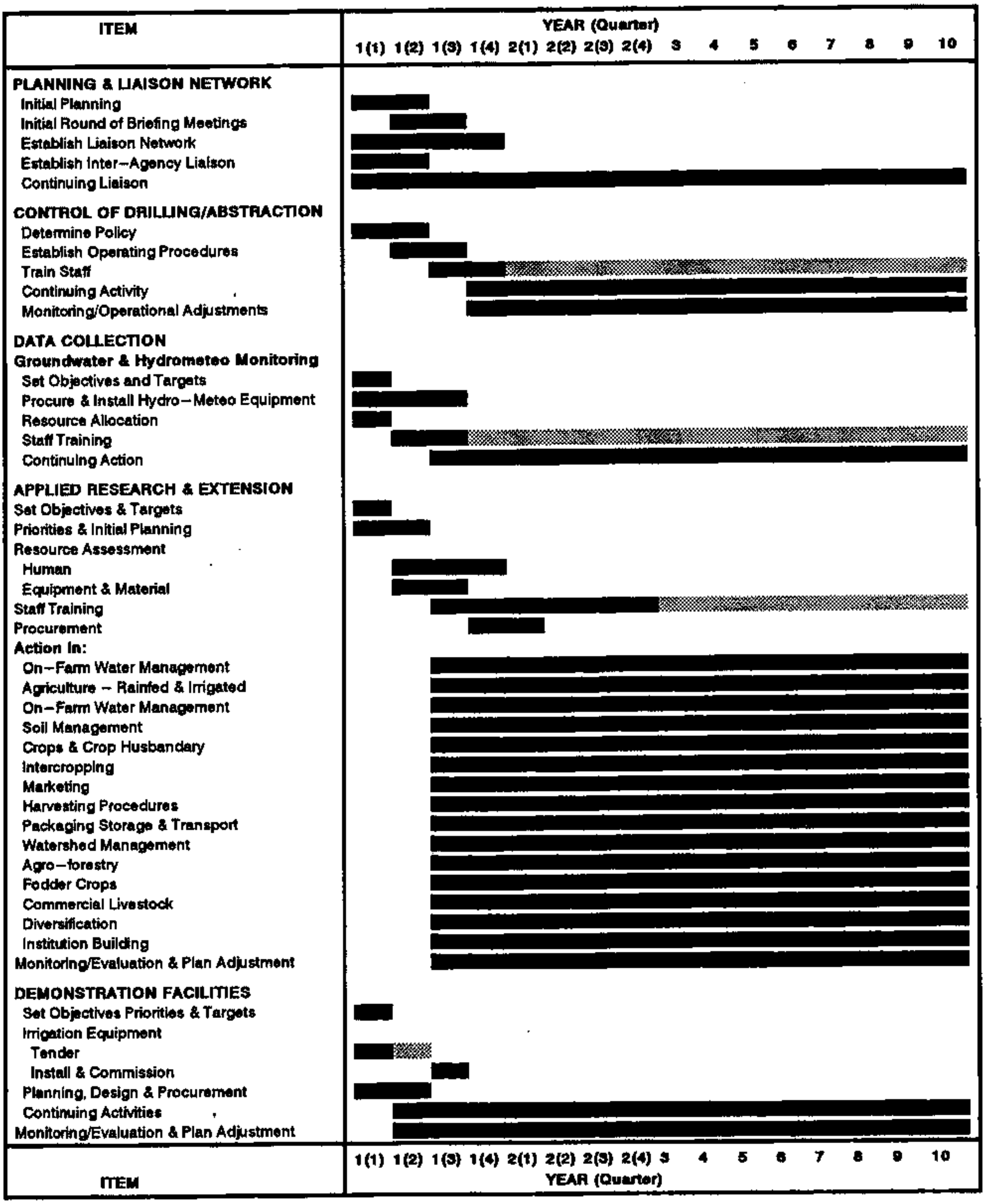
Once established, the planning and liaison functions should be continuous in order to monitor and guide all other activities, and to adjust the approach to particular problems in the light of experience. In the early stages of implementation such adjustments are likely to be frequent and substantial.

7.3.2 General and Detailed Planning Activities

Detailed planning (and the monitoring and adjustment of plans) will be carried out at all levels within SSHARDA, in increasing detail and with narrower focus as the process moves down through management towards execution. It will commence at the highest levels as described in Section 7.3.1 and will consist of the following general components:

- Setting of basic overall objectives in all sectors in which SSHARDA has responsibilities defined by the terms of reference for its activities.
- Drafting of outline plans, sector by sector, with appropriate administrative and operational linkages both internally and with other (external) agencies.
- Preparation of outline indicative resource budgets: man-power, equipment, finance, etc. Preliminary sourcing of funds.
- Setting up at Branch and Block levels liaison with local leadership and Community groups.
- Consultation with:
  - SSHARDA Branch Managers and staff, who will have to implement the final plan.
  - Local leaders and community groups.
  - CACB to ensure efficient credit arrangements.

Fig. 7.1 *Sa'dah Target Area Plan of Action/Implementation Programme*



- External agencies with linking responsibilities to ensure minimum duplication of effort and maximum use of existing resources, eg. MEB for its water resource database.

■ Modification of the original objectives in the light of the consultations, finalisation of plans (keeping all parties informed); detailed budgeting and programming of implementation; sourcing and allocation of funds.

Note
The consultation phase will be lengthy if it is to be effective, but items that are not sensitive to consultation procedures (groundwater, hydro-meteo and some marketing data collection, adaptive research, staff training) should be planned in detail, budgeted and implemented as soon as possible to provide a base for the wider actions to follow.

7.3.3 Control of Drilling and Abstraction

The legal basis (Decree Number 46) already exists for the control of drilling and abstraction. However, implementation will require great diplomatic skill.

This is the most important of the early activities, and potentially the most difficult. The need to agree the objectives and procedures with farmers and their leaders before any action is taken has been emphasised above. Even so the utmost prudence will have to be exercised and staff will have to be carefully selected and trained to deal with the confrontations that will probably arise.

This is one of the major disadvantages of implementing the Decree through SSHARDA since they will inevitably be perceived as giving (extension services, etc.) with one hand and taking away (water) with the other - an almost impossible public relations situation. Reallocation of the policing duties to a centrally administered specialist agency would make the remainder of their tasks - in themselves an enormous burden - very much easier to carry out.

7.3.4 Staff Recruitment and Training

The correct selection and training of new and existing staff is fundamental to the success of the Water Management Plan as a whole. Training, in varying disciplines and skills is needed at all levels in SSHARDA in the form of courses (in country, regionally or overseas) and on-the-job coaching. Like planning, training must be a continuous process, but as staff skills and knowledge improve, so more and more training can be undertaken in-house.

If staff are to become properly motivated a system of objective-driven management will be essential under which responsibility and authority are clearly defined, resources made available, and performance is rewarded according to its quality.

7.3.5 Data Collection

Groundwater monitoring can commence as soon as the objectives and operation procedures have been agreed; sufficient staff are already trained and experienced as a result of the well-inventory (NORADEP Report 8), but equipment and transport will have to be allocated. Areas where water levels are declining most rapidly and where EC levels are highest should be given priority. The records of water levels, salinity, and abstracted quantities will be used to judge the success of the drilling/abstraction control programme.

Hydro-meteo data collection and processing will first require the equipment to be procured and installed, then staff to be trained and liaison set up with other government agencies to avoid duplication of effort and ensure the most efficient processing and publication of data.

The locations for evaporation pans and raingauges (Section 5.3.4) should be agreed at an early stage and procurement put in hand - the pans at least can be manufactured locally to the relevant BSS/ISO code.

7.3.6 Research and Extension

The subjects to be covered are clearly shown in Fig. 7.1, and Section 5.3.5 contains discussion of specific points. There is no more that can usefully be added here, except to emphasise once more that the approach throughout must be flexible to avoid the waste of scarce resources, and that maximum use must be made of relevant work carried out elsewhere in Yemen and regionally to avoid duplication of efforts.

7.3.7 Demonstration Facilities

The need to ensure that demonstration plots are relevant to the needs of the farmers - both as to size and content - was dealt with in Sections 5.3.6/5.4.3. However, it is worth pointing out that demonstrations should also include appropriate mechanisation, livestock husbandry, (including improved fodder and storage), crop quality control and on-farm processing, agro-forestry, watershed and range management techniques, and most importantly in the early stages, on-farm-water-management for all types of farming systems. A series of field days on suitable private farms in addition to the standard arrangements at Al Magash farm would be the best way to achieve this.

8 NOTES ON IMPLEMENTATION

With such a wide range of detailed recommendations to be considered by SSHARDA before the planning process can commence, only general guidelines on priority actions are given here. Preparation of a detailed implementation plan is not the purpose of the technical assistance studies. Implementation of the priority actions can commence once the general planning phase is complete, while detailed planning is being carried out.

8.1 PROGRAMME

Fig. 7.1 shows in bar chart form, against the schedule of required actions, a draft implementation programme. Detailed planning by SSHARDA will expand and modify this in due course.

8.2 TARGETS

Precise targets can only be set during the detailed planning phase, but the following would be typical:

- 50% reduction in drilling in 5 years.
- 40% reduction in abstraction in 5 years, by improving efficiency.
- 100% reduction in abstraction in 10 years, by diversifying away from irrigated agriculture.
- 50% reduction in area under groundwater irrigated cereals in 5 years.
- 25% increase in yields on rainfed and spate irrigated land in 5 years, 50% on groundwater irrigated land in 10 years.
- 500 ha under fuelwood on terraces and runoff areas in 5 years.
- 1000 ha under modern irrigation in 5 years.
- 50% improvement in small livestock productivity in 5 years.

Not all of these targets may be realistic, but they are a good illustration of what SSHARDA must aim at.

8.3 BUDGET

Budgets have not been prepared for individual Target Areas but are consolidated at Regional level.

8.4 FUNDING

Substantial funding will be essential to establish the Programme, although once it is established it should be run on a self-financing basis, drawing its finance from the income earned from providing extension services, and from the proceeds (channelled from central government) of well drilling and abstraction licences, when the regulations are put into force. The provisions of the current IDA Credit would allow rapid implementation of the agricultural and irrigation improvement components of the recommended plan, given that a detailed implementation programme can be agreed. Components of the forthcoming World Bank funded Land and Water Conservation Project will form part of the implementation programme.

It should be noted that funding agencies are likely to look very favourably on specific projects prepared by SSHARDA/MAWR and presented for funding. Such projects could be based on this report.

To ensure successful implementation the physical and human resource base of SSHARDA will have to be extended - in the form of equipment and transport and training - and provision made for the funding of the concessional credit needed to encourage farmers to invest in improvements. Such credit should, however, be applied selectively and discontinued as soon as possible so that farmers do not become "grant driven" as has happened in other economies, where as a result agriculture has become inefficient and the cost of production high.

8.5 COMPLEMENTARY PROJECTS

Great emphasis has been laid in this report on the need for SSHARDA to liaise with other authorities and projects involved in similar or complementary work. Duplication of effort and waste of resources will thus be avoided and objectives will be achieved more quickly. Two current projects, both within MAWR, are of particular relevance to the implementation of the Sa'dah Water Management Plan.

8.5.1 Agro-Forestry Research and Extension (FAO)

This project, within the Department of Forestry and Range Management, commenced in 1985 with the objectives of determining the most appropriate species (native and exotic) for use as fuelwood, building poles, fodder, windbreaks, dune stabilisation and honey production; establishing on-farm nurseries and demonstration plots; providing extension services with particular emphasis on women; and training appropriately qualified government staff. Some SSHARDA staff are receiving training. Response from farmers has been good, but there have been major problems in the provision of counterpart funding and resources. The fourth phase of the project is due to run from September 1993 to August 1996.

8.5.2 Land and Water Conservation Project (WB)

A detailed outline of this project, which became effective in mid-1993 and is being executed by MAWR, is given in Annex 5. Its objective is to strengthen sustainable agriculture and assist in better management of water resources through:

- Institutional and technical developments in irrigation and forestry
- Initiating a programme of water use monitoring and regulation in the agricultural sector.
- Improving the efficiency and water management of controlled and small-scale spate irrigated agriculture.
- Conserving key indigenous woodland areas, accelerating tree planting, extending soil and water conservation.
- Pilot actions to establish an approach to watershed management, including rehabilitation of abandoned terraces.

The major implications for SSHARDA with respect to water management planning are:

- **Groundwater Irrigation Improvements**
  The installation of piped conveyance in Sana'a and Sa'dah Provinces.
- **Pilot Improved Irrigation Systems**
  40 one hectare installations of drip, bubbler or sprinkler irrigation.
- **Spate Irrigation Improvements**
  Demonstration of improved methods.
- **Implementation Unit**
  Provision of buildings, equipment and vehicles.
- **Forestry Development**
  Equipment and materials.
- **Watershed Management and Terrace Stabilisation**
  Pilot scale developments.
- **Use of Saline Water for Irrigation**
  Establishment and monitoring of two one hectare plots in the Northern Tihama.
- **Training and Technical Assistance**

8.6 PRACTICAL EARLY IMPLEMENTATION ACTIVITIES

8.6.1 General

Data packs of selected information from this report and the source reports should be made up, translated into Arabic as appropriate, and distributed through all levels of SSHARDA staff, local and community leadership, and farmers' groups in the Target Area. There is a very substantial body of data contained in the NORADEP Reports and maximum use should be made of it in pursuit of SSHARDA's objectives, the principle one with respect to water management being to convince farmers of the need to reduce water abstraction.

8.6.2 Groundwater Monitoring

Comprehensive data is available from the well inventory carried out in early 1992, of which the most important for immediate purposes are water levels, salinity and abstraction rates. Topographical maps at 1:50 000 scale should be made up for the Target Area, and the surrounding foothills, by assembling a mosaic from the published survey sheets. Enough of these should be produced so that every SSHARDA office in the Target Area has one to put on the wall.

On each map must be marked the lines of typical cross sections through the plain, in particular through areas giving rise to particular concern on the grounds of rapid water level decline or high salinity. Cross sections along these lines (through defined observation wells) should be plotted on strips of graph paper (at 1:50 000 horizontal scale) showing ground level, water level and EC to appropriate vertical scales. After each round of monitoring observations data should be plotted on these cross sections. Trends in the parameters recorded can then be easily detected and the effect of the efforts to control drilling and abstraction judged.

8.6.3 Research and Extension

No precise data is available on crop yields in the Target Area, though the SONDEO data will be a valuable starting point. One of the early research activities will be to determine yield ranges for the crops grown, and the type and levels of input use, cultivation, etc. Since at least half of the land in the Target Area is under rainfed/runoff/spate irrigated cultivation, work on the varieties and husbandry practices traditionally used on these areas must be of equal priority to that on groundwater irrigated farms. This data will then form a baseline against which progress in research and extension can be measured.

8.7 TYPICAL EXTENSION MESSAGES

The data gathered during the NORADEP studies should be put to practical applications. One of the most important of these in the early stages is to convince all relevant people in the Target Area that it is essential to the medium and longterm viability of the community that groundwater abstraction be reduced, and the water that is abstracted be used at maximum efficiency. This should commence with the leaders and opinion formers.

Suggestions for some of the ways in which data can be used in this way follow; many other uses are possible.

8.7.1 Reduction of Abstraction

Farmers generally are very conscious of running costs but apparently do not usually associate water saving or more efficient water use with a reduction in running costs.

Two graphs composed from data in the Well Inventory and derived from it (NORADEP Report 8), would be extremely valuable in this regard. Fig. 8.1 shows the rate at which groundwater levels will decline if abstraction continues at the same rate as in 1991; a line at 184 m below groundlevel (Average depth to water plus average depth of water, ie. the bottom of the average well) is superimposed to indicate the water level at which 50% of the wells in the Target Area will become dry. The data is contained in Table 8.1, together with the mean abstraction rate in the Target Area (3.3 l/s).

Fig 8.1 *Projected Fall in Groundwater Level*

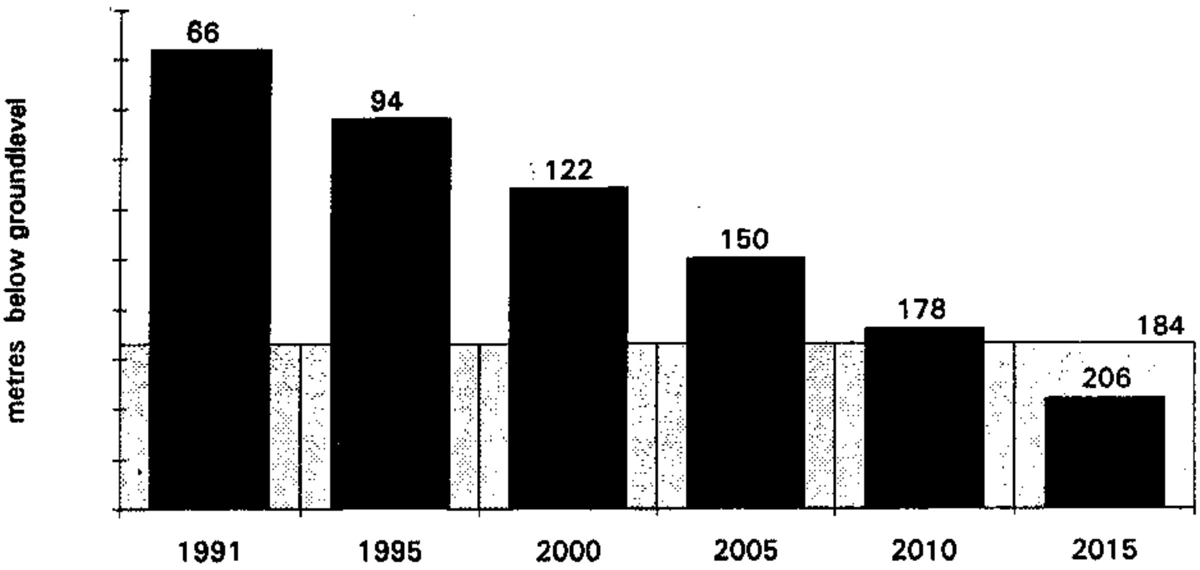


Table 8.1 *Average Water Level Decline Over Time*

YEAR	Water Level (m bgl)
1991	66
1995	94
2000	122
2005	150
2010	178
2015	206
Note Level at which 50% of wells are dry = 184 m Average borehole discharge = 3.3 l/s	

Comparison of this average data with the specific data from an individual farmers' well will allow a more accurate estimation of when his well will run dry.

Fig. 8.2 (data in Table 8.2) shows how the average cost of pumping one cubic metre of water will increase over the next 20 years. It should be pointed out to farmers how many cubic metres are required to irrigate one hectare, eg. 12 100 m^3 for one crop of wheat, 40 700 m^3/year for alfalfa, and 28 700 m^3/year for citrus.

Fig.8.2 *Increase in Cost of Water*

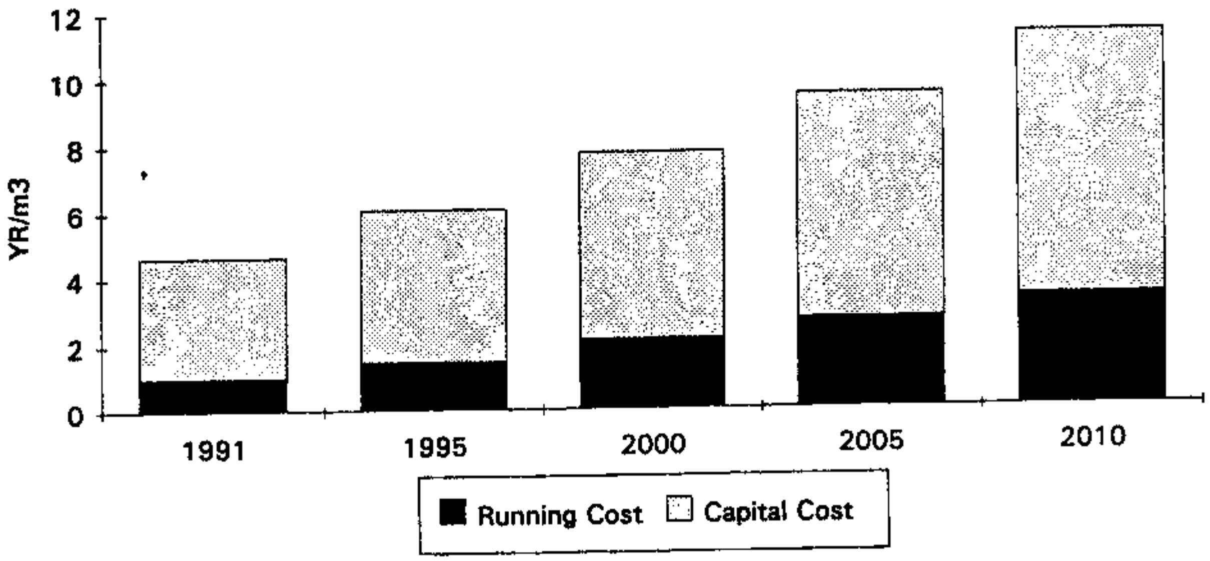


Table 8.2 *Average Increase in Cost of Water (YR/m^3)*

YEAR	Running Cost[1]	Capital Cost[2]	Total Cost
1991	0.99	3.65	4.64
1995	1.46	4.59	6.05
2000	2.11	5.64	7.75
2005	2.69	6.78	9.47
2010	3.33	7.95	11.28

Note
(1) Operation and Maintenance plus diesel
(2) Interest plus capital repayment

The cost of water relative to other production costs and to the value of a typical range of crops is shown in Fig. 8.3 (Table 8.3). This figure demonstrates clearly the financially unsound basis of the lower value crops and the very high proportion of total production costs attributable to irrigation water. It should be noted that Fig. 8.3 would be of equal relevance in Section 8.7.2.

8.7.2 Revision of Cropping Pattern

Fig. 8.4 (Table 8.4) is designed to demonstrate the different benefits to be gained from a range of crops, and that the lower value crops are actually grown at a financial loss when the full cost of water is taken into account.

Fig. 8.3a *Cost of Water Relative to Crop Value*

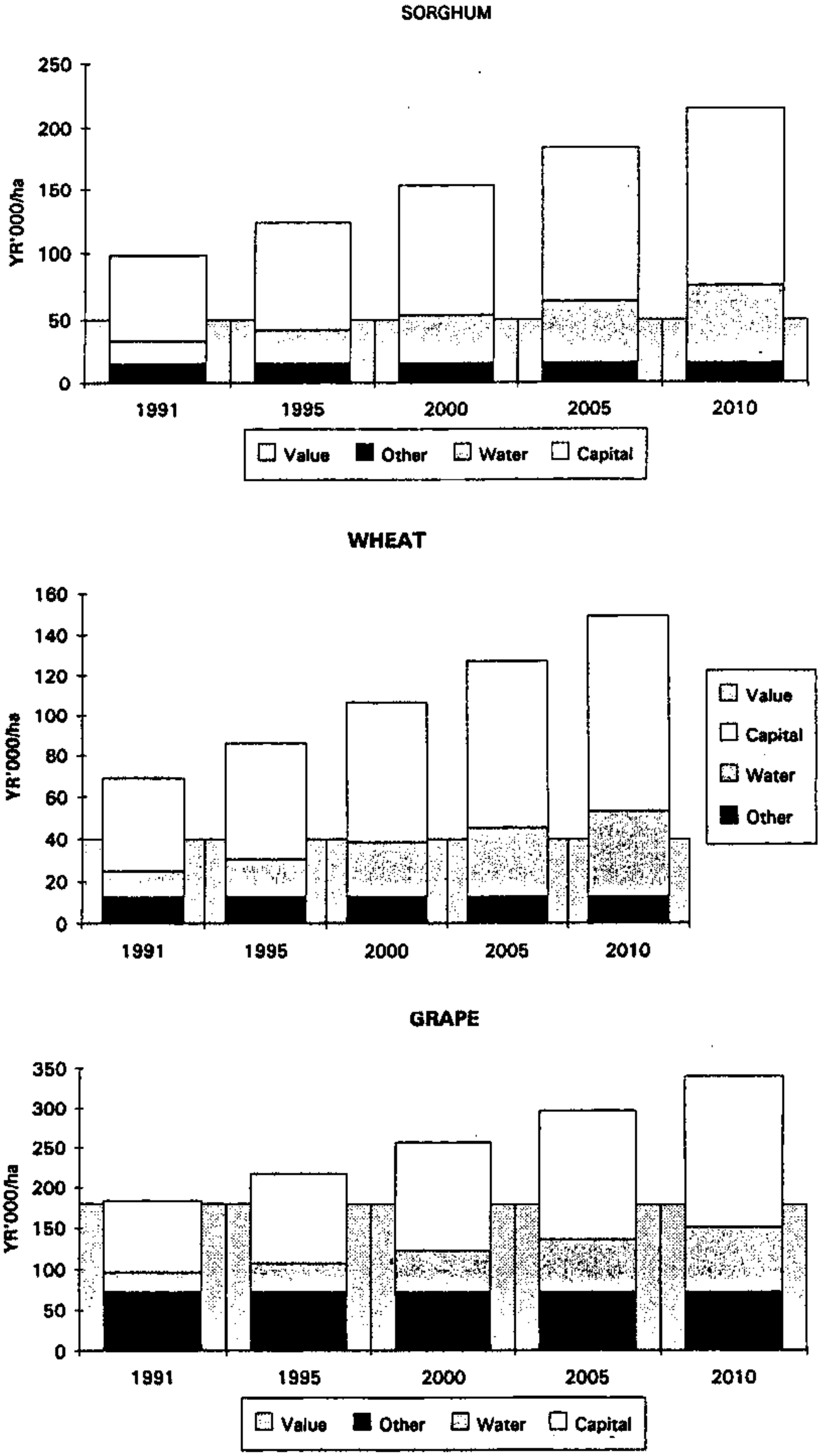
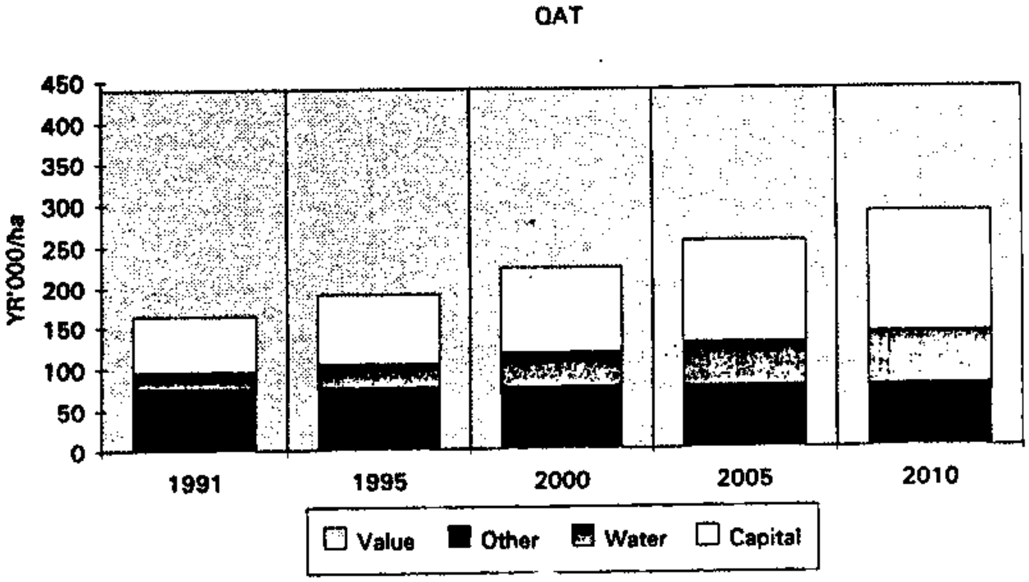
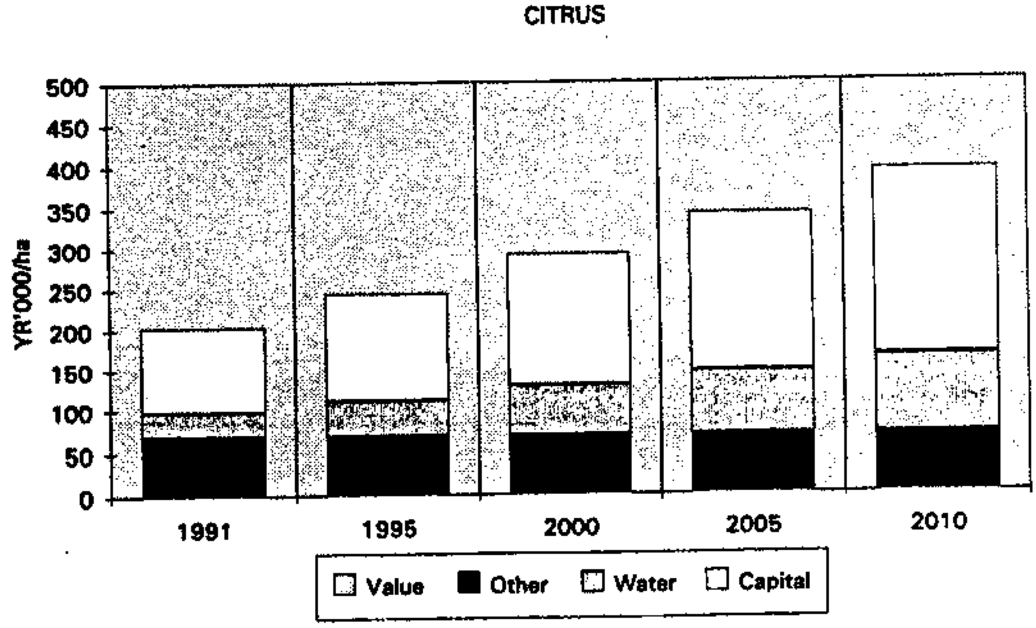


Fig. 8.3b *Cost of Water Relative to Crop Value*





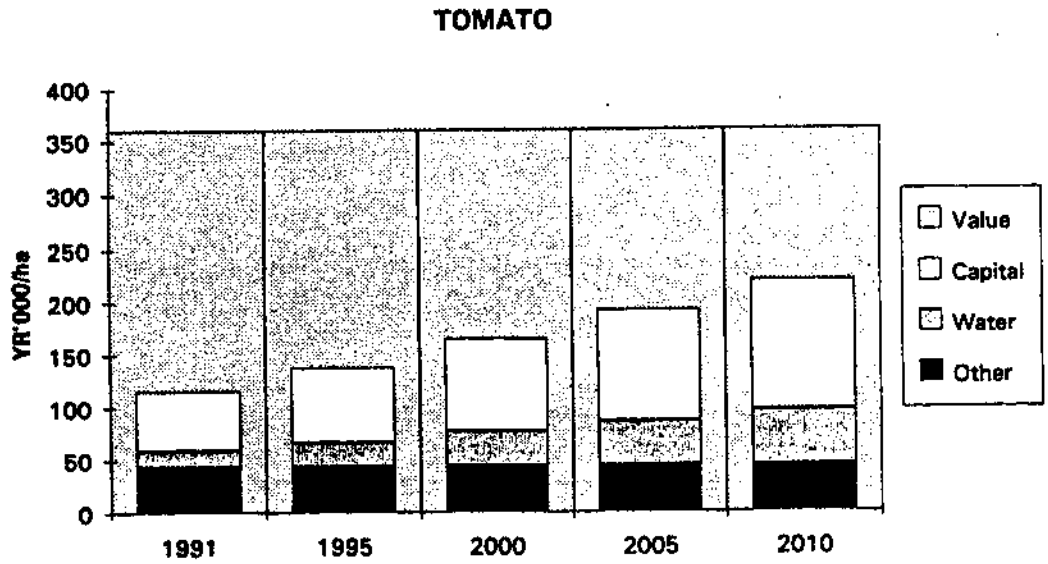


Table 8.3 *Cost of Water Relative to Crop Value (YR'000/ha)*

YEAR	Value	Production Water	Production Other	Capital	Total	YEAR	Value	Production Water	Production Other	Capital	Total
SORGHUM						QAT					
1991	50	17.5	16.1	64.7	98.3	1991	440	18.6	76.8	68.6	164.0
1995	50	25.9	16.1	81.4	123.4	1995	440	27.4	76.8	86.3	190.5
2000	50	37.4	16.1	100.0	153.5	2000	440	39.7	76.8	106.0	222.5
2005	50	47.7	16.1	120.2	184.0	2005	440	50.6	76.8	127.5	254.9
2010	50	59.0	16.1	140.9	216.0	2010	440	62.6	76.8	149.5	288.9
WHEAT						CITRUS					
1991	40	12.0	12.9	44.2	69.1	1991	500	28.4	69.4	104.8	202.6
1995	40	17.7	12.9	55.5	86.1	1995	500	41.9	69.4	131.7	243.0
2000	40	25.5	12.9	68.2	106.6	2000	500	60.6	69.4	161.9	291.9
2005	40	32.5	12.9	82.0	127.4	2005	500	77.2	69.4	194.6	341.2
2010	40	40.3	12.9	96.2	149.4	2010	500	95.6	69.4	228.2	393.2
GRAPE						TOMATO					
1991	180	23.6	73.1	86.9	183.6	1991	360	15.4	43.7	56.7	115.8
1995	180	34.7	73.1	109.2	217.0	1995	360	22.7	43.7	71.3	137.7
2000	180	50.2	73.1	134.2	257.5	2000	360	32.8	43.7	87.7	164.2
2005	180	64.0	73.1	161.4	298.5	2005	360	41.8	43.7	105.4	190.9
2010	180	79.3	73.1	189.2	341.6	2010	360	51.8	43.7	123.6	219.1

Fig. 8.4 *Actual Crop Returns*

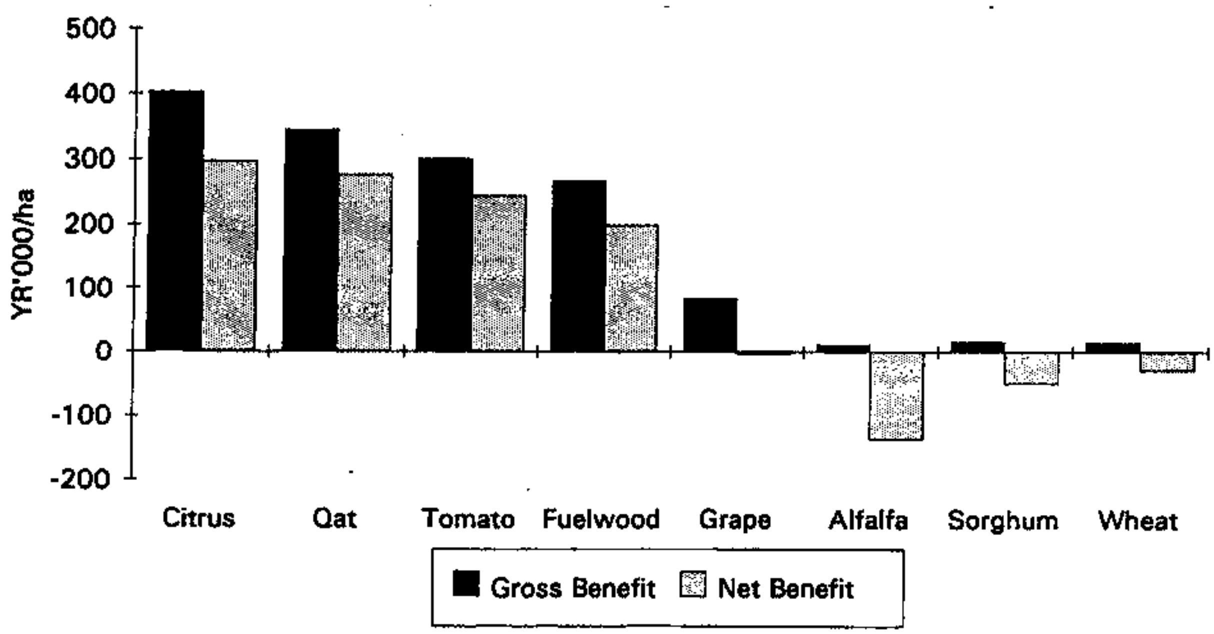


Table 8.4 *Comparative Crop Benefits (YR'000/ha)*

CROP	Yield(1) (t/ha)	Value	Income	Production Cost	Gross Benefit	Capital Cost	Net Benefit
Citrus	25.0	20.0	500	98	402	105	297
Qat	2.0	220.0	440	95	345	69	276
Tomato(2)	24.0	15.0	360	59	301	57	244
Fuelwood	200.0	1.5	300	33	267	69	199
Grape	12.0	15.0	180	97	83	87	(4)
Alfalfa	40.0	1.5	60	49	11	149	(137)
Sorghum(3)	4.0	12.4	50	34	16	65	(49)
Wheat(3)	3.5	11.4	40	25	15	44	(29)

Note
(1) Year 1 Yields
(2) "Mid-season" price: Ranges from YR 5 to YR 60 kg
(3) Including stover/straw

The cost of local production compared with the equivalent costs of imported produce are shown in Fig. 8.5 (Table 8.5), for the full cost of water, and for running costs only. The true cost of "taste-preference" for local produce is demonstrated clearly for the cereals.

Fig. 8.5 *Import Prices Compared with Production Costs (YR'000/tonne)*

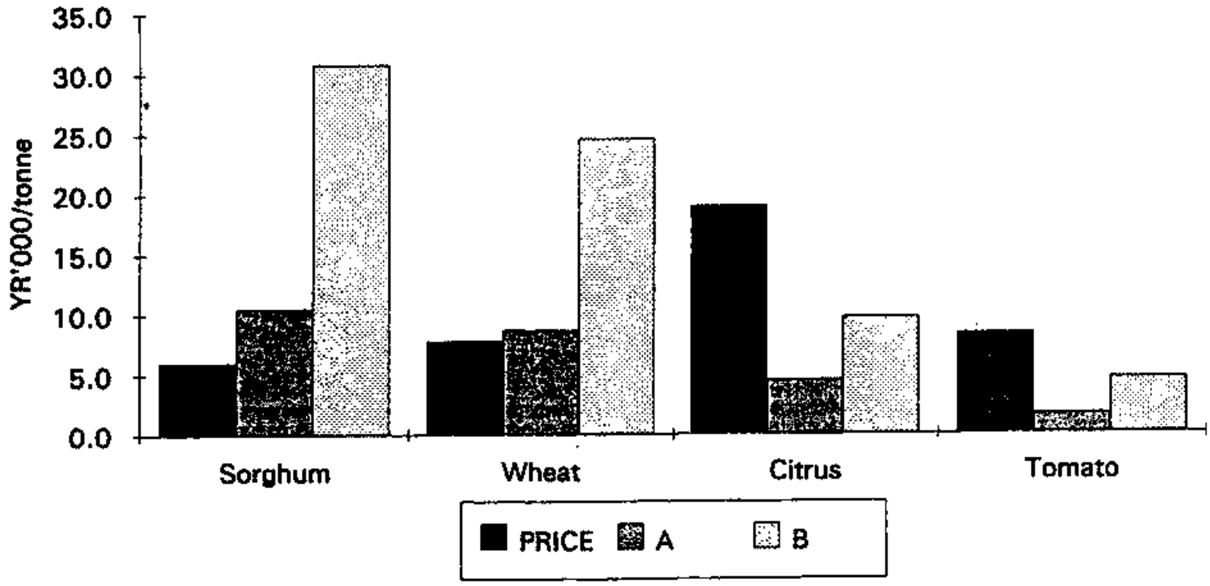


Table 8.5 *Import Prices Compared with Production Costs (YR'000/tonne)*

CROP	IMPORT PRICE	COST OF PRODUCTION (1)	
		A	B
Sorghum	6.0	10.5	30.8
Wheat	7.8	8.7	24.6
Citrus	19.0	4.5	9.7
Tomato	8.3	1.6	4.6

Note
(1) A - Includes irrigation running costs only;
B - Includes irrigation capital costs also

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4. Groundwater Resources in the Attaf Plain
5. Groundwater Resources in the Al Hamra Plain
6. Groundwater Resources in the Al Ashshah Plain
7. Groundwater Resources in the Al Harf Plain
8. Groundwater Resources in the Sa'dah Plain
9. Groundwater Resources in the Baqim Plain
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20. Water Management Plan - Baqim target area
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Multi-purpose dams

22. Reconnaissance Study for Preselection of Small Dams (51 sites)
23. Feasibility Studies for Six Multi-purpose Dams

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24. Soil investigation of four SSHARDA Demo Farms
25. Soil and Water investigations of Four Private Demo Farms
26. Tender Design, Bid Documents and Layout Drawings for Modern Irrigation Systems of Four SSHARDA and Four Private Demo Farms

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ANNEX 1

FARM FAMILY BUDGETS
AND
COST BENEFIT ANALYSES

FARM FAMILY BUDGETS

ANNUAL FAMILY BUDGET SMALL FARM – SA'DAH PLAIN

ASSUMPTIONS

- Farm area 0.75 ha, fully under irrigation
- Family of 6 persons, of whom 3 work fully or partly on the farm
- 20 sheep and goats, and 3 cattle are owned by the farmer

CROPPING PLAN & INCOME (YR'000)

CROPS		Area (ha)	Yield (t/ha)	Value (per t)	Sum	Income
Grape		0.25	12.0	15.0	45	45
Wheat	– Grain	0.50	3.5	10.6	19	20
	– Straw		2.0	1.5	2	
Sorghum	– Grain	0.50	4.0	11.4	23	25
	– Stover		4.0	1.0	2	
	GROSS CROP INCOME					90

OPERATING & PRODUCTION COSTS (YR'000)

OPERATION (per ha)		Grape	Wheat	Sorghum	
Land preparation		3.6	2.3	2.3	
Cultivation		19.3	1.4	2.1	
Inputs		8.0	2.3	3.0	
Irrigation		25.2	11.9	17.4	
Plant protection		5.4	1.6	0.8	
Harvesting		12.9	0.8	1.9	
Threshing			0.4	0.9	
Packing		13.3	1.4	2.1	
Marketing		8.6	0.7	1.0	
Depreciation		7.7	5.6	5.6	
	SUM	104.0	28.4	37.1	
AREA OF CROP (ha)		0.25	0.50	0.50	
PRODUCTION COSTS		26.0	14.2	18.6	59
Family Labour %		60	60	70	

ANNUAL FAMILY BUDGET SMALL FARM – SA'DAH PLAIN

FAMILY COST/BENEFIT ACCOUNT (YR'000)

GROSS CROP INCOME			
Grape		45	
Wheat		20	
Sorghum		25	
	SUM	90	
OTHER INCOME			
Livestock		24	
Casual Labour		9	
	SUM	33	
TOTAL GROSS INCOME			123
PRODUCTION COSTS			
Grape		26	
Wheat		14	
Sorghum		19	
	SUM	59	
GROSS BENEFIT			64
LESS			
Zakat & other taxes		4	
Cost of Capital		2	
	SUM	6	
NET BENEFIT			58

RETURN TO LABOUR

Family input to cultivation and animal care:

Days per year	640
Gross Return	100 YR/day
Net Return	90 YR/day

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ANNUAL FAMILY BUDGET MEDIUM FARM – SA'DAH PLAIN

ASSUMPTIONS

- Farm area 2.5 ha: 1.5 ha fully under irrigation; 1.0 ha rainfed
- Family of 9 persons, of whom 5 work fully or partly on the farm
- 30 sheep and goats, and 5 cattle are owned by the farmer

CROPPING PLAN & INCOME (YR'000)

CROPS		Area (ha)	Yield (t/ha)	Value (per t)	Sum	Income
Irrigated						
Grape		0.50	12.0	15.0	90	90
Qat		0.25	2.0	220.0	110	110
Alfalfa		0.25	40.0	1.5	15	15
Wheat	– Grain	0.50	3.5	10.6	19	20
	– Straw		2.0	1.5	2	
Sorghum	– Grain	0.50	4.0	11.4	23	25
	– Stover		4.0	1.0	2	
Rainfed						
Sorghum	– Grain	1.00	2.0	11.4	23	25
	– Stover		2.0	1.0	2	
	GROSS CROP INCOME					285

OPERATING & PRODUCTION COSTS (YR'000)

OPERATION (per ha)		Grape	Qat	Alfa	Wheat	Srgm_I	Srgm_R	
Land preparation		3.6	3.6	2.3	2.3	2.3	2.3	
Cultivation		19.3	7.6		1.4	2.1	2.1	
Inputs		8.0	15.0	1.2	2.3	3.0	2.0	
Irrigation		25.2	20.6	34.6	11.9	17.4		
Plant protection		5.4	9.6		1.6	0.8		
Harvesting		12.9	6.5	1.6	0.8	1.9	1.9	
Threshing					0.4	0.9	0.7	
Packing		13.3	15.6		1.4	2.1	1.0	
Marketing		8.6	16.7	1.3	0.7	1.0		
Depreciation		7.7	13.4	3.1	5.6	5.6	5.6	
	SUM	104.0	108.8	44.1	28.4	37.1	15.6	
AREA OF CROP (ha)		0.50	0.25	0.25	0.50	0.50	1.00	
PRODUCTION COSTS		52.0	27.2	11.0	14.2	18.6	15.6	139
Family Labour %		60	80	100	60	70	60	

ANNUAL FAMILY BUDGET MEDIUM FARM – SA'DAH PLAIN

FAMILY COST/BENEFIT ACCOUNT (YR'000)

GROSS CROP INCOME				
Grape			90	
Qat			110	
Alfalfa			15	
Wheat			20	
Sorghum	– Irrigtd		25	
	– Rainfed		25	
		SUM	285	
OTHER INCOME				
Livestock			31	
Business			15	
		SUM	46	
	TOTAL GROSS INCOME			330
PRODUCTION COSTS				
Grape			52	
Qat			27	
Alfalfa			11	
Wheat			14	
Sorghum	– Irrigtd		19	
	– Rainfed		16	
		SUM	139	
	GROSS BENEFIT			192
LESS				
Zakat			28	
Other Taxes			11	
Cost of Capital			8	
		SUM	48	
	NET BENEFIT			144

RETURN TO LABOUR

Family input to cultivation and animal care:

Days per year	1260
Gross Return	152 YR/day
Net Return	114 YR/day

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ANNUAL FAMILY BUDGET LARGE FARM – SA'DAH PLAIN

ASSUMPTIONS

- Farm area 5.5 ha: 4.0 ha fully under irrigation; 1.5 ha rainfed
- Family of 12 persons, of whom 8 work fully or partly on the farm
- 50 sheep and goats, 6 cattle, and 3 camels are owned by the farmer
- Farmer has loans

CROPPING PLAN & INCOME (YR'000)

CROPS		Area (ha)	Yield (t/ha)	Value (per t)	Sum	Income
Irrigated						
Grape		1.00	12.0	15.0	180	180
Qat		0.25	2.0	220.0	110	110
Alfalfa		0.50	40.0	1.5	30	30
Citrus		1.00	25.0	20.0	500	500
Tomato		0.25	24.0	5.0	30	30
Barley	– Grain	1.25	3.0	9.5	36	39
	– Straw		2.0	1.5	4	
Sorghum	– Grain	1.00	4.0	11.4	46	50
	– Stover		4.0	1.0	4	
Rainfed						
Sorghum	– Grain	1.50	2.0	11.4	34	37
	– Stover		2.0	1.0	3	
	GROSS CROP INCOME					976

OPERATING & PRODUCTION COSTS (YR'000)

OPERATION (per ha)		Grape	Citrus	Qat	Alfa	Barley	Srgm_I	Tom	Srgm_R	
Land preparation		3.6	4.3	3.6	2.3	2.1	2.3	4.6	2.3	
Cultivation		19.3	20.1	7.8		0.7	2.1	7.8	2.1	
Inputs		8.0	9	15.0	1.2	1.8	3.0	6.8	2.0	
Irrigation		25.2	26.9	20.6	34.6	14.7	17.4	16.3		
Plant protection		5.4	6.9	9.6		1.6	0.8	6.5		
Harvesting		12.9	9.1	6.5	1.6	0.8	1.9	3.8	1.9	
Threshing						0.4	0.9		0.7	
Packing		13.3	8.3	15.6		1.4	2.1	8.4	1.0	
Marketing		8.6	9	16.7	1.3	0.7	1.0	3.1		
Depreciation		7.7	10.3	13.4	3.1	5.0	5.6	5.3	5.8	
	SUM	104.0	103.9	108.8	44.1	29.2	37.1	62.6	15.6	
AREA OF CROP (ha)		1.00	1.00	0.25	0.50	1.25	1.00	0.25	1.50	
PRODUCTION COSTS		104.0	103.9	27.2	22.1	36.5	37.1	15.7	23.4	370
Family Labour %		60	40	80	100	60	70	60	60	

ANNUAL FAMILY BUDGET LARGE FARM – SA'DAH PLAIN

FAMILY COST/BENEFIT ACCOUNT (YR'000)

GROSS CROP INCOME				
Grape			180	
Qat			110	
Alfalfa			30	
Citrus			500	
Tomato			30	
Barley			39	
Sorghum	– Irrigtd		50	
	– Rainfed		37	
		SUM	976	
OTHER INCOME				
Livestock			45	
Business			30	
Employment			36	
		SUM	111	
		TOTAL GROSS INCOME		1087
PRODUCTION COSTS				
Grape			104	
Qat			27	
Alfalfa			22	
Citrus			104	
Tomato			16	
Barley			37	
Sorghum	– Irrigtd		37	
	– Rainfed		23	
		SUM	370	
		GROSS BENEFIT		717
LESS				
Zakat			98	
Other Taxes			48	
Cost of Capital			154	
Credit Repayment			150	
		SUM	450	
		NET BENEFIT		268

RETURN TO LABOUR

Family input to cultivation and animal care:

Days per year	2160
Gross Return	332. YR/day
Net Return	123. YR/day

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COST BENEFIT ANALYSES

SMALL FARM – SA'DAH PLAIN BASE CASE

CROP AREAS (ha) & YIELDS (t/ha)

ITEM		AREA	YEAR 1	2	3	4	5	6	10	15	20
			YIELDS								
IRRIGATED											
Grape		0.25	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Wheat	– Grain	0.50	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
	– Straw		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Sorghum	– Grain	0.50	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	– Stover		4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

CROP PRODUCTION (tonnes), VALUE (per tonne) & GROSS INCOME (YR'000)

ITEM		VALUE	YEAR 1	2	3	4	5	6	10	15	20
			CROP PRODUCTION								
IRRIGATED											
Grape		15.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Wheat	– Grain	10.6	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	– Straw	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Sorghum	– Grain	11.4	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	– Stover	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
GROSS CROP INCOME			90	90	90	90	90	90	90	90	90

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SMALL FARM – SA'DAH PLAIN BASE CASE

CROP PRODUCTION COSTS (YR'000)

		YEAR 1	2	3	4	5	6	10	15	20
Land Prep/Cultivation		10	10	10	10	10	10	10	10	10
Inputs		5	5	5	5	5	5	5	5	5
Plant protection		3	3	3	3	3	3	3	3	3
Irrigation Water – Running (1)		21	23	26	28	30	37	44	56	69
– Lab		3	3	3	3	3	3	3	3	3
Harvesting & Threshing		5	5	5	5	5	5	5	5	5
Packing & Marketing		8	8	8	8	8	8	8	8	8
	TOTAL	54	57	59	61	64	71	77	90	103

FAMILY COST/BENEFIT ACCOUNT (YR'000)

		YEAR 1	2	3	4	5	6	10	15	20
INCOME										
Gross Crop		90	90	90	90	90	90	90	90	90
Gross Livestock		24	24	24	24	24	24	24	24	24
Employment		9	9	9	9	9	9	9	9	9
	Sum	123	123	123	123	123	123	123	123	123
COSTS										
Crop Production		54	57	59	61	64	71	77	90	103
	Sum	54	57	59	61	64	71	77	90	103
GROSS BENEFIT		69	66	64	61	59	52	45	33	20
LESS										
Depreciation		8	8	8	8	8	8	8	8	8
Zakat		7	7	6	6	6	5	5	3	2
Cost of capital		2	2	2						
	Sum	16	16	16	14	13	13	12	11	9
NET BENEFIT		52	50	48	48	45	39	33	22	10

Note
(1) O&M plus Diesel

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SMALL FARM – SA'DAH PLAIN CASE 1

CROP AREAS (ha) & YIELDS (t/ha)

ITEM		AREA	YEAR 1	2	3	4	YIELDS 5	6	10	15	20
IRRIGATED											
Grape		0.25	12.0	12.0	12.5	13.0	14.0	15.0	20.0	20.0	20.0
Wheat	– Grain	0.50	3.5	3.6	3.8	4.0	4.2	4.5	4.5	4.5	4.5
	– Straw		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Sorghum	– Grain	0.50	4.0	4.1	4.3	4.5	4.5	4.5	4.5	4.5	4.5
	– Stover		4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

CROP PRODUCTION (tonnes), VALUE (per tonne) & GROSS INCOME (YR'000)

ITEM		VALUE	YEAR 1	2	3	4	CROP PRODUCTION 5	6	10	15	20
IRRIGATED											
Grape		15.0	3.0	3.0	3.1	3.3	3.5	3.8	5.0	5.0	5.0
Wheat	– Grain	10.6	1.8	1.8	1.9	2.0	2.1	2.3	2.3	2.3	2.3
	– Straw	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Sorghum	– Grain	11.4	2.0	2.1	2.2	2.3	2.3	2.3	2.3	2.3	2.3
	– Stover	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
GROSS CROP INCOME			90	91	95	99	104	109	128	128	128

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SMALL FARM – SA'DAH PLAIN CASE 1

CROP PRODUCTION COSTS (YR'000)

		YEAR 1	2	3	4	5	6	10	15	20
Land Prep/Cultivation		10	10	10	10	10	10	10	10	10
Inputs		5	6	6	6	7	7	7	7	7
Plant protection		3	3	3	3	3	3	3	3	3
Irrigation Water – Running (1)		21	19	20	21	22	27	32	41	51
– Lab		3	3	3	3	3	3	3	3	3
Harvesting& Threshing		5	5	5	5	5	5	5	5	5
Packing & Marketing		8	8	8	8	8	8	8	8	8
	TOTAL	54	53	55	56	57	63	68	77	86

FAMILY COST/BENEFIT ACCOUNT (YR'000)

		YEAR 1	2	3	4	5	6	10	15	20
INCOME										
Gross Crop		90	91	95	99	104	109	128	128	128
Gross Livestock		24	24	24	24	24	24	24	24	24
Employment		9	9	9	9	9	9	9	9	9
	Sum	123	124	128	132	137	142	161	161	161
COSTS										
Crop Production		54	53	55	56	57	63	68	77	86
	Sum	54	53	55	56	57	63	68	77	86
GROSS BENEFIT		69	71	73	76	79	79	93	84	74
LESS										
Depreciation		8	8	8	8	8	8	8	8	8
Zakat		7	7	7	8	8	8	9	8	7
Cost of capital		2	2	2						
Credit Repayments			4	4	4	4	4			
	Sum	16	21	21	19	19	19	17	16	15
NET BENEFIT		52	50	52	56	60	60	76	68	59

Note
(1) O&M plus Diesel

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SMALL FARM – SA'DAH PLAIN CASE 2

CROP AREAS (ha) & YIELDS (t/ha)

ITEM		AREA	YEAR 1	2	3	4	5	6	10	15	20
			YIELDS								
IRRIGATED											
Grape		0.25	12.0	12.0	12.5	13.0	14.0	15.0	20.0	20.0	20.0
Wheat	– Grain	0.50	3.5	3.6	3.8	4.0	4.2	4.5	4.5	4.5	4.5
	– Straw		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Sorghum	– Grain	0.50	4.0	4.1	4.3	4.5	4.5	4.5	4.5	4.5	4.5
	– Stover		4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

CROP PRODUCTION (tonnes), VALUE (per tonne) & GROSS INCOME (YR'000)

ITEM		VALUE	YEAR 1	2	3	4	5	6	10	15	20
			CROP PRODUCTION								
IRRIGATED											
Grape		15.0	3.0	3.0	3.1	3.3	3.5	3.8	5.0	5.0	5.0
Wheat	– Grain	10.6	1.8	1.8	1.9	2.0	2.1	2.3	2.3	2.3	2.3
	– Straw	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Sorghum	– Grain	11.4	2.0	2.1	2.2	2.3	2.3	2.3	2.3	2.3	2.3
	– Stover	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
GROSS CROP INCOME			90	91	95	99	104	109	128	128	128

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SMALL FARM – SA'DAH PLAIN CASE 2

CROP PRODUCTION COSTS (YR'000)

		YEAR 1	2	3	4	5	6	10	15	20
Land Prep/Cultivation		10	10	10	10	10	10	10	10	10
Inputs		5	6	6	6	7	7	7	7	7
Plant protection		3	3	3	3	3	3	3	3	3
Irrigation Water – Running (1)		21	19	16	17	18	22	26	34	42
– Lab		3	3	3	3	3	3	3	3	3
Irrig Equipment Maintenance				6	6	6	6	6	6	6
Harvesting & Threshing		5	5	5	5	5	5	5	5	5
Packing & Marketing		8	8	8	8	8	8	8	8	8
	TOTAL	54	53	57	58	60	64	68	76	84

FAMILY COST/BENEFIT ACCOUNT (YR'000)

		YEAR 1	2	3	4	5	6	10	15	20
INCOME										
Gross Crop		90	91	95	99	104	109	128	128	128
Gross Livestock		24	24	24	24	24	24	24	24	24
Employment		9	9	9	9	9	9	9	9	9
	Sum	123	124	128	132	137	142	161	161	161
COSTS										
Crop Production		54	53	57	58	60	64	68	76	84
	Sum	54	53	57	58	60	64	68	76	84
GROSS BENEFIT		69	71	71	73	77	78	92	85	77
LESS										
Depreciation		8	8	8	8	8	8	8	8	8
Zakat		7	7	7	7	8	8	9	9	8
Cost of Capital		2	2	2						
Credit Repayments			4	15	15	15	15	3	3	3
	Sum	16	21	32	30	30	30	19	19	18
NET BENEFIT		52	50	39	44	47	47	73	66	59

Note
(1) O&M plus Diesel

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MEDIUM FARM – SA'DAH PLAIN BASE CASE

CROP AREAS (ha) & YIELDS (t/ha)

ITEM		AREA	YEAR 1	2	3	4	5	6	10	15	20
			YIELDS								
IRRIGATED											
Grape		0.50	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Qat		0.25	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Alfalfa		0.25	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Wheat	– Grain	0.50	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
	– Straw		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Sorghum	– Grain	0.50	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	– Stover		4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
RAINFED											
Sorghum *	– Grain	1.00	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	– Stover		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

CROP PRODUCTION (tonnes), VALUE (per tonne) & GROSS INCOME (YR'000)

ITEM		VALUE	YEAR 1	2	3	4	5	6	10	15	20
			CROP PRODUCTION								
IRRIGATED											
Grape		15.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Qat		220.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Alfalfa		1.5	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Wheat	– Grain	10.6	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	– Straw	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Sorghum	– Grain	11.4	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	– Stover	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
RAINFED											
Sorghum	– Grain	11.4	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	– Stover	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
GROSS CROP INCOME			285	285	285	285	285	285	285	285	285

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MEDIUM FARM – SA'DAH PLAIN BASE CASE

CROP PRODUCTION COSTS (YR'000)

		YEAR 1	2	3	4	5	6	10	15	20
Land Prep/Cultivation		23	23	23	23	23	23	23	23	23
Inputs		13	13	13	13	13	13	13	13	13
Plant protection		6	6	6	6	6	6	6	6	6
Irrigation Water	–Running (1)	41	46	51	56	61	75	88	112	139
	– Labour	6	6	6	6	6	6	6	6	6
Harvesting & Threshing		13	13	13	13	13	13	13	13	13
Packing & Marketing		23	23	23	23	23	23	23	23	23
	TOTAL	126	131	136	140	145	159	173	197	223

FAMILY COST/BENEFIT ACCOUNT (YR'000)

		YEAR 1	2	3	4	5	6	10	15	20
INCOME										
Gross Crop		285	285	285	285	285	285	285	285	285
Gross Livestock		31	31	31	31	31	31	31	31	31
Business		15	15	15	15	15	15	15	15	15
	Sum	330	330	330	330	330	330	330	330	330
COSTS										
Crop Production		126	131	136	140	145	159	173	197	223
	Sum	126	131	136	140	145	159	173	197	223
GROSS BENEFIT		205	200	195	190	185	171	158	134	107
LESS										
Depreciation		19	19	19	19	19	19	19	19	19
Zakat		20	20	19	19	19	17	16	13	11
Other Taxes		19	19	20	20	20	22	23	26	28
Cost of Capital		8	8	8						
	Sum	66	66	66	58	58	58	58	58	58
NET BENEFIT		138	133	128	132	127	113	100	76	49

Note
(1) O&M plus Diesel

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MEDIUM FARM – SA'DAH PLAIN CASE 1

CROP AREAS (ha) & YIELDS (t/ha)

ITEM		AREA	YEAR 1	2	3	4	5	6	10	15	20
			YIELDS								
IRRIGATED											
Grape		0.50	12.0	12.0	12.5	13.0	14.0	15.0	20.0	20.0	20.0
Qat		0.25	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.0	3.0
Alfalfa		0.25	40.0	42.0	45.0	50.0	55.0	60.0	60.0	60.0	60.0
Wheat	– Grain	0.50	3.5	3.6	3.8	4.0	4.2	4.5	4.5	4.5	4.5
	– Straw		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Sorghum	– Grain	0.50	4.0	4.1	4.3	4.5	4.5	4.5	4.5	4.5	4.5
	– Stover		4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
RAINFED											
Sorghum	– Grain	1.00	2.0	2.2	2.4	2.6	2.8	3.0	3.0	3.0	3.0
	– Stover		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

CROP PRODUCTION (tonnes), VALUE (per tonne) & GROSS INCOME (YR'000)

ITEM		VALUE	YEAR 1	2	3	4	5	6	10	15	20
			CROP PRODUCTION								
IRRIGATED											
Grape		15.0	6.0	6.0	6.3	6.5	7.0	7.5	10.0	10.0	10.0
Qat		220.0	0.5	0.5	0.6	0.6	0.8	0.8	0.8	0.8	0.8
Alfalfa		1.5	10.0	10.5	11.3	12.5	13.8	15.0	15.0	15.0	15.0
Wheat	– Grain	10.6	1.8	1.8	1.9	2.0	2.1	2.3	2.3	2.3	2.3
	– Straw	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Sorghum	– Grain	11.4	2.0	2.1	2.2	2.3	2.3	2.3	2.3	2.3	2.3
	– Stover	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
RAINFED											
Sorghum	– Grain	11.4	2.0	2.2	2.4	2.6	2.8	3.0	3.0	3.0	3.0
	– Stover	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
GROSS CROP INCOME			285	289	326	336	376	389	427	427	427

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MEDIUM FARM – SA'DAH PLAIN CASE 1

CROP PRODUCTION COSTS (YR'000)

		YEAR 1	2	3	4	5	6	10	15	20
Land Prep/Cultivation		23	23	23	23	23	23	23	23	23
Inputs		13	16	17	17	18	19	19	19	19
Plant protection		6	6	6	6	6	6	6	6	6
Irrigation Water	– Running (1)	41	37	40	42	44	55	64	82	101
	– Labour	6	6	6	6	6	6	6	6	6
Harvesting & Threshing		13	13	13	13	13	13	13	13	13
Packing & Marketing		23	23	23	23	23	23	23	23	23
	TOTAL	126	125	128	131	134	145	155	173	192

FAMILY COST/BENEFIT ACCOUNT (YR'000)

		YEAR 1	2	3	4	5	6	10	15	20
INCOME										
Gross Crop		285	289	326	336	376	389	427	427	427
Gross Livestock		31	31	31	31	31	31	31	31	31
Business		15	15	15	15	15	15	15	15	15
	Sum	330	335	371	382	422	435	473	473	473
COSTS										
Crop Production		126	125	128	131	134	145	155	173	192
	Sum	126	125	128	131	134	145	155	173	192
GROSS BENEFIT		205	210	243	250	288	290	317	300	280
LESS										
Depreciation		19	19	19	19	19	19	19	19	19
Zakat		20	21	24	25	29	29	32	30	28
Other Taxes		19	18	15	14	10	10	7	9	11
Cost of Capital		8	8	8						
Credit Repayments			6	6	6	6	6			
	Sum	66	72	72	64	64	64	58	58	58
NET BENEFIT		138	138	171	186	223	225	259	242	222

Note
(1) O&M plus Diesel

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MEDIUM FARM – SA'DAH PLAIN CASE 2

CROP AREAS (ha) & YIELDS (t/ha)

ITEM		AREA	YEAR 1	2	3	4	5	6	10	15	20
			YIELDS								
IRRIGATED											
Grape		0.50	12.0	12.0	12.5	13.0	14.0	15.0	20.0	20.0	20.0
Qat		0.25	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.0	3.0
Alfalfa		0.25	40.0	42.0	45.0	50.0	55.0	60.0	60.0	60.0	60.0
Wheat	– Grain	0.50	3.5	3.6	3.8	4.0	4.2	4.5	4.5	4.5	4.5
	– Straw		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Sorghum	– Grain	0.50	4.0	4.1	4.3	4.5	4.5	4.5	4.5	4.5	4.5
	– Stover		4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
RAINFED											
Sorghum	– Grain	1.00	2.0	2.2	2.4	2.6	2.8	3.0	3.0	3.0	3.0
	– Stover		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

CROP PRODUCTION (tonnes), VALUE (per tonne) & GROSS INCOME (YR'000)

ITEM		VALUE	YEAR 1	2	3	4	5	6	10	15	20
			CROP PRODUCTION								
IRRIGATED											
Grape		15.0	6.0	6.0	6.3	6.5	7.0	7.5	10.0	10.0	10.0
Qat		220.0	0.5	0.5	0.6	0.6	0.8	0.8	0.8	0.8	0.8
Alfalfa		1.5	10.0	10.5	11.3	12.5	13.8	15.0	15.0	15.0	15.0
Wheat	– Grain	10.6	1.8	1.8	1.9	2.0	2.1	2.3	2.3	2.3	2.3
	– Straw	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Sorghum	– Grain	11.4	2.0	2.1	2.2	2.3	2.3	2.3	2.3	2.3	2.3
	– Stover	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
RAINFED											
Sorghum	– Grain	11.4	2.0	2.2	2.4	2.6	2.8	3.0	3.0	3.0	3.0
	– Stover	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
GROSS CROP INCOME			285	289	326	336	376	389	427	427	427

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MEDIUM FARM – SA'DAH PLAIN CASE 2

CROP PRODUCTION COSTS (YR'000)

		YEAR 1	2	3	4	5	6	10	15	20
Land Prep/Cultivation		23	23	23	23	23	23	23	23	23
Inputs		13	16	17	17	18	19	19	19	19
Plant protection		6	6	6	6	6	6	6	6	6
Irrigation Water	– O & M	41	37	32	34	37	45	53	67	83
	– Labour	6	6	6	6	6	6	6	6	6
Irrig Equipmnt Maintenance				25	25	25	25	25	25	25
Harvesting & Threshing		13	13	13	13	13	13	13	13	13
Packing & Marketing		23	23	23	23	23	23	23	23	23
	TOTAL	126	125	145	148	151	161	169	183	199

FAMILY COST/BENEFIT ACCOUNT (YR'000)

		YEAR 1	2	3	4	5	6	10	15	20
INCOME										
Gross Crop		285	289	326	336	376	389	427	427	427
Gross Livestock		31	31	31	31	31	31	31	31	31
Business		15	15	15	15	15	15	15	15	15
	Sum	330	335	371	382	422	435	473	473	473
COSTS										
Crop Production		126	125	145	148	151	161	169	183	199
	Sum	126	125	145	148	151	161	169	183	199
GROSS BENEFIT		205	210	226	233	271	274	304	289	273
LESS										
Depreciation		19	19	19	19	19	19	19	19	19
Zakat		20	21	23	23	27	27	30	29	27
Other Taxes		19	18	16	16	12	12	9	10	12
Cost of Capital		8	8	8						
Credit Repayments			6	50	50	50	50	11	11	11
	Sum	66	72	116	108	108	108	69	69	69
NET BENEFIT		138	138	110	125	163	167	235	220	204

Notes
(1) O&M plus Diesel

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LARGE FARM – SA'DAH PLAIN BASE CASE

CROP AREAS (ha) & YIELDS (t/ha)

ITEM		AREA	YEAR 1	2	3	4	5	6	10	15	20
			YIELDS								
IRRIGATED											
Grape		1.00	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Citrus		1.00	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Qat		0.25	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Alfalfa		0.50	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Sorghum	– Grain	1.00	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	– Stover		4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Barley	– Grain	1.25	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	– Straw		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Tomato		0.25	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
RAINFED											
Sorghum	– Grain	1.50	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	– Stover		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

CROP PRODUCTION (tonnes), VALUE (per tonne) & GROSS INCOME (YR'000)

ITEM		VALUE	YEAR 1	2	3	4	5	6	10	15	20
			CROP PRODUCTION								
IRRIGATED											
Grape		15.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Citrus		20.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Qat		220.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Alfalfa		1.5	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Sorghum	– Grain	11.4	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	– Stover	1.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Barley	– Grain	9.5	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
	– Straw	1.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Tomato		5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
RAINFED											
Sorghum	– Grain	11.4	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	– Stover	1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
GROSS CROP INCOME			976	976	976	976	976	976	976	976	976

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LARGE FARM – SA'DAH PLAIN BASE CASE

CROP PRODUCTION COSTS (YR'000)

		YEAR 1	2	3	4	5	6	10	15	20
Land Prep/Cultivation		69	69	69	69	69	69	69	69	69
Inputs		31	31	31	31	31	31	31	31	31
Plant protection		19	19	19	19	19	19	19	19	19
Irrigation Water	– Running (1)	114	128	141	154	168	206	243	309	383
	– Labour	17	17	17	17	17	17	17	17	17
Harvesting & Threshing		34	34	34	34	34	34	34	34	34
Packing & Marketing		58	58	58	58	58	58	58	58	58
	TOTAL	342	355	369	382	396	434	470	537	611

FAMILY COST/BENEFIT ACCOUNT (YR'000)

		YEAR 1	2	3	4	5	6	10	15	20
INCOME										
Gross Crop		976	976	976	976	976	976	976	976	976
Gross Livestock		45	45	45	45	45	45	45	45	45
Business		30	30	30	30	30	30	30	30	30
Employment		36	36	36	36	36	36	36	36	36
	Sum	1087	1087	1087	1087	1087	1087	1087	1087	1087
COSTS										
Crop Production		342	355	369	382	396	434	470	537	611
	Sum	342	355	369	382	396	434	470	537	611
GROSS BENEFIT		745	732	718	705	691	654	617	550	477
LESS										
Depreciation		44	44	44	44	44	44	44	44	44
Zakat		75	73	72	71	69	65	62	55	48
Other Taxes		71	73	74	75	77	81	84	91	98
Cost of Capital		154	154	154						
Credit Repayments		150	150	150	150	150				
	Sum	494	494	494	340	340	190	190	190	190
NET BENEFIT		251	237	223	365	351	463	426	360	286

Note
(1) O&M plus Diesel

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CROP AREAS (ha) & YIELDS (t/ha)

ITEM		AREA	YEAR 1	2	3	4	5	6	10	15	20
			YIELDS								
IRRIGATED											
Grape		1.00	12.0	12.0	12.5	13.0	14.0	15.0	20.0	20.0	20.0
Citrus		1.00	25.0	26.0	27.0	28.0	29.0	30.0	30.0	30.0	30.0
Qat		0.25	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.0	3.0
Alfalfa		0.50	40.0	42.0	45.0	50.0	55.0	60.0	60.0	60.0	60.0
Sorghum	– Grain	1.00	4.0	4.1	4.3	4.5	4.5	4.5	4.5	4.5	4.5
	– Stover		4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Barley	– Grain	1.25	3.0	3.1	3.3	3.5	3.7	4.0	4.0	4.0	4.0
	– Straw		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Tomato		0.25	24.0	25.0	26.0	27.0	28.0	30.0	30.0	30.0	30.0
RAINFED											
Sorghum	– Grain	1.50	2.0	2.2	2.4	2.6	2.8	3.0	3.0	3.0	3.0
	– Stover		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

CROP PRODUCTION (tonnes), VALUE (per tonne) & GROSS INCOME (YR'000)

ITEM		VALUE	YEAR 1	2	3	4	5	6	10	15	20
			CROP PRODUCTION								
IRRIGATED											
Grape		15.0	12.0	12.0	12.5	13.0	14.0	15.0	20.0	20.0	20.0
Citrus		20.0	25.0	26.0	27.0	28.0	29.0	30.0	30.0	30.0	30.0
Qat		220.0	0.5	0.5	0.6	0.6	0.8	0.8	0.8	0.8	0.8
Alfalfa		1.5	20.0	21.0	22.5	25.0	27.5	30.0	30.0	30.0	30.0
Sorghum	– Grain	11.4	4.0	4.1	4.3	4.5	4.5	4.5	4.5	4.5	4.5
	– Stover	1.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Barley	– Grain	9.5	3.8	3.9	4.1	4.4	4.6	5.0	5.0	5.0	5.0
	– Straw	1.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Tomato		5.0	6.0	6.3	6.5	6.8	7.0	7.5	7.5	7.5	7.5
RAINFED											
Sorghum	– Grain	11.4	3.0	3.3	3.6	3.9	4.2	4.5	4.5	4.5	4.5
	– Stover	1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
GROSS CROP INCOME			976	1005	1071	1112	1185	1233	1308	1308	1308

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LARGE FARM – SA'DAH PLAIN CASE 1

CROP PRODUCTION COSTS (YR'000)

		YEAR 1	2	3	4	5	6	10	15	20
Land Prep/Cultivation		69	69	69	69	69	69	69	69	69
Inputs		31	39	41	42	44	47	47	47	47
Plant protection		19	19	19	19	19	19	19	19	19
Irrigation Water	– Running (1)	114	102	110	117	122	150	177	226	279
	– Labour	17	17	17	17	17	17	17	17	17
Harvesting & Threshing		34	34	34	34	34	34	34	34	34
Packing & Marketing		58	58	58	58	58	58	58	58	58
	TOTAL	342	338	348	356	363	394	421	469	523

FAMILY COST/BENEFIT ACCOUNT (YR'000)

		YEAR 1	2	3	4	5	6	10	15	20
INCOME										
Gross Crop		976	1005	1071	1112	1185	1233	1308	1308	1308
Gross Livestock		45	45	45	45	45	45	45	45	45
Business		30	30	30	30	30	30	30	30	30
Employment		36	36	36	36	36	36	36	36	36
	Sum	1087	1116	1182	1223	1296	1344	1419	1419	1419
COSTS										
Crop Production		342	338	348	356	363	394	421	469	523
	Sum	342	338	348	356	363	394	421	469	523
GROSS BENEFIT		745	778	835	867	933	951	999	950	896
LESS										
Depreciation		44	44	44	44	44	44	44	44	44
Zakat		75	78	83	87	93	95	100	95	90
Other Taxes		71	68	63	59	53	51	46	51	56
Cost of Capital		154	154	154						
Credit Repayments		150	166	166	166	166	166	150	150	150
	Sum	494	511	511	357	357	357	340	340	340
NET BENEFIT		251	267	324	510	576	594	658	610	556

Note
(1) O&M plus Diesel

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CROP AREAS (ha) & YIELDS (t/ha)

ITEM		AREA	YEAR 1	2	3	4	5	6	10	15	20
			YIELDS								
IRRIGATED											
Grape		1.00	12.0	12.0	12.5	13.0	14.0	15.0	20.0	20.0	20.0
Citrus		1.00	25.0	26.0	27.0	28.0	29.0	30.0	30.0	30.0	30.0
Qat		0.25	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.0	3.0
Alfalfa		0.50	40.0	42.0	45.0	50.0	55.0	60.0	60.0	60.0	60.0
Sorghum	– Grain	1.00	4.0	4.1	4.3	4.5	4.5	4.5	4.5	4.5	4.5
	– Stover		4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Barley	– Grain	1.25	3.0	3.1	3.3	3.5	3.7	4.0	4.0	4.0	4.0
	– Straw		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Tomato		0.25	24.0	25.0	26.0	27.0	28.0	30.0	30.0	30.0	30.0
RAINFED											
Sorghum	– Grain	1.50	2.0	2.2	2.4	2.6	2.8	3.0	3.0	3.0	3.0
	– Stover		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

CROP PRODUCTION (tonnes), VALUE (per tonne) & GROSS INCOME (YR'000)

ITEM		VALUE	YEAR 1	2	3	4	5	6	10	15	20
			CROP PRODUCTION								
IRRIGATED											
Grape		15.0	12.0	12.0	12.5	13.0	14.0	15.0	20.0	20.0	20.0
Citrus		20.0	25.0	26.0	27.0	28.0	29.0	30.0	30.0	30.0	30.0
Qat		220.0	0.5	0.5	0.6	0.6	0.8	0.8	0.8	0.8	0.8
Alfalfa		1.5	20.0	21.0	22.5	25.0	27.5	30.0	30.0	30.0	30.0
Sorghum	– Grain	11.4	4.0	4.1	4.3	4.5	4.5	4.5	4.5	4.5	4.5
	– Stover	1.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Barley	– Grain	9.5	3.8	3.9	4.1	4.4	4.6	5.0	5.0	5.0	5.0
	– Straw	1.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Tomato		5.0	6.0	6.3	6.5	6.8	7.0	7.5	7.5	7.5	7.5
RAINFED											
Sorghum	– Grain	11.4	3.0	3.3	3.6	3.9	4.2	4.5	4.5	4.5	4.5
	– Stover	1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
GROSS CROP INCOME			976	1005	1071	1112	1185	1233	1308	1308	1308

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7 September 1993

LARGE FARM – SA'DAH PLAIN CASE 2

CROP PRODUCTION COSTS (YR'000)

		YEAR 1	2	3	4	5	6	10	15	20
Land Prep/Cultivation		69	69	69	69	69	69	69	69	69
Inputs		31	39	41	42	44	47	47	47	47
Plant protection		19	19	19	19	19	19	19	19	19
Irrigation Water	– Running (1)	114	102	88	95	101	123	146	185	230
	– Labour	17	17	17	17	17	17	17	17	17
Irrig Equipment Maintenance			38	38	38	63	63	63	63	63
Harvesting & Threshing		34	34	34	34	34	34	34	34	34
Packing & Marketing		58	58	58	58	58	58	58	58	58
	TOTAL	342	375	363	371	404	430	452	492	536

FAMILY COST/BENEFIT ACCOUNT (YR'000)

		YEAR 1	2	3	4	5	6	10	15	20
INCOME										
Gross Crop		976	1005	1071	1112	1185	1233	1308	1308	1308
Gross Livestock		45	45	45	45	45	45	45	45	45
Business		30	30	30	30	30	30	30	30	30
Employment		36	36	36	36	36	36	36	36	36
	Sum	1087	1116	1182	1223	1296	1344	1419	1419	1419
COSTS										
Crop Production		342	375	363	371	404	430	452	492	536
	Sum	342	375	363	371	404	430	452	492	536
GROSS BENEFIT		745	740	819	852	892	915	968	928	884
LESS										
Depreciation		44	44	44	44	44	44	44	44	44
Zakat		75	74	82	85	89	91	97	93	88
Other Taxes		71	72	64	61	57	55	49	53	58
Cost of Capital		154	154	154						
Credit Repayments		150	166	231	231	274	274	177	177	177
	Sum	494	511	575	421	464	464	367	367	367
NET BENEFIT		251	230	244	431	428	451	600	560	516

Note
(1) O&M plus Diesel

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ANNEX 2

DETAILED ACTION LISTS

ANNEX 2 DETAILED ACTION LISTS

A2.1 DATA COLLECTION AND PUBLICATION

A.2.1 *Groundwater Monitoring*

- Establish a set of display material (cross-sections, contour maps, etc) to demonstrate clearly to all staff **and farmers** the most critical monitoring parameters: pumping rates, water level and salinity.
- Publish updates quarterly and distribute to all parties to ensure the message is continuously reinforced.
- Complete well inventory, using same questionnaire, **taking care to get accurate crop areas.**
- Annual monitoring programme (on a rotating sample) to note changes; specific measurements of water levels EC and yield; complete inventory for new boreholes.
- Use of GIS system linked to Database to permit monitoring and analysis of trends. NB. Such a system is being set up within MOMR under the WRAY Programme. This should be used, duplication would be a waste of resources.

A.2.2 *Hydro-Meteo Monitoring*

- Regular data collection: existing and new stations; regular publication for use in research
- Establishment of new stations as need becomes apparent (especially rain gauges)
- Liaison with other agencies to ensure common availability of data
- Setting up of raingauges and class A Evaporation Pans at Extension Centres, Demo Farms and Research Facilities for day-to-day use in irrigation scheduling

A2.2 EXTENSION

A.2.2.1 General

- Establish plans, objectives, guidelines, standards, monitoring parameters
- Research: on-farm and demo farms
- Links with others

A.2.2.1 *On-Farm Water Management*

- Crop Water Requirements
- Piped conveyance
- Field layout
- Land preparation
- Farmer co-operation to "consolidate" land holdings
- Irrigation method/crop type
- Irrigation scheduling
- Application efficiency
- Intermediate methods "gated pipe" /sub-irrigation
- Advanced (modern) methods, e.g bubbler/drip/sprinkler
- Leaching/Drainage
- Spate management

- Conjunctive use of water

A2.2.2 ***Agriculture - Rainfed & Irrigated***

- Cultivation
- Planting techniques
- Use of inputs
- Inter-cropping and agro-forestry
- Varieties, including traditional low-input ones
- Response to water and inputs
- Harvesting

A2.2.3 ***Watershed Management***

- Soil conservation
- Water conservation
- Forestry
- Vegetation
- Terrace conservation & management

A2.24 ***Commercial Livestock***

- Breeds and breed improvement
- Growth rates
- Response to feeds
- Breeding
- Animal welfare

A2.2.5 ***Diversification***

- (Agro) Forestry
  - Species
  - Planting density
  - Yield pattern
  - Water requirements
  - Harvesting
  - Use
  - Fuelwood
  - Charcoal
  - Animal feed
  - Mulching
- Dried Fruit
- Processing
  - Juice
  - Jam
- Herbs
- Essential Oils

A2.2.6 ***Marketing***

- Data gathering and dissemination
- Pre & post harvesting handling and transport
- Co-operative action (to sell in bulk)

A2.2.7 *Institution Building*

- LCCD
- Farmer Associations
- Agricultural
- Crop
- Finance
- Marketing
- SSHARDA
- Extension:
    - Existing (young) staff
    - Farmer/Extension Agents
    - Women
- Women's Groups

A2.3 APPLIED/ADAPTIVE RESEARCH

A2.3.1 General

- Establish plans, objectives, guidelines, standards, monitoring parameters
- Research: on-farm and demo farms
- Links with others

A2.3.2 Farming Systems

- Cropping patterns
- Crop husbandry
- Livestock
- Irrigation
- Labour patterns

A2.3.3 *On-Farm Water Management*

- Intermediate & advanced methods
- Scheduling/application efficiency
- Yield response to water
- Land preparation
- Yield response to salinity
- Leaching/drainage

A2.3.4 *Soil Management*

- Mulching
- Organic manure
- Chemical fertiliser
- Cultivation

A2.3.5 *Crops*

- Varieties, including low-input traditional ones
- Planting dates
- Crop seasons
- Response to inputs
- Water
- Fertiliser and Pesticides
- Fodder crops

A2.3.6 ***Intercropping***

- Crop patterns
- Individual & total yields to inputs

A2.3.7 ***Agro-forestry***

- Varieties
- Planting density
- Management, including water requirements
- Yields
- Intercropping
- Uses

A2.3.8 ***Livestock***

- Breeds and breed improvement
- Feeds
- Husbandry

ANNEX 3

MICROTUBE-BUBBLER IRRIGATION

Republic of Yemen
Ministry of Agriculture
and Water Resources

Kingdom of the Netherlands
Ministry of Foreign Affairs
Development Cooperation
(Asia) Department

THE DEVELOPMENT AND EXTENSION OF A MICROTUBE-BUBBLER IRRIGATION SYSTEM FOR FRUIT TREES

FINAL REPORT OF THE IRRIGATION EXTENSION ADVISER

Technical Note No. 50

Turner. A.E.
May 1992

Ilaco
Arnhem, The Netherlands

ABSTRACT

A high economic benefit is identified for the localised irrigation of fruit trees and the problems and requirements of the local farmers are discussed.

Bubbler irrigation systems have been used in the Republic of Yemen since 1986 but face some problems. An alternative "microtube" system overcomes these problems but introduces others. By combining the good points of both systems, a "microtube-bubbler" system has been developed which costs about Yr100 per tree (Yr40,000/ha) and is simple to operate. The system shows a benefit - cost ratio of 5.9 : 1 mainly on account of reduced operating costs.

All the necessary materials for such systems are now available on the local market and most are manufactured in the Republic of Yemen.

Extension demonstrations of this system have been made and considerable interest from farmers has been found.

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LIST OF ABBREVIATIONS

CHRDP	Central Highlands Rural Development Project
HITS	Horticultural Improvement and Training Scheme
ID	Inside diameter
OD	Outside diameter
MAWR	Ministry of Agriculture and Water Resources
NCSPIL	National Company for Sponge and Plastic Industry Limited
PVC	Polyvinylchloride
RoY	Republic of Yemen
RIRDP	Rada Integrated Rural Development Project
TDA	Tehama Development Authority
USAID	United States Agricultural Improvement and Development

1 INTRODUCTION

During the 1980's the declared policy of the Government of The Republic of Yemen was to promote import substitution and increased production of fruits. By 1989 fruit production nationally had reached some 47,000 hectares and production of fruit tree seedlings was at about 400.000 per year (MAWR, 1990).

Assuming that this area of fruit trees is given 1500mm of irrigation water annually then the national crop is using in the order of 700 million cubic metres each year.

A study was made by the Rada Integrated Rural Development Project (RIRDP.1988) on the economic impact of a range of irrigation systems on various crops. In this study it was calculated that the greatest impact on the gross margin for any of the crops which are grown in The Republic of Yemen (RoY) can be expected from the introduction of localised irrigation on fruit trees. This is partly because flood irrigation methods are not well suited for tree crops which, especially in early years, do not cover the full field area.

2 IRRIGATION REQUIREMENTS

2.1 Management and labour requirements

For centuries Yemeni farmers have been flooding fields with spate water and, more recently, with water pumped from boreholes. The flow rate is of major importance to them because it determines whether or not the water will reach their distant fields. The depth of flooding determines the amount of water applied and the duration of the flow is of only secondary importance.

Localised irrigation goes against everything which they have learnt: The concept of giving a small quantity of water over a long period of time is the exact opposite of spate irrigation: Also localised irrigation requires a high level of management whereas flood irrigation has a very low management requirement.

Drip irrigation seems to be particularly difficult for Yemeni farmers to understand because they cannot see the water except in extremely small quantities. There are very few examples in Yemen of drip irrigation systems which are successfully managed by small farmers and there are several examples of failures.

It appears that what is needed is some kind of intermediate step between flood irrigation and drip systems, a system which does not require a very high level of understanding, labour or management.

Farmers are usually very concerned with the cost of labour for irrigation and this should be reflected in the choice of extension interventions. "Solid-set" systems which remain in place throughout the life of the crop and do not need to be moved from field to field, can best meet this requirement.

2.2 Water pressure and pumping costs

Farmers are generally little concerned with saving water resources but are very much aware of the costs of running a pump. This implies that, although saving water may still be our main objective, we must concentrate on irrigation systems which give significant savings in pumping costs. This rules out systems such as sprinkler irrigation, rain guns and even high pressure drip systems because, although they may use a lower volume of water, they require a much higher operating pressure which is expensive to provide: Hussein (1991) estimates the hourly variable costs of irrigation for high pressure drip or sprinkler irrigation at Yr 55.16 compared to Yr 17.58 for traditional flood irrigation. This is unlikely to be of interest to farmers. In contrast, by concentrating on very low pressure systems, considerable savings in pumping costs and water use are possible.

2.3 Availability of materials

For successful extension of irrigation systems the necessary materials must be available in the local market.

In 1990/91 the Irrigation Systems and Technologies Project, RIRDP and the Tehama Development Authority (TDA) put much effort into encouraging the private sector in the local manufacture and supply of irrigation pipes and fittings suitable for a range of localised irrigation systems. The results were very fruitful and by late 1991 the situation was greatly improved with a range of high quality polyethylene pipes and fittings being available. A corresponding improvement in the quality of the installed systems can be noted.

2.4 Maintenance requirements

The maintenance requirements of any irrigation system are closely related to the number of moving parts involved, the operating pressure and, most of all, movement of the system. A portable, high pressure sprinkler system for example would have a relatively high maintenance requirement: pipes and sprinkler heads would be easily damaged during transport from field to field and the high pressure would exacerbate the problem. Such a system would depend heavily on imported materials and so maintenance problems would be compounded by difficulties in obtaining spare parts. Clearly this kind of system would not be appropriate for rural areas of the RoY.

What is needed is a simple, low maintenance system which would be inherently more reliable, cheaper to operate and, ideally, even possible for a farmer to maintain and repair by himself.

3 REVIEW OF PREVIOUS WORK

The development of a simple, very low head bubbler irrigation system was reported as long ago as 1977 by Rawlins, S.L. in the USA. This system was essentially a closed conduit distribution system in which each tree was supplied with water from it's own small diameter "riser pipe". The elevation of the riser pipe outlet was used to adjust the flow rate at each tree until all the trees received the same flow rate, thereby compensating for the head losses in the system.

A trial system, very similar to that developed by Rawlins, was installed in the RoY in 1986 by Twine (1986) for the Central Highlands Rural Development Project at the Risabah station and this was later followed up with some limited extension work. (Turner, A.E., 1990). These systems were based on PVC pipes which needed to be buried to avoid degradation from sunlight, and consequently they were rather expensive. Similar systems were installed in 1988/89 by the USAID HITS project in the Ibb area as well as at the Al Irra demonstration farm near Sana'a.

Rawlins used materials which were cheap and readily available in the USA and he explains clearly the procedures used for connecting the pipes in the field. But unfortunately he does not pay as much attention to the problems and costs of burying the pipes, supplying water at a constant low head and calibrating the system. In the RoY it was these problems which were found to be most difficult to overcome (Twine, J., 1987) and which limited the interest of farmers. In addition, difficulties also arose because the materials which were used in the USA were not available in the RoY and, although other pipes were available, alternative methods for connecting them had to be found.

These systems also have two serious disadvantages: Firstly, any change in the supply pressure upsets, not only the discharge, but also the uniformity of irrigation: and secondly, the elevation of each riser pipe is very easily disrupted.

Both these problems can be overcome by using the length of the riser pipe, instead of the elevation, to control the discharge, as in the microtube systems described by Vermeiren and Jobling (1984). These systems use very small diameter microtubes coupled with an operating pressure of about 1 bar and were the forerunners of drip irrigation.

These early microtube systems mainly used medium pressures, very small diameter microtubes and low flow rates in order to obtain good uniformity (Vermeiren, L. and Jobling, G.A., 1984). However they also suffered from two major disadvantages: The microtube lengths were calculated manually and, even with the use of design charts, this remained a tedious operation; and secondly, the very small diameters of microtubes which were used led to problems of clogging and hence to the need for expensive filtering systems.

By combining the good points of these alternative systems a suitable design can be made: The use of slightly larger microtubes of 3 to 4mm inside diameter with a discharge of about 50 l/hr still overcomes the problems associated with the bubbler systems but also avoids the problem of clogging which was experienced with microtube systems. It furthermore maintains the advantage of a very low operating pressure and avoids problems of ponding resulting from the even higher flow rates of bubbler systems. The problem of tedious design is now less, due to the widespread availability of personal computers and spreadsheet programmes which make it possible to quickly design each system according to the actual field conditions and thereby obtain a high irrigation uniformity.

It is this "microtube-bubbler" system which has been used by the RIRDP.

4 TECHNICAL DETAILS OF THE SELECTED SYSTEM

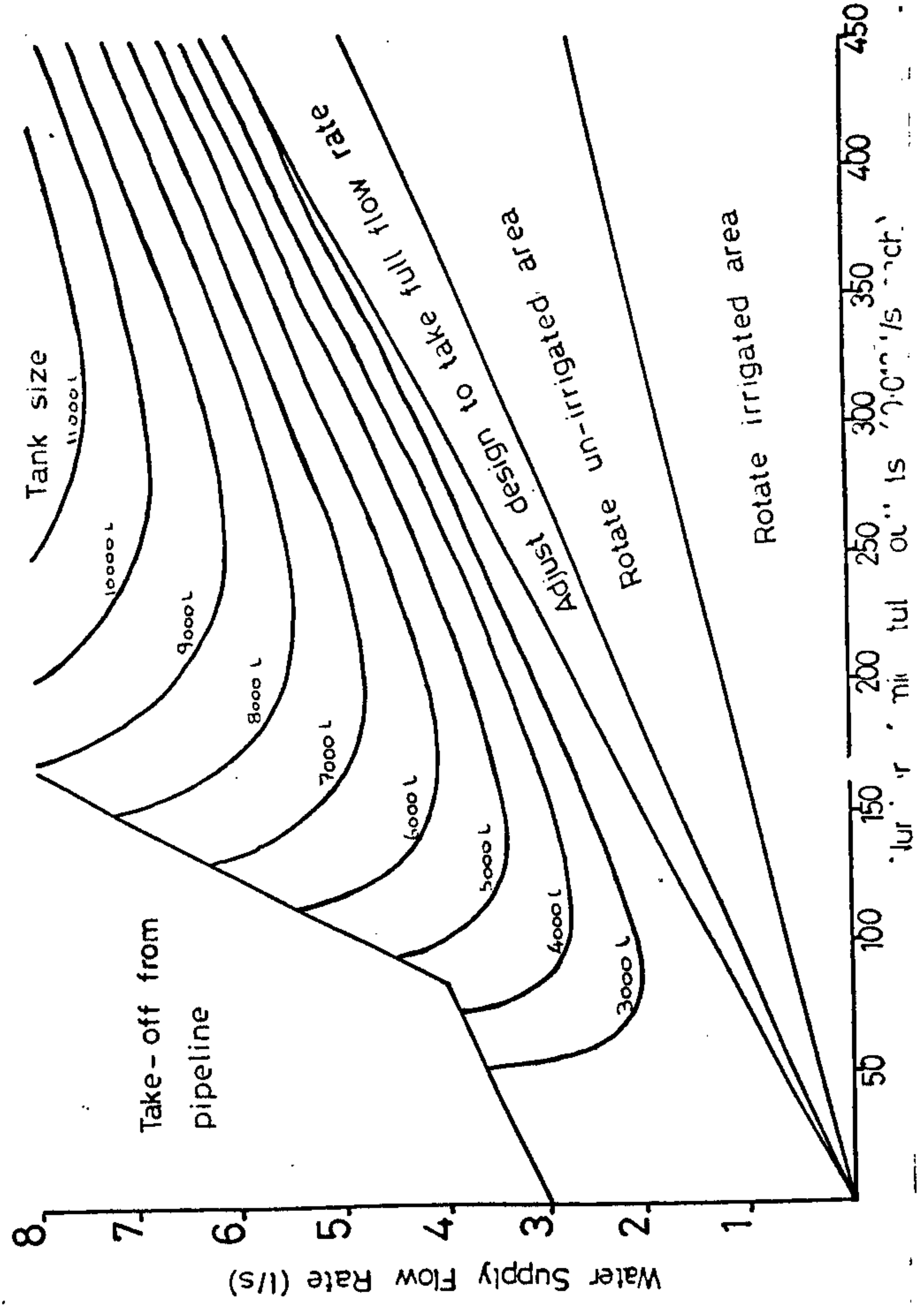
4.1 General description

The water supply for microtube-bubbler irrigation systems can be provid-d either by gravity from an elevated tank or by a low pressure take-off from a pipeline. The total head of water required to operate this system is, in most cases, 1m to 2m and it is regulated by means of a gate valve and a manometer pipe. This head delivers water to a sub-main pipe which is normally of 63mm diameter PVC sewer pipe and supplies water to all the lateral pipes at a similar pressure. (See Figure 1).

The lateral pipes may be of either 25mm or 16mm diameter polyethylene depending on the number of trees to be served in each line. In orchards which have more than 16 trees in each line it is possible to place the sub-main through the centre of the orchard and irrigate half the orchard from each side.

From each lateral pipe the small diameter microtubes carry the water to the trees. These microtubes are connected to the lateral pipe by a push fit into a hole made by a punch and their lengths are calculated to compensate for the head losses due to friction along the lateral pipe. (ie. The microtubes get shorter towards the end of the lateral pipe). Each microtube lays on the soil surface and discharges water at 0.012 l/s into a circular furrow which carries the water around the tree.

Figure 2. Water supply requirements for microtube-bubbler systems.



4.2 Design procedures

Before the design work can begin it is necessary to make a field visit to check and measure the site. A check list is given in Annex 1 which details all the information which should be collected on this visit.

4.2.1 Water supply

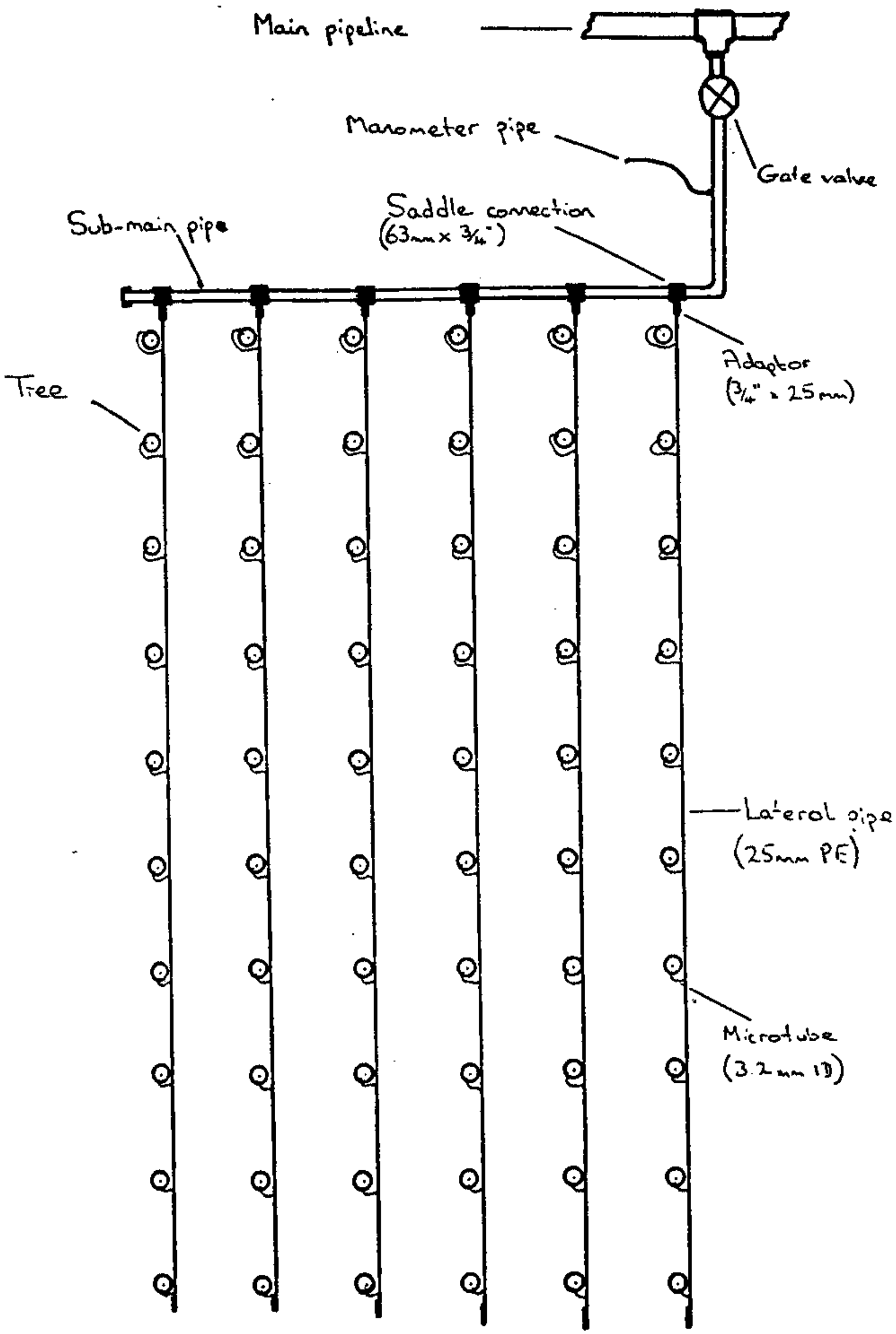
For small systems requiring a flow rate of upto 25% of the total flow rate from the farmer's pump it is most economical to simply use a take-off from the pipeline with a gate valve for regulation and a manometer (made of clear pipe) to measure the pressure. Most farmers in Al Bayda Governorate now use GI or PVC pipelines within their farms and the only conditions for this kind of take-off are that the pipeline should also be in frequent use for other fields, and that the reduced discharge at these other fields should not pose a problem.

For slightly larger systems it is necessary to draw off a higher flow rate from the main pipeline leaving the farmer with inadequate water for irrigation elsewhere. This occurs with systems which need about 25% to 90% of the total available flow rate and in these cases a water reservoir is required. (See Figure 2) The size of this reservoir can be kept within reasonable bounds by arranging that irrigation and tank filling take place simultaneously using the full flow from the pipeline. A manometer and pressure regulating valve is not normally required with a tank provided that the elevation of the tank can be set so that the average water level corresponds with the required pressure.

For systems requiring 90% to 110% of the available flow rate it is best to make some modifications to the design of the irrigation system to match the system to the available flow rate.

For very large systems it is possible to rotate the irrigated area.

Figure 1. Schematic layout of a typical microtube-bubbler system.



4.2.2 Selection of the lateral pipe size

It is best to use only one lateral pipe size for each orchard because the local head losses at the connection to the sub-main are different for 16mm and 25mm laterals. Mixing these two sizes within one orchard will therefore disrupt the uniformity of irrigation.

16mm diameter laterals are adequate for lines of upto 5 trees and can be connected to the sub-main with a grommet connector which is cheap but rather troublesome. In contrast to this, the 25mm diameter laterals can serve upto 16 trees but need to be connected to the sub-main with a more expensive, but better quality, saddle fitting.

It has been found that farmers normally prefer systems with 25mm lateral pipes because in most cases it is possible to place the sub-main along one side of the orchard and then the lateral pipes can be rolled up leaving the field clear for mechanised weed control.

Where ever possible the Project is now trying to use 25mm systems in order to standardise the design.

4.2.3 Calculation of microtube lengths

Calculating the necessary microtube lengths is the most complex part of the design procedure. The flow rate is different in each section of the lateral pipe and the lengths of these sections may also be different. Therefore the head losses must be calculated separately for each section of each lateral pipe.

The lateral pipe which serves the largest number of trees and/or is furthest from the water supply will experience the greatest head losses and so it is best to base the initial calculations on this lateral.

The first step is to choose a nominal length for the microtube (also called the riser pipe). The length of each subsequent microtube must then be reduced in order to compensate for the head losses in the preceding section of the lateral pipe.

The length of the last microtube should normally be not less than 200mm (so that it can be easily directed to the correct point for irrigation). The calculation is therefore an iterative procedure which must be continued until the length of the last microtube is acceptable and the pressure required in the sub-main is convenient and similar for each lateral. For this reason the calculation is most simply and quickly done by using a computer spreadsheet program as shown in Table 1.

At the top right hand side of this table are the details of the microtube (or riser pipe). The main variables are the inside diameter, discharge and length of the microtube. From these the Renould's number (Re), head loss and kinetic energy component are calculated.

The inside diameter (ID) of the microtube is, in practice, fixed. Initially the Sub-Section was using pipe of 3.81mm ID but on our request a large quantity of microtube of 3.2mm ID has been made locally. Although this is not exactly to our specifications, the system has been adapted to use this microtube. The design procedures which are explained here assume that this microtube will be used.

Having accepted this microtube, the optimum discharge was found to be 0.012 l/s. This is variable only within a small range: To avoid transitional flow in the microtubes Re should be greater than 4000, and a slight decrease in the discharge will cause Re to drop below this value: On the other hand a slight increase in the discharge will cause the head loss in the microtube to increase considerably and this will be particularly troublesome in cases where we wish to supply the necessary head by means of an elevated tank.

The length of the microtube is therefore the main variable. It directly affects the head loss in the microtube and it is used in the design to balance the head losses throughout the system. This head loss in the microtube is calculated according to the following formula (Rawlins, 1977).

$$h_l = 8.86 \times 10^{5} \times l \times q^{1.75} / d^{4.75}$$

where l = microtube length (m)
q = discharge (l/s)
d = inside diameter (mm)
h_l = head loss (m)

The main body of the spreadsheet (Table 1) describes the hydraulic conditions in the lateral pipe. Column 1 specifies the number of each tree and each section of the lateral pipe. Column 2 specifies the length of each section and in practice this is simply the spacing between the trees as measured in the field. In Column 3 is the inside diameter of the lateral pipe (25mm PE pipe has an ID of 21.0mm and 16mm PE pipe has an ID of 13.0mm). Column 4 gives the flow rate in each section of the lateral pipe and it is calculated by taking the discharge chosen for the microtubes and multiplying by the number of microtubes served by each section of the lateral pipe.

Now it is necessary to calculate the head loss in each section of the lateral pipe. Firstly the head loss per metre length is calculated in column 5 according to the following equation which is based on the Darcy-Wiesbach and Blasius equations (see Annex 2 for the derivation).

$$(Q/1000)^{1.75} \; / \; ((D/1000)^{4.75} \times 1245.1)$$

where Q = discharge in the lateral pipe (m^3/s)
D = diameter of the lateral pipe (m)

This is then multiplied by the length of the lateral pipe section in column 6 in order to obtain the head loss for each section (Column 6).

The cumulative head loss is simply the sum of all the section head losses from the start of the lateral to the point being considered.

TABLE 1. SPREADSHEET FOR THE DESIGN OF MICROTUBE-BUBBLER SYSTEMS

	ID mm	3.20
RISER	LENGTH m	.570
	DISCHARGE l/s	.0120
	HEAD LOSS	.376
	REYNOLDS NO.	4185
	V2/2g	.1133

FARMER..........
ORCHARD......................
LATERAL........

PIPE SECTION	SECTION LENGTH (m)	PIPE I.D. (mm)	DISCHARGE l/s	HEAD LOSS/m	SECTION HEAD LOSS	CUMULATIVE HEAD LOSS	REQD. RISER LENGTH m	REQD. RISER LENGTH m
0- 1	3.50	21.00	.144	[illegible]	.049597	.049597	.072	.528
1- 2	3.70	21.00	.132	[illegible]	.045026	.094623	.062	.502
2- 3	4.00	21.00	.120	[illegible]	.041198	.135821	.088	.492
3- 4	3.90	21.00	.108	[illegible]	.032405	.168226	.110	.460
4- 5	4.20	21.00	.096	[illegible]	.028274	.196500	.127	.441
5- 6	3.90	21.00	.084	[illegible]	.020967	.219466	.140	.427
6- 7	4.30	21.00	.072	.004213	.018116	.237582	.155	.415
7- 8	4.20	21.00	.060	[illegible]	.012861	.250443	.167	.407
8- 9	3.50	21.00	.048	[illegible]	.007253	.257696	.168	.402
9- 10	3.90	21.00	.036	[illegible]	.004883	.262580	.171	.399
10- 11	4.00	21.00	.024	.000616	.002464	.265045	.173	.398
11- 12	4.10	21.00	.012	[illegible]	.000751	.265796	.173	.397

TOTAL HEAD LOSS =	1.08	TOTAL 4.877
KINETIC ENERGY COMP =	.11	
ENTRANCE LOSSES =	.05	
TOTAL ENERGY =	1.25	

4.2.4 Calculation of sub-main pressure

Having setup a spreadsheet to properly describe each lateral (ie. the correct number of microtubes and the correct length for each section of the lateral) it is then necessary to consider the total head available in the sub-main at the junction of each lateral. For small systems with less than 7 lateral lines the pressure in the 63mm sub-main can be assumed to be uniform but for larger systems some detailed analysis is required.

This can best be done with a separate spreadsheet to describe the head losses and corresponding pressure gradient along the sub-main. This spreadsheet should be linked to those for the laterals so that it can automatically take the total flow rate for each lateral pipe and use these to compute the flow rate in each section of the sub-main. After choosing a convenient figure for the total head at the start of the sub-main, the head available for each lateral is calculated by simply subtracting the head losses upto that point. See Table 2.

TABLE 2. SPREADSHEET FOR THE DESIGN OF THE SUB-MAIN PIPE

SUPPLY PRESSURE (m)..... 1.87

SUB-MAIN SECTION	LENGTH	INSIDE DIAMETER (mm)	DISCHARGE l/s	HEAD LOSS/M	SECTION HEAD-LOSS	SUB-MAIN PRESSURE
S-1	15.26	57.50	1.23	.005450	.08[illegible]	1.79
1-2	4.60	57.50	1.19	.004757	.021881	1.77
2-3	4.30	57.50	1.04	.003794	.016314	1.75
3-4	4.00	57.50	.89	.002791	.011164	1.74
4-5	4.70	57.50	.72	.001990	.009[illegible]	1.73
5-6	4.20	57.50	.59	.001339	.005575	1.72
6-7	4.50	57.50	.47	.000932	.004195	1.72
7-8	4.50	57.50	.36	.000589	.002649	1.72
8-9	4.10	57.50	.23	.000265	.001085	1.71
9-10	4.80	57.50	.12	.000086	.000413	1.71

4.2.5 Readjustment of microtube lengths

The final step in the design is then to return to each of the lateral pipe spreadsheets and to re-adjust the nominal microtube length until the total energy head for the lateral corresponds to the available head at that point in the sub-main.

Annex 4 gives a large number of standard designs which can be used in cases where the trees (and hence the microtubes) are regularly spaced along each line.

4.3 Sources and costs of materials

All of the materials which are needed for this kind of irrigation system are available in Yemen and almost all are manufactured here.

All the polyethylene and PVC pipes for the sub-main and lateral pipes are manufactured by the National Company for Sponge and Plastic Industry Limited (NCSPIL) of Taiz. The polyethylene pipes and fittings are available from this factory in bulk orders but are not yet generally found in local markets. The PVC pipes and fittings can be purchased from the market in any town but are also available more cheaply from the NCSPIL factory.

The saddle connection between the PVC sub-main and the 25mm lateral is the only component which is difficult to find locally. There is one trader (Mohammad Banoub) in Al Hodeidah who imports these fittings from Cyprus on a regular basis but at present this is the only source in Yemen. This trader also has some useful tools such as the punch which is required for the microtube connections.

Table 3. List of materials, costs and sources for typical 60 tree microtube-bubbler irrigation system.

Item	Quantity	Unit cost Yr	Total cost Yr	Source of supply
63mm PVC pipe	36m	19	684	NCSPIL or local suq
63mm PVC elbow	1	11	11	NCSPIL or local suq
63mm PVC nipple	2	39	78	NCSPIL or local suq
63mm PVC end cap	1	31	31	NCSPIL or local suq
2 inch gate valve	1	280	280	Local suq
2 inch GI nipple	1	35	35	Local suq
63mm to 3/4" saddle	6	175	1050	Hodeidah
3/4" to 25mm adaptor	6	35	210	Hodeidah
16mm grommet	1	15	15	NCSPIL
16mm clear pipe	3m	10	30	NCSPIL or major suq
25mm PE pipe	270m	12	3240	NCSPIL
Microtube	36m	8	288	NCSPIL
Adhesive, tape etc.			100	Local suq
		Total Yr	6052	

Note: 1/ A water tank would not normally be needed for a system of this size.
2/ Assuming the recommended density of 400 trees/ha this gives a cost of Yr 40,000/ha.

4.4 Installation procedures

Installing these systems is a straight forward procedure.

The first step is to layout and join the PVC pipes and fittings for the sub-main and to make the connection to the pressure regulation and water supply. Care should be taken to clean all the PVC joints thoroughly with thinner before applying the adhesive. The manometer pipe should be fitted (by means of a 16mm grommet or saddle connection) into the PVC sub-main on the downstream side of the gate valve at a convenient place near the edge of the field. The operating pressure should be measured above the field level and marked onto the upright which is used to support the manometer (not onto the manometer pipe itself).

The second step is to roll out the polyethylene lateral pipe for each line of trees, cut each one to the correct length (leaving 1.5m extra past the last tree) and to connect it to the sub-main. This is simply a matter of drilling a hole of about 16mm diameter (for a 63mm x 3/4 inch saddle) in the side of the sub-main, fitting the saddle over the hole and attaching the polyethylene lateral by means of an adaptor or compression fitting. The end of the lateral pipe can be easily closed by bending the pipe through 180 degrees and tying it with string or wire.

The final step is to cut the microtubes according to the design and fit them into the lateral pipes. The cutting can best be done before going to the field by means of a 1.5m length of wood with a measuring tape fixed to it. each microtube should be cut at a slight angle for easy insertion into the lateral. The microtubes for each lateral should be taped together in the correct sequence and the number of the lateral should be written on the tape. In the field care must be taken to push the microtubes only about 5mm into the lateral pipe as more than this would cause some blockage of the lateral.

During initial operation the sub-main should be checked. any leaks should be repaired and the PVC pipe should then be covered by soil to protect it from the sunlight.

Annex 3 gives the actual work rates which have been obtained under field conditions.

4.5 Operation and maintenance

Before the system is operated for the first time the sub-main end caps and the ends of the lateral pipes should all be opened and the system should be flushed out to remove any material which may have been left inside the pipes during construction. This procedure should also be repeated every 6 months and is the main routine maintenance operation.

Operating the system is a very simple procedure: For systems which are connected directly to a main pipeline. it is necessary to open the regulation valve until the water level in the manometer pipe reaches the mark which was made to indicate th operating pressure; For systems which are connected to a water tank which has been selected according to Figure 2. the control valve should be left fully open and irrigation will start automatically as the water is pumped into the tank. Pumping should be stopped when the tank is full and the irrigation will then continue until the tank has emptied again.

In both of these cases it is advisable to check occasionally that each microtube is discharging correctly. If it is not it should be removed from the lateral and cleared of any blockage which may have occurred. If there is no blockage and the problem affects several microtubes then this may be due to the one or more microtubes having been pushed too far into the lateral thereby partly blocking the flow of water. In this case the microtubes should be removed and re-inserted to just 5mm depth.

Occasionally it happens that there are spaces within an orchard where a tree has died and is to be replanted later. At these locations it is necessary to install a microtube in order to make the system complete but the water is temporarily not needed. A simple solution to this problem is to tie a knot in the microtube, this will stop the flow but allow it to be easily reconnected when needed. This method should not be used for routine regulation of water.

4.6 System performance

The performance of this irrigation system has been found to be generally good. The coefficient of variation of the microtube discharges has been calculated at 7.5% for a system installed on a farmer's field and no significant change in this uniformity was found with changes in the supply pressure upto 150% of the desig pressure.

This means that systems which use a water tank can be operated without concern for the changes in pressure which occur as the water level drops, because the required volume of water will be distributed uniformly over the field irrespective of the flow rate.

The design procedures have been generally found to give a good simulation of the actual hydraulic conditions of the system. however a new point of concern has recently emerged which has made it difficult to quantify this. The quality of locally manufactured microtube was initially thought to be good but now some variations in the inside diameter have been found. Furthermore the ID which was quoted by the NCSPIL appears to be less than the actual average ID and this has led to microtube discharges which are higher than the design discharge.

This may simply be the result of a bad roll of pipe but clearly indicates that careful attention must be given to quality control and that it is advisable to check the actual microtube discharges in the field before preparing an irrigation schedule.

4.7 Irrigation scheduling

This irrigation system offers considerable savings in water over traditional basin techniques, but, in order to achieve the full potential, it is necessary to operate the irrigation system according to a schedule which is based on the water requirements of the crop.

At the RIRDP centre a long time series of good quality meteorological data now exists (Timmermans and Johaish, 1991). This data is processed to give values of ETo according to the recommendations of the Soil Survey and Land Classification Project of the Agricultural Research and Extension Authority (van Waveren, 1990). From this, and other information (Doorenbos, et al, 1984 & 1986), a detailed irrigation schedule is made for each system (as shown in Table 4), and the farmer is given a simplified version written in arabic.

In cases where the farmer is using a water tank, the schedule is based on the number of tanks to be given at each irrigation. The irrigation interval is usually 4 days or less and is adjusted so that complete tanks of water can be applied. This is very simple for the farmer to understand and control and has given good results in the field. but for systems which do not use a water tank the scheduling has to be based on the number of hours of operation.

TABLE 4. IRRIGATION SCHEDULE FOR MICROTUBE-BUBBLER SYSTEM

FARMER........
VILLAGE.......

Number of trees......... [illegible]
Size of orchard........ 2500 sq.metres
Size of tank........... 6 cubic metres

TREES.........Apples
YEAR PLANTED..[illegible]
AGE OF TREES..1 year

Irrigation efficiency.. .85
Microtube discharge.. .0020 l/s

	Average ETo (mm)	Crop Coef Kc	Reduction Factor Kr	ETcrop (mm)	ETcrop gross (mm)	Cubic M for field	Irrig. Interval (days)	Cubic M per irrig.	Tanks per irrigation	Minutes per irrigation
Jan	[illegible]	.00	.60	0	0	0	0	0	.0	0
Feb	[illegible]	.60	.60	61	72	[illegible]	1	5.51	[illegible]	54
Mar	[illegible]	.75	.60	[illegible]	95	[illegible]	1	[illegible]	[illegible]	[illegible]
Apr	[illegible]	.85	.60	97	114	[illegible]	1	[illegible]	1.5	[illegible]
May	[illegible]	1.00	.60	120	141	353	1	11.79	[illegible]	105
Jun	205	.95	.60	117	137	344	1	11.07	1.8	103
Jul	[illegible]	.95	.60	114	134	335	1	10.81	1.8	100
Aug	[illegible]	.90	.60	103	121	302	1	9.73	1.6	90
Sep	195	.85	.60	95	117	293	1	9.44	1.6	87
Oct	190	.80	.60	86	102	254	1	8.20	1.4	76
Nov	170	.70	.60	71	84	210	1	6.77	1.1	63
Dec	160	.00	.60	0	0	0	0	0	.0	0
Total	2200			950	1117	2794				

5 ECONOMICS OF THE SYSTEM

Continuing with the example of Section 4.3 the calculation of the total capital cost of the irrigation system is as follows:

Total cost of materials		Yr 6052
Labour		
Initial site measurement	2hrs @ Yr200/day	Yr 67
Design	2hrs @ Yr200/day	Yr 67
Installation	8 man.hrs @ Yr120/day	Yr 160
Administration and procurement		Yr 300
	Total capital cost	Yr 6646

Field results from a system which was installed on a 60 tree citrus orchard in September 1990 have shown an annual saving in the cost of labour for irrigation and weed control of Yr 4720.

The life of these microtube-bubbler irrigation systems is not known. However a relatively low quality system which was installed by CHRDP in 1986 is still functioning normally and so we can estimate the life to be at least 10 years.

The maintenance requirements of these systems are very low because there is no booster pump or filtration equipment. In reality it may even be less than the cost of maintaining canals and basins with traditional irrigation methods. 5% of the initial material cost is therefore included to account for repair costs only.

TABLE 5. ECONOMIC ANALYSIS FOR MICROTUBE BUBBLER IRRIGATION SYSTEM

BASED ON ACTUAL FIELD DATA FROM AN EXTENSION DEMONSTRATION ON A 60 TREE ORCHARD OF FOUR YEAR OLD CITRUS AT AL RAHAB, JUBAN.

Initial capital cost for irrigation system		
Cost of materials	Yr	6052
Cost of installation		600
	Total capital cost Yr	6652

Annual recurrent costs

Description	Without irrigation system	With irrigation system	Savings
Pumping costs *	150 hours 55 Yr/hour 8250	90 hours 55 Yr/hour 4950	3300
Labour for irrigation	2500	0	2500
Labour for weeding	5850	3600	2250
	------ 16600	------ 8550	------ 8050

Assuming a 10 year life for the irrigation system and 10% discount rate:

Year	Costs	Savings
0	6652	
1	303	8050
2	273	7245
3	245	6521
4	221	5868
5	199	5282
6	179	4753
7	161	3850
8	145	3465
9	130	3119
10	117	2807
	-------- 8625.50	-------- 50960

Benefit / cost ratio = 5.9 : 1

Note: 1/ Other unquantified benefits include
- a. Saving of water resources for the future.
- b. Improved crop yield.

* From Hagenz, P., 199[illegible].

6 EXTENSION APPROACH

6.1 Training Extension Agents

Initial training for Extension Agents in bubbler irrigation was given as part of a more general course on irrigation which lasted for one week. The difficulty at this early stage was that no demonstration of bubbler irrigation could be shown in the Rada area and so the training was rather superficial.

This training was later followed up with individual training for the Extension Agents in each area where a demonstration was installed.

6.2 Demonstrations

The project's policy has been to identify target areas for irrigation interventions and to establish demonstrations in these areas as the first step in extension to farmers. The areas of Rada basin, Juban, Dhi Na'im and Al Bayda were selected according to the criterion of maximum anticipated extension impact coupled with some other minor criteria.

Having selected the general area for a demonstration, the Extension Agent is then primarily responsible for identifying a suitable farmer. This will normally be one of the leader farmers with whom he is already working.

The Irrigation Sub-Section then takes responsibility for checking the site and ensuring that the farmer is fully understanding the irrigation system and his duties within the extension programme.

Next the Irrigation Sub-Section prepares an initial cost estimate and the farmer is then expected to contribute 50% of this cost either in cash or in materials (eg. a water tank). Only when this is received does the work proceed further.

The Irrigation Sub-Section has now established a total of five demonstrations of microtube-bubbler irrigation giving reasonable coverage of the target areas. Details are given in Table 6 below.

Table 6. Details of Microtube-bubbler Irrigation Demonstrations.

Village	Area	Year	Trees
Al Wathbah	Rada	1990	19 Apple
Al Rahab	Juban	1990	60 Citrus
Al Gariim	Dhi Na'im	1992	120 Apple, citrus
Duraybah	Rada	1992	198 Peach, apple, pomegranate
Project	Al Bayda	1992	60 Almond, fig, pomegranate

6.3 Farmer meetings

A programme of farmer meetings was planned for each demonstration site in order to inform other farmers about the irrigation system and it's advantages over traditional systems.

The first of these meetings is normally conducted during installation of the demonstration system. But the follow-up meetings have been indefinitely postponed because the demand from other farmers very quickly exceeded the capacity of the Sub-Section to install these irrigation systems.

7 EXTENSION RESULTS

7.1 General

The demand for this irrigation system has been such that until now it has not been necessary to try to convince farmers about it's advantages.

7.2 Farmers' interest

The number of farmers who are aware of this irrigation system is in the order of 86. Of these farmers, 49 have shown interest in the system and have visited the extension agent to ask about it.

For each enquiry it is first made clear that the farmer must pay for the full cost of the materials and that a first approximation of the cost is Yr 100 per tree.

If the farmer is still interested a field visit is made to measure the field and check the water supply (see Annex 1). Following this a preliminary design and a more detailed costing is made and the farmer is informed how much he should pay. When this money is received the detailed design is made and the farmer's name joins the bottom of a list farmers who are waiting for their systems to be installed.

4 systems have so far been installed for farmers and three more are currently under installation.

7.3 Installation

At present the RIRDP is trying to install these irrigation systems for farmers but the capacity of the project to do this is limited. For this reason the RIRDP has been actively looking for a local contractor who could learn to do this work, but unfortunately these efforts have not yet been successful. It was envisaged that the project would continue to do the initial site survey, the system design and preparation of irrigation schedules whilst the contractor would be responsible for installation of the systems under RIRDP supervision.

An alternative strategy is now being investigated in which the Extension Agents would advise farmers on the main layout of the system (after training), farmers would buy the main bulk of the materials from the Agricultural Cooperatives and install them by themselves, leaving the project technical staff to measure the system in the field and design and fit the microtubes.

8 CONCLUSIONS

This irrigation system appears to meet the priorities of farmers within the constraints of the available levels of management, labour, and the availability of water pressure and irrigation materials.

The costs of the system are acceptable to most farmers and show a clear and quick return on the investment.

What is now required is the involvement of the private sector in the installation work in order to increase the work output and at the same time allow the project to concentrate on the extension of this irrigation system and on the development of other systems.

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ANNEX 1. Check List for Initial Site Survey

1/ The Water Supply

Water Quality EC = ...

Other problems ....

Water Quantity

Flow rate.........................

Pipeline Yes/No

If Yes diameter ....

If No distance from pump ....

Check number of trees and refer to Figure 2
and discuss with the farmer:

a. Use of remaining flow rate
and frequency of pumping (hr/day and days/month)

OR b. Water Tank - Size, location, elevation.

Do floods enter the field? Yes/No

If Yes then: Depth of flooding
Av. ....
Max. ....
Min. ....

Frequency of flooding
Av. ....
Max. ....
Min. ....

2. The Orchard

Type of trees..

Condition of trees.....................................

Intercrop ....

Weed control by tractor? ....

3. Access

Distance for carrying materials ....

Is the orchard fenced? ....

4. Schetch of the site..

ANNEX 2.

Derivation of Equation to Determine Headloss in Smooth Pipe

$$Re = \frac{VD}{\nu} = \frac{4\,DQ}{\pi \nu D^2}$$

Where Re Reynolds no. (Dimensionless)
V Water velocity (m/s)
ν Kinematic viscosity (m 2/s)
Q Water discharge (m 3/s)
D Pipe diameter (m)

$$= \frac{4Q}{\pi \nu D}$$

$$\lambda = \frac{0.316}{Re^{0.25}} \text{ (Blasius' equan)}$$

λ friction factor

$$Hf = \lambda L \frac{V^2}{2\,g\,D}$$

Hf headloss (m)
g force of gravity (m2/s)
L length of pipe (m)

$$= \frac{0.316}{\left(\frac{4Q}{D\pi\nu}\right)^{0.25}} \frac{L}{2gD} \frac{16\,Q^2}{\pi^2\,D^4}$$

$$= \frac{8 \times 0.316\,LQ^{1.75}\,\nu^{0.25}}{4^{0.25}\,8\;\pi^{1.75}\;D^{4.75}}$$

$$= 8.032 \times 10^{-4}\,L\,\frac{Q^{1.75}}{D^{4.75}}$$

$$= \frac{L\,Q^{1.75}}{1245.1\,D^{4.75}}$$

Source: Twine, J., 1986.

ANNEX 3. Work Rates for Installing Microtube-bubbler systems

Operation	Unit of work	Minutes
Laying out and connecting PVC sub-main	6m pipe	6
Fitting saddle connections	unit	4
Laying out and connecting 25mm PE lateral	50m	7
Fitting manometer	Total job	10
Connecting system to water supply	Total job	15

Notes:

1/ All times are based on 2 technicians with some experience.

2/ Additional time should be allowed for un-loading and carrying materials to the field. this depends on the distance.

ANNEX 4. Standard Designs

MICROTUBE IRRIG. DESIGN

RISER	ID mm	3.20
	LENGTH m	.590
	DISCHARGE l/s	.0120
	HEAD LOSS	.907
	REYNOULD NO.	4188
	v2/2g	.1135

FARMER..........
ORCHARD.....................
LATERAL........

PIPE SECTION	SECTION LENGTH (m)	PIPE I.D.(mm)	DISCHARGE l/s	HEAD LOSS/m	SECTION HEAD LOSS	CUMULATIVE HEAD LOSS	DECR. RISER LENGTH m	REQD RISER LENGTH m
0- 1	5.00	21.00	.096	.006970	.034850	.034850	.023	.567
1- 2	5.00	21.00	.084	.005518	.027588	.062437	.041	.549
2- 3	5.00	21.00	.072	.004213	.021065	.083502	.054	.536
3- 4	5.00	21.00	.060	.003062	.015310	.098812	.064	.526
4- 5	5.00	21.00	.048	.002072	.010361	.109173	.071	.519
5- 6	5.00	21.00	.036	.001253	.006263	.115436	.075	.515
6- 7	5.00	21.00	.024	.000616	.003080	.118516	.077	.513
7- 8	5.00	21.00	.012	.000183	.000916	.119432	.078	.512

TOTAL HEAD LOSS = 1.11 TOTAL 4.237
KINETIC ENERGY COMP = .11
ENTRANCE LOSSES = .02
TOTAL ENERGY = 1.25

MICROTUBE IRRIG. DESIGN

RISER	ID mm	3.20
	LENGTH m	.590
	DISCHARGE l/s	.0120
	HEAD LOSS	.907
	REYNOULD NO.	4188
	v2/2g	.1135

FARMER..........
ORCHARD.....................
LATERAL........

PIPE SECTION	SECTION LENGTH (m)	PIPE I.D.(mm)	DISCHARGE l/s	HEAD LOSS/m	SECTION HEAD LOSS	CUMULATIVE HEAD LOSS	DECR. RISER LENGTH m	REQD RISER LENGTH m
0- 1	4.50	21.00	.096	.006970	.031365	.031365	.020	.570
1- 2	4.50	21.00	.084	.005518	.024829	.056193	.037	.553
2- 3	4.50	21.00	.072	.004213	.018958	.075152	.049	.541
3- 4	4.50	21.00	.060	.003062	.013779	.088931	.058	.532
4- 5	4.50	21.00	.048	.002072	.009325	.098256	.064	.526
5- 6	4.50	21.00	.036	.001253	.005636	.103892	.068	.522
6- 7	4.50	21.00	.024	.000616	.002772	.106665	.069	.521
7- 8	4.50	21.00	.012	.000183	.000824	.107489	.070	.520

TOTAL HEAD LOSS = 1.11 TOTAL 4.285
KINETIC ENERGY COMP = .11
ENTRANCE LOSSES = .02
TOTAL ENERGY = 1.25

MICROTUBE IRRIG. DESIGN

FARMER..........
ORCHARD.....................
LATERAL........

RISER

ID mm	3.20
LENGTH m	.590
DISCHARGE l/s	.0120
HEAD LOSS	.907
REYNOULD NO.	4188
v2/2g	.1135

PIPE SECTION	SECTION LENGTH (m)	PIPE I.D. (mm)	DISCHARGE l/s	HEAD LOSS/m	SECTION HEAD LOSS	CUMULATIVE HEAD LOSS	DECR. RISER LENGTH m	REQD RISER LENGTH m
0- 1	4.00	21.00	.096	.006970	.027880	.027880	.018	.572
1- 2	4.00	21.00	.084	.005518	.022070	.049950	.033	.557
2- 3	4.00	21.00	.072	.004213	.016852	.066802	.043	.547
3- 4	4.00	21.00	.060	.003062	.012248	.079050	.051	.539
4- 5	4.00	21.00	.048	.002072	.008289	.087339	.057	.533
5- 6	4.00	21.00	.036	.001253	.005010	.092349	.060	.530
6- 7	4.00	21.00	.024	.000616	.002464	.094813	.062	.528
7- 8	4.00	21.00	.012	.000183	.000733	.095546	.062	.528

TOTAL HEAD LOSS =	1.11	TOTAL 4.334
KINETIC ENERGY COMP =	.11	
ENTRANCE LOSSES =	.02	
TOTAL ENERGY =	1.25	

MICROTUBE IRRIG. DESIGN

FARMER..........
ORCHARD.....................
LATERAL........

RISER

ID mm	3.20
LENGTH m	.590
DISCHARGE l/s	.0120
HEAD LOSS	.907
REYNOULD NO.	4188
v2/2g	.1135

PIPE SECTION	SECTION LENGTH (m)	PIPE I.D. (mm)	DISCHARGE l/s	HEAD LOSS/m	SECTION HEAD LOSS	CUMULATIVE HEAD LOSS	DECR. RISER LENGTH m	REQD RISER LENGTH m
0- 1	3.50	21.00	.096	.006970	.024395	.024395	.016	.574
1- 2	3.50	21.00	.084	.005518	.019311	.043706	.028	.562
2- 3	3.50	21.00	.072	.004213	.014745	.058451	.038	.552
3- 4	3.50	21.00	.060	.003062	.010717	.069169	.045	.545
4- 5	3.50	21.00	.048	.002072	.007253	.076421	.050	.540
5- 6	3.50	21.00	.036	.001253	.004384	.080805	.053	.537
6- 7	3.50	21.00	.024	.000616	.002156	.082961	.054	.536
7- 8	3.50	21.00	.012	.000183	.000641	.083602	.054	.536

TOTAL HEAD LOSS =	1.11	TOTAL 4.382
KINETIC ENERGY COMP =	.11	
ENTRANCE LOSSES =	.02	
TOTAL ENERGY =	1.25	

ANNEX 4

IRRIGATION EQUIPMENT
OUTLINE SPECIFICATIONS

AND

PRICE INDICATIONS

FOR

SMALL-SCALE INSTALLATIONS OF
SPRINKLER, DRIP AND MICROJET

A4.1 INTRODUCTION

In order to provide realistic input to the Cost/Benefit Analyses carried out for typical farm families, up-to-date prices were obtained for a range of modern irrigation equipment specified for small farm use.

The data is given in two sections:

- General descriptions of the systems for different crops.
- Outline Specifications and Indicative Prices.

A4.2 GENERAL DESCRIPTIONS

Alfalfa - 0.25 ha - Sprinkler Hose Irrigation System
Capacity to apply 64 mm per 8 days operating 12 hours/day, comprising a diesel engine driven pump set complete with suction and delivery fittings. A portable supply main runs up the side of the area to be irrigated which has valve take-offs 12 m apart. A sprinkler on tripod and hose assembly is positioned at a valve take-off connection. The sprinkler is then reset to the next take-off position. This sequence of operation continues until the complete area is irrigated.

Vegetables - 0.5 ha Hand Move Sprinkler System
Capacity to apply 18mm/2 days operating 8 hours/day, suction and delivery fittings. A portable supply main runs along the end of the area to be irrigated which has valve take-offs 12 m apart. A sprinkler line with 8 sprinklers on risers is connected to the first irrigating set position and operates for the required time. At the end of the set the complete sprinkler line is moved and set up to operate in the next set position. This sequence of operation continues until the complete area is irrigated.

Wheat/Barley - 1 ha Hand Move Sprinkler System
Capacity to apply 48 mm per 8 days operating 11 hours/day, comprising a diesel engine driven pump set complete with suction and delivery fittings. A portable supply main runs up the side of the area to be irrigated which has valve take-offs 12 m apart. A sprinkler on tripod and hose assembly is positioned at a valve take-off connection. The sprinkler is then reset to the next take-off position. This sequence of operation continues until the complete area is irrigated.

Sorghum 1 ha Hand Move Sprinkler System
Capacity to apply 64 mm per 8 days operating 12 hours/day, comprising a diesel engine driven pumpset complete with suction and delivery fittings. A portable supply main runs up the side of the area to be irrigated which has valve take-offs 12 m apart. A sprinkler on tripod and hose assembly is positioned at a valve take-off connection. The sprinkler is then reset to the next take off position. This sequence of operation continues until the complete area is irrigated.

Vegetables - 0.5 ha Drip Irrigation System
Capacity to apply 9mm per 1 day operating 12 hours/day, comprising a diesel engine driven pumpset complete with suction and delivery fittings, and including filtration equipment. A portable supply main runs along the end of the area to be irrigated which has 3 valve take-offs. Header mains run from each valve and connect to the

drip lateral lines. The drip lateral lines run down each crop row and water the vegetables spaced at 0.5 m x 1.0 m apart. The control valves are operated in sequence to complete the irrigation of the area.

Trees - 0.5 ha Drip Irrigation System
Capacity to apply 192 litres of water per tree in a 2 day cycle, comprising a diesel engine driven pumpset complete with suction and delivery fittings, and including filtration equipment. A portable supply main runs along the end of the area to be irrigated which has 2 valve take-offs. Header main runs from each valve and connect to the drip lateral lines. The drip lateral lines run down each crop row and water the trees spaced at 4 m x 5 m apart. The control valves are operated in sequence to complete the irrigation of the area.

Trees - 0.5ha Microjet Irrigation System
Capacity to apply 198 litres of water per tree in a 2.5 day cycle, suction and delivery fittings, all including filtration equipment. A portable supply main runs along the end of the area to be irrigated and connects to the microjet lateral lines. The lateral lines run down each row and water the trees spaced at 4 m x 5 m apart. There is one take-off at each tree location and to this take-off are fitted 2 microjets with 180 degree arcs to ensure that the complete root zone of the tree is watered. The control valves are operated in sequence to complete the irrigation of the area.

A4.3 OUTLINE SPECIFICATIONS AND INDICATIVE PRICES

These follow on separate sheets.

It should be noted that large plots would give rise to economies of scale and lower unit costs per hectare.

Wright Rain

Wright Rain Ltd., Planned Irrigation
Ringwood, Hampshire, BH24 1PA, England
Telephone: Ringwood (0425) 472251
Telegrams: Wrightrain, Ringwood Telex: 41206
Facsimile No: 0425 472258

Proposal

QUOTATION SUMMARY

Quoting to: DHV Consultants BV
P O Box 19152
Sana'a
Yemen

Date 27.7.93
Enqy No 0350/ME

Budgetary Proposal for Price Indication use for Guideline only.
for: Area of 0.25 has
Sprinkler hose irrigation system
Capacity to apply: 64 mm gross in 8 days per cycle
Irrigating daily for: 12 hours

SUMMARY Pstl £

Pumpsets comprising:
1 x WR Dsl pumpset diesel engine driven
c/w hand starting on base
Suction and delivery fittngs:
1 x suction, footvalve, hose and primer
1 x delivery, valves, hose to mains
Supply mains comprising:
96mts x ali. mains pipe and fittings
c/w 8 valved take offs
In field irrigation equipment comprising:
1 x sprinkler assembly on tripod
c/w hose and fittings

Total F C A S.UK.Port (inclusive of export packing) - Pstl £		2610.00
Estimated cost to ship goods - Pstl £		456.75
Estimated total C P T - Pstl £	Port Sana'a	3066.75

Terms of payment:
In full against shipping documents from an irrevocable letter of credit confirmed in our favour by the Midland Bank Plc, The Bridge, Walsall, W Midlands, WS1 1LN - Sort code 404519 - Account No. 21325566 - in terms acceptable to ourselves.which shall include acceptance and or payment of our draft by the UK advising bank.The letter of credit to be valid for negotiation for 6 weeks after the date indicated below for completion of delivery. Or other terms to be agreed. Any additional shipping costs incurred by Wright Rain shall be for the account of the customer Shipping costs are estimated due to world fuel situation and will be invoiced at actuals at the time of shipping. If client requires a firm shipping cost, then a proforma invoice should be requested against this offer.
Full bill of materials to be submitted at time of order.

Packing: For ocean shipment.

Shipment: C P T PortSana'a Incoterms 1990

Delivery: 8-10 working weeks. from date of acceptance of FOB.S.UK.Port of order and acceptable letter of credit (subject).

Quotation valid for 60 days.

Wright Rain

Wright Rain Ltd., Planned Irrigation
Ringwood, Hampshire, BH24 1PA, England
Telephone: Ringwood (0425) 472251
Telegrams: Wrightrain, Ringwood Telex 41206
Facsimile No. 0425 472258

Proposal

QUOTATION SUMMARY

Quoting to: DHV Consultants BV
P O Box 19152
Sana'a
Yemen

Date 27.7.93
Enqy No 0350/ME

Budgetary Proposal for Price Indication use for Guideline only.
for: Area of 0.5 has
Hand move sprinkler irrigation system
Capacity to apply: 18 mm gross in 2 days per cycle
Irrigating daily for: 8 hours

SUMMARY Pstl £

Pumpsets comprising:
1 x WR Dsl pumpset diesel engine driven
c/w hand starting on base
Suction and delivery fittngs:
1 x suction, footvalve, hose and primer
1 x delivery, valves, hose to mains
Supply mains comprising:
30mts x ali. mains pipe and fittings
c/w 2 valved take offs
In field irrigation equipment comprising:
96mts x sprinkler line pipe and fittings
and 8 sprinklers on 1 mt risers

Total F C A S.UK.Port (inclusive of export packing) - Pstl £		3074.00
Estimated cost to ship goods - Pstl £		537.95
Estimated total C P T - Pstl £	Port Sana'a	3611.95

Terms of payment:
In full against shipping documents from an irrevocable letter of credit confirmed in our favour by the Midland Bank Plc, The Bridge, Walsall, W Midlands, WS1 1LN - Sort code 404519 - Account No. 21325566 - in terms acceptable to ourselves.which shall include acceptance and or payment of our draft by the UK advising bank.The letter of credit to be valid for negotiation for 6 weeks after the date indicated below for completion of delivery. Or other terms to be agreed. Any additional shipping costs incurred by Wright Rain shall be for the account of the customer Shipping costs are estimated due to world fuel situation and will be invoiced at actuals at the time of shipping. If client requires a firm shipping cost, then a proforma invoice should be requested against this offer.
Full bill of materials to be submitted at time of order.

Packing: For ocean shipment.

Shipment: C P T PortSana'a Incoterms 1990

Delivery: 8-10 working weeks. from date of acceptance of FOB.S.UK.Port of order and acceptable letter of credit (subject).

Quotation valid for 60 days.

Wright Rain

Wright Rain Ltd., Planned Irrigation
Ringwood, Hampshire, BH24 1PA, England
Telephone: Ringwood (0425) 472251
Telegrams: Wrightrain, Ringwood. Telex: 41206
Facsimile No: 0425 472258

Proposal

QUOTATION SUMMARY

Quoting to: DHV Consultants BV
P O Box 19152
Sana'a
Yemen

Date 27.7.93
Enqy No 0350/ME

Budgetary Proposal for Price Indication use for Guideline only.
for: Area of 1.0 has
Hand move sprinkler irrigation system
Capacity to apply: 48 mm gross in 8 days per cycle
Irrigating daily for: 11 hours

SUMMARY Pstl £

Pumpsets comprising:
1 x WR Dsl pumpset diesel engine driven
c/w hand starting on base
Suction and delivery fittngs:
1 x suction, footvalve, hose and primer
1 x delivery, valves, hose to mains
Supply mains comprising:
48mts x ali. mains pipe and fittings
c/w 4 valved take offs
In field irrigation equipment comprising:
96mts x sprinkler line pipe and fittings
and 8 sprinklers on 1 mt risers

Total F C A S.UK.Port (inclusive of export packing)- Pstl £		3241.00
Estimated cost to ship goods - Pstl £		567.18
Estimated total C P T - Pstl £	Port Sana'a	3808.18

Terms of payment:
In full against shipping documents from an irrevocable letter of credit confirmed in our favour by the Midland Bank Plc, The Bridge, Walsall, W Midlands, WS1 1LN - Sort code 404519 - Account No. 21325566 - in terms acceptable to ourselves.which shall include acceptance and or payment of our draft by the UK advising bank.The letter of credit to be valid for negotiation for 6 weeks after the date indicated below for completion of delivery. Or other terms to be agreed. Any additional shipping costs incurred by Wright Rain shall be for the account of the customer Shipping costs are estimated due to world fuel situation and will be invoiced at actuals at the time of shipping. If client requires a firm shipping cost, then a proforma invoice should be requested against this offer.
Full bill of materials to be submitted at time of order.

Packing: For ocean shipment.

Shipment: C P T PortSana'a Incoterms 1990

Delivery: 8-10 working weeks. from date of acceptance of FOB.S.UK.Port of order and acceptable letter of credit (subject).

Quotation valid for 60 days.

Wright Rain

Wright Rain Ltd., Planned Irrigation
Ringwood, Hampshire, BH24 1PA, England
Telephone: Ringwood (0425) 472251
Telegrams: Wrightrain, Ringwood Telex 41206
Facsimile No. 0425 472258

Proposal

QUOTATION SUMMARY

Quoting to: DHV Consultants BV
P O Box 19152
Sana'a
Yemen

Date 27.7.93
Enqy No 0350/ME

Budgetary Proposal for Price Indication use for Guideline only.
for: Area of 0.5 has
Drip irrigation system - for vegetables 0.5m x 1.0m
Capacity to apply: 9 mm gross in 1 days per cycle
Irrigating daily for: 12 hours

SUMMARY — Pstl £

Pumpsets comprising:
1 x WR Dsl pumpset diesel engine driven
c/w hand starting on base
Suction and delivery fittngs:
1 x suction, footvalve, hose and primer
1 x delivery, valves, filter units, hose to mains
Supply mains comprising:
35mts x supply mains pipe and fittings
c/w 3 control valves take offs
In field irrigation equipment comprising:
50mts x p.e. header mains pipe and fittings
5000mts x drip lateral piping and fittings

Total F C A S.UK.Port (inclusive of export packing)- Pstl £		3181.00
Estimated cost to ship goods - Pstl £		556.68
Estimated total C P T - Pstl £	Port Sana'a	3737.68

Terms of payment:
In full against shipping documents from an irrevocable letter of credit confirmed in our favour by the Midland Bank Plc, The Bridge, Walsall, W Midlands, WS1 1LN - Sort code 404519 - Account No. 21325566 - in terms acceptable to ourselves.which shall include acceptance and or payment of our draft by the UK advising bank.The letter of credit to be valid for negotiation for 6 weeks after the date indicated below for completion of delivery. Or other terms to be agreed. Any additional shipping costs incurred by Wright Rain shall be for the account of the customer Shipping costs are estimated due to world fuel situation and will be invoiced at actuals at the time of shipping. If client requires a firm shipping cost, then a proforma invoice should be requested against this offer.
Full bill of materials to be submitted at time of order.

Packing: For ocean shipment.

Shipment: C P T PortSana'a Incoterms 1990

Delivery: 8-10 working weeks. from date of acceptance of FOB.S.UK.Port of order and acceptable letter of credit (subject).

Quotation valid for 60 days.

Wright Rain

Wright Rain Ltd., Planned Irrigation
Ringwood, Hampshire, BH24 1PA, England
Telephone: Ringwood (0425) 472251
Telegrams: Wrightrain, Ringwood. Telex 41206
Facsimile No: 0425 472258

Proposal

QUOTATION SUMMARY

Quoting to: DHV Consultants BV
P O Box 19152
Sana'a
Yemen

Date 27.7.93
Enqy No 0350/ME

Budgetary Proposal for Price Indication use for Guideline only.
for: Area of 0.5 has
Drip irrigation system - for trees 4m x 5m
Capacity to apply: 192 litres in 2 days per cycle
Irrigating daily for: 12 hours

SUMMARY	Pstl £
Pumpsets comprising:	
1 x WR Dsl pumpset diesel engine driven	
c/w hand starting on base	
Suction and delivery fittngs:	
1 x suction, footvalve, hose and primer	
1 x delivery, valves, filter units, hose to mains	
Supply mains comprising:	
25mts x supply mains pipe and fittings	
c/w 2 control valves take offs	
In field irrigation equipment comprising:	
50mts x p.e. header mains pipe and fittings	
1000mts x drip lateral piping and fittings	
1000 x 4lph on line emitters	
Total F C A S.UK.Port (inclusive of export packing)- Pstl £	3233.00
Estimated cost to ship goods - Pstl £	565.78
Estimated total C P T - Pstl £ Port Sana'a	3798.78

Terms of payment:
In full against shipping documents from an irrevocable letter of credit confirmed in our favour by the Midland Bank Plc, The Bridge, Walsall, W Midlands, WS1 1LN - Sort code 404519 - Account No. 21325566 - in terms acceptable to ourselves.which shall include acceptance and or payment of our draft by the UK advising bank.The letter of credit to be valid for negotiation for 6 weeks after the date indicated below for completion of delivery. Or other terms to be agreed. Any additional shipping costs incurred by Wright Rain shall be for the account of the customer Shipping costs are estimated due to world fuel situation and will be invoiced at actuals at the time of shipping. If client requires a firm shipping cost, then a proforma invoice should be requested against this offer.
Full bill of materials to be submitted at time of order.

Packing: For ocean shipment.

Shipment: C P T PortSana'a Incoterms 1990

Delivery: 8-10 working weeks. from date of acceptance of FOB.S.UK.Port of order and acceptable letter of credit (subject).

Quotation valid for 60 days.

Wright Rain

Wright Rain Ltd., Planned Irrigation
Ringwood, Hampshire, BH24 1PA, England
Telephone: Ringwood (0425) 472251
Telegrams: Wrightrain, Ringwood Telex 41206
Facsimile No: 0425 472258

Proposal

QUOTATION SUMMARY

Quoting to: DHV Consultants BV
P O Box 19152
Sana'a
Yemen

Date 27.7.93
Enqy No 0350/ME

Budgetary Proposal for Price Indication use for Guideline only.
for: Area of 0.5 has
Microjet irrigation system - for trees 4m x 5m
Capacity to apply: 198 litres in 2 days per cycle
Irrigating daily for: 10 hours

SUMMARY	Pstl £
Pumpsets comprising:	
1 x WR Dsl pumpset diesel engine driven	
c/w hand starting on base	
Suction and delivery fittngs:	
1 x suction, footvalve, hose and primer	
1 x delivery, valves, filter units, hose to mains	
Supply mains comprising:	
45mts x supply mains pipe and fittings	
c/w 5 control valves take offs	
In field irrigation equipment comprising:	
40mts x p.e. header mains pipe and fittings	
1000mts x p.e. lateral piping and fittings	
500 x 180deg. microjet assemblies and fittings	
Total F C A S.UK.Port (inclusive of export packing)- Pstl £	3794.00
Estimated cost to ship goods - Pstl £	663.95
Estimated total C P T - Pstl £ Port Sana'a	4457.95

Terms of payment:
In full against shipping documents from an irrevocable letter of credit confirmed in our favour by the Midland Bank Plc, The Bridge, Walsall, W Midlands, WS1 1LN - Sort code 404519 - Account No. 21325566 - in terms acceptable to ourselves.which shall include acceptance and or payment of our draft by the UK advising bank.The letter of credit to be valid for negotiation for 6 weeks after the date indicated below for completion of delivery. Or other terms to be agreed. Any additional shipping costs incurred by Wright Rain shall be for the account of the customer Shipping costs are estimated due to world fuel situation and will be invoiced at actuals at the time of shipping. If client requires a firm shipping cost, then a proforma invoice should be requested against this offer.
Full bill of materials to be submitted at time of order.

Packing: For ocean shipment.

Shipment: C P T PortSana'a Incoterms 1990

Delivery: 8-10 working weeks. from date of acceptance of FOB.S.UK.Port of order and acceptable letter of credit (subject).

Quotation valid for 60 days.

ANNEX 5

EFFECT OF PRODUCTION COST INCREASES ON MARGINS

SA'DAH – EFFECT OF PRODUCTION COST INCREASES ON MARGINS (YR'000/ha)

SORGHUM – Base Case									
YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	50	50	50	50	50	50	50	50	50
PRODUCTION COSTS									
Irrigation Water ('000m3/crop)	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7
Diesel	10.3	11.5	12.7	13.9	15.1	18.4	21.8	28.0	34.7
O&M	7.3	8.2	9.0	9.9	10.8	13.2	15.6	19.7	24.3
Sum (Running Costs)	17.5	19.6	21.7	23.8	25.9	31.6	37.4	47.7	59.0
Other (1)	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1
Total Production Costs	33.6	35.7	37.8	39.9	42.0	47.7	53.5	63.8	75.1
GROSS MARGIN	16.0	13.9	11.8	9.7	7.6	1.9	(3.9)	(14.2)	(25.5)
Irrigation Capital Cost	64.7	68.9	73.0	77.2	81.4	90.7	100.0	120.2	140.9
NET MARGIN	(48.7)	(55.0)	(61.2)	(67.5)	(73.7)	(88.8)	(103.9)	(134.3)	(166.4)

SORGHUM – Case 1 & Case 2									
YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	50	51	53	55	55	55	55	55	55
PRODUCTION COSTS									
Irrigation Water ('000m3/crop)	17.7				13	13	13	13	13
Diesel	10.3	10.5	10.6	10.8	11.0	13.5	15.9	20.4	25.4
O&M	7.3	7.4	7.6	7.7	7.9	9.6	11.4	14.4	17.7
Sum (Running Costs)	17.5	17.9	18.2	18.6	18.9	23.1	27.3	34.8	43.1
Other (1)	16.1	16.9	17.0	17.2	17.3	17.6	17.6	17.6	17.6
Total Production Costs	33.6	34.7	35.2	35.7	36.2	40.7	44.9	52.4	60.7
GROSS MARGIN	16.0	16.0	17.8	19.6	19.1	14.6	10.4	2.9	(5.4)
Irrigation Capital Cost	64.7	63.4	62.0	60.7	59.4	66.2	73.0	87.7	102.9
NET MARGIN	(48.7)	(47.4)	(44.2)	(41.1)	(40.3)	(51.6)	(62.6)	(84.8)	(108.2)

(1) Total production costs minus irrigation & depreciation

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25 August 1993

SA'DAH – EFFECT OF PRODUCTION COST INCREASES ON GROSS MARGINS (YR'000/ha)

WHEAT – Base Case									
YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	40	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1
PRODUCTION COSTS									
Irrigation Water ('000m3/crop)	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
Diesel	7.0	7.8	8.7	9.5	10.3	12.6	14.9	19.1	23.7
O&M	5.0	5.6	6.2	6.8	7.4	9.0	10.6	13.4	16.6
Sum (Running Costs)	12.0	13.4	14.8	16.2	17.7	21.6	25.5	32.5	40.3
Other (1)	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9
Total Production Costs	24.9	26.3	27.7	29.1	30.6	34.5	38.4	45.4	53.2
GROSS MARGIN	15.2	13.8	12.4	11.0	9.5	5.6	1.7	(5.3)	(13.1)
Irrigation Capital Cost	44.2	47.0	49.9	52.7	55.5	61.9	68.2	82.0	96.2
NET MARGIN	(28.9)	(33.2)	(37.5)	(41.7)	(46.0)	(56.3)	(66.6)	(87.4)	(109.3)

WHEAT – Case 1 & Case 2									
YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	40	41.2	43.3	45.4	47.5	50.7	50.7	50.7	50.7
PRODUCTION COSTS									
Irrigation Water ('000m3/crop)	12.1				8.8	8.8	8.8	8.8	8.8
Diesel	7.0	7.1	7.2	7.4	7.5	9.2	10.8	13.9	17.2
O&M	5.0	5.1	5.2	5.3	5.4	6.6	7.7	9.8	12.1
Sum (Running Costs)	12.0	12.2	12.4	12.6	12.8	15.7	18.6	23.7	29.3
Other (1)	12.9	13.5	13.6	13.7	13.8	14.1	14.1	14.1	14.1
Total Production Costs	24.9	25.7	26.0	26.3	26.7	29.8	32.6	37.7	43.4
GROSS MARGIN	15.2	15.5	17.3	19.1	20.9	20.9	18.1	13.0	7.3
Irrigation Capital Cost	44.2	43.2	42.3	41.3	40.4	45.0	49.6	59.7	70.0
NET MARGIN	(28.9)	(27.7)	(25.0)	(22.3)	(19.5)	(24.1)	(31.6)	(46.7)	(62.6)

(1) Total production costs minus irrigation & depreciation

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25 August 1993

SA'DAH – EFFECT OF PRODUCTION COST INCREASES ON GROSS MARGINS (YR'000/ha)

GRAPE – Base Case

YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	180	180.0	180.0	180.0	180.0	180.0	180.0	180.0	180.0
PRODUCTION COSTS									
Irrigation Water ('000m3/year)	23.8	23.8	23.8	23.8	23.8	23.8	23.8	23.8	23.8
Diesel	13.8	15.4	17.0	18.6	20.2	24.8	29.3	37.6	46.6
O&M	9.8	10.9	12.1	13.3	14.5	17.7	20.9	26.4	32.6
Sum (Running Costs)	23.6	26.4	29.2	32.0	34.7	42.5	50.2	64.0	79.3
Other (1)	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1
Total Production Costs	96.7	99.5	102.3	105.1	107.8	115.6	123.3	137.1	152.4
GROSS MARGIN	83.3	80.5	77.7	74.9	72.2	64.4	56.7	42.9	27.6
Irrigation Capital Cost	86.9	92.5	98.1	103.6	109.2	121.7	134.2	161.4	189.2
NET MARGIN	(3.5)	(11.9)	(20.3)	(28.7)	(37.1)	(57.3)	(77.6)	(118.5)	(161.6)

GRAPE – Case 1

YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	180	180.0	187.5	195.0	210.0	225.0	300.0	300.0	300.0
PRODUCTION COSTS									
Irrigation Water ('000m3/year)	23.8				17.5	17.5	17.5	17.5	17.5
Diesel	13.8	14.1	14.3	14.6	14.9	18.2	21.5	27.7	34.3
O&M	9.8	10.0	10.2	10.4	10.7	13.0	15.4	19.4	24.0
Sum (Running Costs)	23.6	24.1	24.6	25.1	25.6	31.2	36.9	47.1	58.3
Other (1)	73.1	74.1	74.3	74.5	74.7	75.1	75.1	75.1	75.1
Total Production Costs	96.7	98.2	98.9	99.6	100.3	106.3	112.0	122.2	133.4
GROSS MARGIN	83.3	81.8	88.6	95.4	109.8	118.7	188.0	177.8	166.6
Irrigation Capital Cost	86.9	85.2	83.6	82.0	80.3	89.5	98.7	118.7	139.1
NET MARGIN	(3.5)	(3.4)	5.0	13.5	29.4	29.2	89.3	59.2	27.5

GRAPE – Case 2

YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	180	180.0	187.5	195.0	210.0	225.0	300.0	300.0	300.0
PRODUCTION COSTS									
Irrigation Water ('000m3/year)	23.8				14.3	14.3	14.3	14.3	14.3
Diesel	13.8	13.4	13.0	12.6	12.2	14.9	17.6	22.6	28.0
O&M	9.8	9.5	9.2	9.0	8.7	10.7	12.6	15.9	19.6
Sum (Running Costs)	23.6	22.9	22.2	21.5	20.9	25.5	30.2	38.5	47.6
Other (1)	73.1	99.1	99.3	99.5	99.7	100.1	100.1	100.1	100.1
Total Production Costs	96.7	122.0	121.5	121.0	120.6	125.6	130.3	138.6	147.7
GROSS MARGIN	83.3	58.0	66.0	74.0	89.4	99.4	169.7	161.4	152.3
Irrigation Capital Cost	86.9	81.6	76.3	70.9	65.6	73.1	80.7	97.0	113.7
NET MARGIN	(3.5)	(23.6)	(10.3)	3.0	23.8	26.2	89.1	64.5	38.6

(1) Total production costs minus irrigation & depreciation

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SA'DAH – EFFECT OF PRODUCTION COST INCREASES ON GROSS MARGINS (YR'000/ha)

ALFALFA – Base Case

YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	60	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
PRODUCTION COSTS									
Irrigation Water ('000m3/year)	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7
Diesel	23.6	26.4	29.1	31.8	34.6	42.3	50.1	64.3	79.8
O&M	16.7	18.7	20.8	22.8	24.8	30.3	35.8	45.2	55.8
Sum (Running Costs)	40.3	45.1	49.9	54.6	59.4	72.6	85.9	109.5	135.5
Other (1)	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
Total Production Costs	48.7	53.5	58.3	63.0	67.8	81.0	94.3	117.9	143.9
GROSS MARGIN	11.3	6.5	1.7	(3.0)	(7.8)	(21.0)	(34.3)	(57.9)	(83.9)
Irrigation Capital Cost	148.6	158.1	167.7	177.2	186.8	208.2	229.5	275.9	323.6
NET MARGIN	(137.2)	(151.6)	(165.9)	(180.3)	(194.6)	(229.2)	(263.8)	(333.8)	(407.5)

ALFALFA – Case 1 & Case 2

YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	60	63.0	67.5	75.0	82.5	90.0	90.0	90.0	90.0
PRODUCTION COSTS									
Irrigation Water ('000m3/year)	40.7				29.7	29.7	29.7	29.7	29.7
Diesel	23.6	24.0	24.4	24.8	25.2	30.9	36.5	46.9	58.2
O&M	16.7	17.0	17.4	17.8	18.1	22.1	26.1	33.0	40.7
Sum (Running Costs)	40.3	41.1	41.8	42.6	43.4	53.0	62.7	79.9	98.9
Other (1)	8.4	8.7	8.8	8.8	8.9	9.0	9.0	9.0	9.0
Total Production Costs	48.7	49.8	50.6	51.4	52.2	62.0	71.7	88.9	107.9
GROSS MARGIN	11.3	13.2	16.9	23.6	30.3	28.0	18.3	1.1	(17.9)
Irrigation Capital Cost	148.6	145.5	142.4	139.4	136.3	151.9	167.5	201.4	236.1
NET MARGIN	(137.2)	(132.3)	(125.5)	(115.8)	(106.1)	(123.9)	(149.2)	(200.3)	(254.0)

(1) Total production costs minus irrigation & depreciation

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SA'DAH – EFFECT OF PRODUCTION COST INCREASES ON MARGINS (YR'000/ha)

SORGHUM – Base Case									
YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	50	50	50	50	50	50	50	50	50
PRODUCTION COSTS									
Irrigation Water ('000m3/crop)	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7
Diesel	10.3	11.5	12.7	13.9	15.1	18.4	21.8	28.0	34.7
O&M	7.3	8.2	9.0	9.9	10.8	13.2	15.6	19.7	24.3
Sum (Running Costs)	17.5	19.6	21.7	23.8	25.9	31.6	37.4	47.7	59.0
Other (1)	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1
Total Production Costs	33.6	35.7	37.8	39.9	42.0	47.7	53.5	63.8	75.1
GROSS MARGIN	16.0	13.9	11.8	9.7	7.6	1.9	(3.9)	(14.2)	(25.5)
Irrigation Capital Cost	64.7	68.9	73.0	77.2	81.4	90.7	100.0	120.2	140.9
NET MARGIN	(48.7)	(55.0)	(61.2)	(67.5)	(73.7)	(88.8)	(103.9)	(134.3)	(166.4)

SORGHUM – Case 1 & Case 2									
YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	50	51	53	55	55	55	55	55	55
PRODUCTION COSTS									
Irrigation Water ('000m3/crop)	17.7				13	13	13	13	13
Diesel	10.3	10.5	10.6	10.8	11.0	13.5	15.9	20.4	25.4
O&M	7.3	7.4	7.6	7.7	7.9	9.6	11.4	14.4	17.7
Sum (Running Costs)	17.5	17.9	18.2	18.6	18.9	23.1	27.3	34.8	43.1
Other (1)	16.1	16.9	17.0	17.2	17.3	17.6	17.6	17.6	17.6
Total Production Costs	33.6	34.7	35.2	35.7	36.2	40.7	44.9	52.4	60.7
GROSS MARGIN	16.0	16.0	17.8	19.6	19.1	14.6	10.4	2.9	(5.4)
Irrigation Capital Cost	64.7	63.4	62.0	60.7	59.4	66.2	73.0	87.7	102.9
NET MARGIN	(48.7)	(47.4)	(44.2)	(41.1)	(40.3)	(51.6)	(62.6)	(84.8)	(108.2)

(1) Total production costs minus irrigation & depreciation

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SA'DAH – EFFECT OF PRODUCTION COST INCREASES ON GROSS MARGINS (YR'000/ha)

WHEAT – Base Case									
YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	40	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1
PRODUCTION COSTS									
Irrigation Water ('000m3/crop)	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
Diesel	7.0	7.8	8.7	9.5	10.3	12.6	14.9	19.1	23.7
O&M	5.0	5.6	6.2	6.8	7.4	9.0	10.6	13.4	16.6
Sum (Running Costs)	12.0	13.4	14.8	16.2	17.7	21.6	25.5	32.5	40.3
Other (1)	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9
Total Production Costs	24.9	26.3	27.7	29.1	30.6	34.5	38.4	45.4	53.2
GROSS MARGIN	15.2	13.8	12.4	11.0	9.5	5.6	1.7	(5.3)	(13.1)
Irrigation Capital Cost	44.2	47.0	49.9	52.7	55.5	61.9	68.2	82.0	96.2
NET MARGIN	(28.9)	(33.2)	(37.5)	(41.7)	(46.0)	(56.3)	(66.6)	(87.4)	(109.3)

WHEAT – Case 1 & Case 2									
YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	40	41.2	43.3	45.4	47.5	50.7	50.7	50.7	50.7
PRODUCTION COSTS									
Irrigation Water ('000m3/crop)	12.1				8.8	8.8	8.8	8.8	8.8
Diesel	7.0	7.1	7.2	7.4	7.5	9.2	10.8	13.9	17.2
O&M	5.0	5.1	5.2	5.3	5.4	6.6	7.7	9.8	12.1
Sum (Running Costs)	12.0	12.2	12.4	12.6	12.8	15.7	18.6	23.7	29.3
Other (1)	12.9	13.5	13.6	13.7	13.8	14.1	14.1	14.1	14.1
Total Production Costs	24.9	25.7	26.0	26.3	26.7	29.8	32.6	37.7	43.4
GROSS MARGIN	15.2	15.5	17.3	19.1	20.9	20.9	18.1	13.0	7.3
Irrigation Capital Cost	44.2	43.2	42.3	41.3	40.4	45.0	49.6	59.7	70.0
NET MARGIN	(28.9)	(27.7)	(25.0)	(22.3)	(19.5)	(24.1)	(31.6)	(46.7)	(62.6)

(1) Total production costs minus irrigation & depreciation

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SA'DAH – EFFECT OF PRODUCTION COST INCREASES ON GROSS MARGINS (YR'000/ha)

QAT – Base Case

YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	440	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0
PRODUCTION COSTS									
Irrigation Water ('000m3/year)	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8
Diesel	10.9	12.2	13.4	14.7	16.0	19.6	23.1	29.7	36.8
O&M	7.7	8.6	9.6	10.5	11.5	14.0	16.5	20.9	25.8
Sum (Running Costs)	18.6	20.8	23.0	25.2	27.4	33.6	39.7	50.6	62.6
Other (1)	76.8	76.8	76.8	76.8	76.8	76.8	76.8	76.8	76.8
Total Production Costs	95.4	97.6	99.8	102.0	104.2	110.4	116.5	127.4	139.4
GROSS MARGIN	344.6	342.4	340.2	338.0	335.8	329.6	323.5	312.6	300.6
Irrigation Capital Cost	68.6	73.0	77.5	81.9	86.3	96.2	106.0	127.5	149.5
NET MARGIN	276.0	269.3	262.7	256.1	249.5	233.5	217.5	185.2	151.1

QAT – Case 1

YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	440	440.0	550.0	550.0	660.0	660.0	660.0	660.0	660.0
PRODUCTION COSTS									
Irrigation Water ('000m3/year)	18.8				13.8	13.8	13.8	13.8	13.8
Diesel	10.9	11.1	11.3	11.5	11.7	14.4	17.0	21.8	27.0
O&M	7.7	7.9	8.1	8.2	8.4	10.3	12.1	15.3	18.9
Sum (Running Costs)	18.6	19.0	19.4	19.8	20.1	24.6	29.1	37.1	46.0
Other (1)	76.8	80.6	81.3	82.1	82.8	84.3	84.3	84.3	84.3
Total Production Costs	95.4	99.5	100.7	101.8	102.9	108.9	113.4	121.4	130.3
GROSS MARGIN	344.6	340.5	449.3	448.2	557.1	551.1	546.6	538.6	529.7
Irrigation Capital Cost	68.6	67.3	66.0	64.7	63.3	70.6	77.8	93.6	109.7
NET MARGIN	276.0	273.2	383.3	383.5	493.7	480.5	468.8	445.0	420.0

QAT – Case 2

YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	440	440.0	550.0	550.0	660.0	660.0	660.0	660.0	660.0
PRODUCTION COSTS									
Irrigation Water ('000m3/year)	18.8				11.3	11.3	11.3	11.3	11.3
Diesel	10.9	10.6	10.3	9.9	9.6	11.8	13.9	17.9	22.1
O&M	7.7	7.5	7.3	7.1	6.9	8.4	9.9	12.5	15.5
Sum (Running Costs)	18.6	18.1	17.6	17.0	16.5	20.2	23.8	30.4	37.6
Other (1)	76.8	105.6	106.3	107.1	107.8	109.3	109.3	109.3	109.3
Total Production Costs	95.4	123.6	123.9	124.1	124.3	129.5	133.1	139.7	146.9
GROSS MARGIN	344.6	316.4	426.1	425.9	535.7	530.5	526.9	520.3	513.1
Irrigation Capital Cost	68.6	64.4	60.2	56.1	51.9	57.8	63.7	76.6	89.8
NET MARGIN	276.0	251.9	365.9	369.9	483.8	472.7	463.1	443.7	423.2

(1) Total production costs minus irrigation & depreciation

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SA'DAH – EFFECT OF PRODUCTION COST INCREASES ON GROSS MARGINS (YR'000/ha)

CITRUS – Base Case

YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	500	500	500	500	500	500	500	500	500
PRODUCTION COSTS									
Irrigation Water ('000m3/year)	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7
Diesel	16.6	18.6	20.5	22.5	24.4	29.8	35.3	45.3	56.3
O&M	11.8	13.2	14.6	16.1	17.5	21.4	25.3	31.9	39.3
Sum (Running Costs)	28.4	31.8	35.2	38.5	41.9	51.2	60.6	77.2	95.6
Other (1)	69.4	69.4	69.4	69.4	69.4	69.4	69.4	69.4	69.4
Total Production Costs	97.8	101.2	104.6	108.0	111.3	120.7	130.0	146.6	165.0
GROSS MARGIN	402.2	398.8	395.4	392.0	388.7	379.3	370.0	353.4	335.0
Irrigation Capital Cost	104.8	111.5	118.2	125.0	131.7	146.8	161.9	194.6	228.2
NET MARGIN	297.4	287.3	277.2	267.1	256.9	232.5	208.1	158.8	106.8

CITRUS – Case 1

YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	500.0	520.0	540.0	560.0	580.0	600.0	600.0	600.0	600.0
PRODUCTION COSTS									
Irrigation Water ('000m3/year)	28.7				21.0	21.0	21.0	21.0	21.0
Diesel	16.6	16.9	17.2	17.5	17.9	21.8	25.8	33.2	41.2
O&M	11.8	12.0	12.3	12.5	12.8	15.6	18.5	23.3	28.8
Sum (Running Costs)	28.4	29.0	29.5	30.1	30.7	37.5	44.3	56.5	69.9
Other (1)	69.4	71.7	72.1	72.6	73.0	73.9	73.9	73.9	73.9
Total Production Costs	97.8	100.7	101.7	102.7	103.7	111.4	118.2	130.4	143.9
GROSS MARGIN	402.2	419.3	438.3	457.3	476.3	488.6	481.8	469.6	456.1
Irrigation Capital Cost	104.8	102.7	100.6	98.5	96.4	107.4	118.4	142.4	167.0
NET MARGIN	297.4	316.7	337.8	358.8	379.9	381.2	363.3	327.2	289.2

CITRUS – Case 2

YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE	500.0	520.0	540.0	560.0	580.0	600.0	600.0	600.0	600.0
PRODUCTION COSTS									
Irrigation Water ('000m3/year)	28.7				17.2	17.2	17.2	17.2	17.2
Diesel	16.6	16.1	15.6	15.1	14.6	17.9	21.2	27.2	33.7
O&M	11.8	11.4	11.1	10.8	10.5	12.8	15.1	19.1	23.6
Sum (Running Costs)	28.4	27.6	26.8	25.9	25.1	30.7	36.3	46.3	57.3
Other (1)	69.4	96.7	97.1	97.6	98.0	98.9	98.9	98.9	98.9
Total Production Costs	97.8	124.3	123.9	123.5	123.1	129.6	135.2	145.2	156.2
GROSS MARGIN	402.2	395.7	416.1	436.5	456.9	470.4	464.8	454.8	443.8
Irrigation Capital Cost	104.8	98.3	91.9	85.4	78.9	88.0	97.0	116.6	136.7
NET MARGIN	297.4	297.4	324.3	351.1	377.9	382.4	367.8	338.2	307.1

(1) Total production costs minus irrigation & depreciation

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SA'DAH – EFFECT OF PRODUCTION COST INCREASES ON GROSS MARGINS (YR'000/ha)

TOMATO – Base Case									
YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE (5 per ton)	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0
PRODUCTION COSTS									
Irrigation Water ('000m3/crop)	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
Diesel	9.0	10.1	11.1	12.2	13.2	16.2	19.1	24.6	30.5
O&M	6.4	7.1	7.9	8.7	9.5	11.6	13.7	17.3	21.3
Sum (Running Costs)	15.4	17.2	19.0	20.9	22.7	27.7	32.8	41.8	51.8
Other (1)	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7
Total Production Costs	59.1	60.9	62.8	64.6	66.4	71.5	76.5	85.5	95.5
GROSS MARGIN	60.9	59.1	57.2	55.4	53.6	48.5	43.5	34.5	24.5
Irrigation Capital Cost	56.7	60.4	64.0	67.7	71.3	79.5	87.7	105.4	123.6
NET MARGIN	4.2	(1.3)	(6.8)	(12.3)	(17.8)	(31.0)	(44.2)	(70.9)	(99.0)

TOMATO – Case 1									
YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE (5 per ton)	120.0	125.0	130.0	135.0	140.0	150.0	150.0	150.0	150.0
PRODUCTION COSTS									
Irrigation Water ('000m3/crop)	15.5				11.3	11.3	11.3	11.3	11.3
Diesel	9.0	9.2	9.3	9.5	9.6	11.8	13.9	17.9	22.1
O&M	6.4	6.5	6.6	6.8	6.9	8.4	9.9	12.5	15.5
Sum (Running Costs)	15.4	15.7	15.9	16.2	16.5	20.2	23.8	30.4	37.6
Other (1)	43.7	45.4	45.8	46.1	46.4	47.1	47.1	47.1	47.1
Total Production Costs	59.1	61.1	61.7	62.3	62.9	67.3	71.0	77.5	84.8
GROSS MARGIN	60.9	63.9	68.3	72.7	77.1	82.7	79.0	72.5	65.2
Irrigation Capital Cost	56.7	55.5	54.3	53.1	51.9	57.8	63.7	76.6	89.8
NET MARGIN	4.2	8.4	14.0	19.6	25.2	24.9	15.3	(4.1)	(24.6)

TOMATO – Case 2									
YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE (5 per ton)	120.0	125.0	130.0	135.0	140.0	150.0	150.0	150.0	150.0
PRODUCTION COSTS									
Irrigation Water ('000m3/crop)	15.5				9.3	9.3	9.3	9.3	9.3
Diesel	9.0	8.7	8.5	8.2	7.9	9.7	11.4	14.7	18.2
O&M	6.4	6.2	6.0	5.8	5.7	6.9	8.2	10.3	12.7
Sum (Running Costs)	15.4	14.9	14.5	14.0	13.6	16.6	19.6	25.0	31.0
Other (1)	43.7	70.4	70.8	71.1	71.4	72.1	72.1	72.1	72.1
Total Production Costs	59.1	85.4	85.2	85.1	85.0	88.7	91.8	97.1	103.1
GROSS MARGIN	60.9	39.6	44.8	49.9	55.0	61.3	58.2	52.9	46.9
Irrigation Capital Cost	56.7	53.2	49.7	46.2	42.7	47.6	52.5	63.1	73.9
NET MARGIN	4.2	(13.6)	(5.0)	3.7	12.3	13.7	5.8	(10.2)	(27.0)

(1) Total production costs minus irrigation & depreciation

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SA'DAH – EFFECT OF PRODUCTION COST INCREASES ON GROSS MARGINS (YR'000/ha)

TOMATO – Base Case									
YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE (15 per ton)	360.0	360.0	360.0	360.0	360.0	360.0	360.0	360.0	360.0
PRODUCTION COSTS									
Irrigation Water ('000m3/crop)	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
Diesel	9.0	10.1	11.1	12.2	13.2	16.2	19.1	24.6	30.5
O&M	6.4	7.1	7.9	8.7	9.5	11.6	13.7	17.3	21.3
Sum (Running Costs)	15.4	17.2	19.0	20.9	22.7	27.7	32.8	41.8	51.8
Other (1)	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7
Total Production Costs	59.1	60.9	62.8	64.6	66.4	71.5	76.5	85.5	95.5
GROSS MARGIN	300.9	299.1	297.2	295.4	293.6	288.5	283.5	274.5	264.5
Irrigation Capital Cost	56.7	60.4	64.0	67.7	71.3	79.5	87.7	105.4	123.6
NET MARGIN	244.2	238.7	233.2	227.7	222.2	209.0	195.8	169.1	141.0

TOMATO – Case 1									
YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE (15 per ton)	360.0	360.0	360.0	360.0	360.0	360.0	360.0	360.0	360.0
PRODUCTION COSTS									
Irrigation Water ('000m3/crop)	15.5				11.3	11.3	11.3	11.3	11.3
Diesel	9.0	9.2	9.3	9.5	9.6	11.8	13.9	17.9	22.1
O&M	6.4	6.5	6.6	6.8	6.9	8.4	9.9	12.5	15.5
Sum (Running Costs)	15.4	15.7	15.9	16.2	16.5	20.2	23.8	30.4	37.6
Other (1)	43.7	45.4	45.8	46.1	46.4	47.1	47.1	47.1	47.1
Total Production Costs	59.1	61.1	61.7	62.3	62.9	67.3	71.0	77.5	84.8
GROSS MARGIN	300.9	298.9	298.3	297.7	297.1	292.7	289.0	282.5	275.2
Irrigation Capital Cost	56.7	55.5	54.3	53.1	51.9	57.8	63.7	76.6	89.8
NET MARGIN	244.2	243.4	244.0	244.6	245.2	234.9	225.3	205.9	185.4

TOMATO – Case 2									
YEAR	1	2	3	4	5	6	10	15	20
CROP VALUE (15 per ton)	360.0	360.0	360.0	360.0	360.0	360.0	360.0	360.0	360.0
PRODUCTION COSTS									
Irrigation Water ('000m3/crop)	15.5				9.3	9.3	9.3	9.3	9.3
Diesel	9.0	8.7	8.5	8.2	7.9	9.7	11.4	14.7	18.2
O&M	6.4	6.2	6.0	5.8	5.7	6.9	8.2	10.3	12.7
Sum (Running Costs)	15.4	14.9	14.5	14.0	13.6	16.6	19.6	25.0	31.0
Other (1)	43.7	70.4	70.8	71.1	71.4	72.1	72.1	72.1	72.1
Total Production Costs	59.1	85.4	85.2	85.1	85.0	88.7	91.8	97.1	103.1
GROSS MARGIN	300.9	274.6	274.8	274.9	275.0	271.3	268.2	262.9	256.9
Irrigation Capital Cost	56.7	53.2	49.7	46.2	42.7	47.6	52.5	63.1	73.9
NET MARGIN	244.2	221.4	225.0	228.7	232.3	223.7	215.8	199.8	183.0

(1) Total production costs minus irrigation & depreciation

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29 August 1993

ANNEX 6

OUTLINE OF LAND & WATER CONSERVATION PROJECT

WORLD BANK PROJECT
LAND AND WATER CONSERVATION PROJECT

OUTLINE

1 OBECTIVES

- Strengthen sustainable agriculture and assist in better management of water resources through:
  - Institutional and technical developments in irrigation and forestry
  - Initiating a programme of water use monitoring and regulation in the agricultural sector
  - Improvingthe efficiency and water management of controlled and small-scale spate irrigated agriculture
  - Conserving key indigenous woodland areas, accelerating tree planting, extending soil and water conservation
  - Pilot actions to establish an approach to watershed management, including rehabilitation of abandoned terraces

2 MEANS (Project Scope)

- Irrigation Development
  - Supply and installation of groundwater conveyance pipes
  - Supply and installation of equipment to establish improved (1ha) irrigation demonstration units on farmers' fields
  - Gabion baskets and other materials for improving existing traditional spate schemes
  - Equipment, vehicles and staff allowances for implementation units in regional agencies

- Forestry Development
  - Technical assistance, training, equipment, vehicles, materials and staff allowances for:
  - Initiating a programme of indigenous woodland management and rehabilitation
  - Upgrading the network of tree nurseries
  - Sand dune fixation, coastal sand stabilisation, and flood control

- Institution Strengthening
  - Technical assistance, training, facilities, equipment, vehicles and staff allowances for central and regional agencies for:
  - Strengthening the respective Directorates General
  - Establishing a system of water monitoring and regulating its use in irrigated agriculture
  - Strengthening technical capabilities in irrigation agronomy, engineering and forestry

3.7 Forestry Development

- Overseas training for graduates and technicians from regional staff
- Establishment of large nursery (250 000 seedlings/year) in Hajjah (Wadi Shiras), primarily for water catchment management; equipping of LCCD nursery
- Equipment, materials and transport
- Training for two graduates; materials and transport for an extension programme using the extension service of SSHARDA, including technical assistance

3.8 Watershed Management and Terrace Stabilisation

- Pilot scale development in Wadi Shiras of integrated approach for future replication, emphasising self-help by farmers.
- Construction of office-residence-store, provision of materials for wadi training, bubbler and drip irrigation and hydrometric and sediment measuring stations

3.9 Use of Saline Water for Irrigation

- Consultant input forestablishing and monitoring two one-hectare plots in the Northern Tihama