Water Stress: Some Symptoms and Causes: A Case Study of Ta'iz, Yemen

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Thesis submitted for the degree of Doctor of Philosophy

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1999

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Abstract:

This study claims that to develop water resources sustainably in areas facing water shortage an understanding of the factors leading to scarcity require an integrated, interdisciplinary and holistic approach. This hypothesis has been tested in the context of a water shortage crisis in the Yemeni city of Ta'iz (population 400,000) that peaked in 1995.

The crisis was triggered by the demise of the main aquifer supplying the city. Numerical assessment of the aquifer's water resources permits an historical reconstruction of its degradation. The environmental cost of its demise, were irrigated agriculture to cease so that the aquifer could recover, is modelled. The returns to water from agriculture and industry are estimated in economic and livelihood provision terms, and contrasted. Sectoral contribution to water resource pollution is also contrasted. The area's dependence on grain imports is evaluated in terms of 'virtual water' (Allan,1998). Adaptation to water shortage of individual households and water-related businesses is assessed quantitatively (through questionnaires) and that of political actors qualitatively through interviews. An assessment of the influence of the legal and institutional frameworks to the adaptive process utilises secondary data and interviews.

These data and analysis suggest that the reality of water allocation in the Ta'iz area reflects politcal rather than economic factors, and economic rather than water resource criteria. The data are also used to examine critically the causes of the crisis in terms of political ecology and environmental reconstructionist models of sustainable development. An alternative model is proposed which incorporates economic progress, environmental protection and equity provision. Northern hydropolitical theory is found inadequate to encompass the allocative process of a Southern weak state (Migdal, 1988).

Acknowledgments

I would like to acknowledge Dr Mohammed Lutf Al Eryani for making the research in Yemen possible and Abd Ar Rahman Al Eryani for giving insights into the political makeup of the field area. Abd As Salam Abd Al Alim Hasan provided valuable exposure to indigenous legal and institutional frameworks, Abdullah Saif provided hydrological data, and Drs Gazi As Saqqaf and Khalid Riaz agricultural economics data. Digby Davies, Christopher Ward, Cecile de Rouville and Drs Aslam Chaudhry, Marcus Moench, Alex McPhail, Tony Zagni and Peter Mawson are gratefully acknowledged for stimulating discussion and assistance in understanding socio-economic issues related to the study. Drs Richard Morris, Malcolm Lonsdale, Barry Lakeman and John and Andrew Mitchell, and Roy Avis, Gavin Thomas and Debbie Lakeman generously gave of their time in discussions, statistical and meteorological advice, support and logistics. Office facilities were made available by Margaret Shaw and the Kerith Centre. Jane Dottridge (UCL) patiently guided chapter three and Yasir Mohieldeen and Hirouki Yoshida (SOAS) processed the satellite image data used in Figures 3.10 and 4.2. The frontispiece is by Dan Westin. I would especially like to thank Gerhard Lichtenthaler for his continued encouragement, my wife for her patience and proof-reading and last, and perhaps most, Professor Tony Allan for his supervision, provision of facilities, encouragement and support.

I am also grateful to UNDP and Dar El-Yemen for permitting me to use data collected whilst on contract to them.

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Notes

1. During the main period of field work (1995 to 1998) the exchange rate for the Yemeni Riyal varied from 120 to 140 YR = $1US

2. Because the literature prefers North – South terminology to Developed World– Developing World or First World – Third World terminology, North – South has been used. However, when the context is internal to Yemen North – South refers to the pre-unification states (pre 1990) or after that date, or generally, to the peoples north and south of Yarim.

Abbreviations and Acronyms

AREA	Agricultural Research and Extension Authority
CACB	Cooperative and Agricultural Credit Bank
CES	Consulting Engineers Salzgitter GmbH
CPR	Common Pool Resources
CROPWAT	Computer program for irrigation planning and management
CSO	Central Statistical Office (Ministry of Planning)
DISWC	Department of Irrigation and Soil and Water Conservation
EEC	European Economic Community
EC	Electrical Conductivity
EKC	Environmental Kuznetz Curve
FAO	Food and Agricultural Organisation
GAREWS	General Authority of Rural Electricity and Water Supply
GDP	Gross Domestic Product
GPS	Geographical Positioning System (Hardware)
GTZ	Deutsche Gesellschaft fur Technische Zusammenarbeit
GWV	Ground Water Vistas (Software)
HP	Horse Power
HWC	High Water Council (of Yemen Arab Republic)
IDAS	Innovation Development in the Agricultural Sector
LC	Local Council
LCCD	Local Councils for Cooperative Development
LDA	Local Development Association
LWCP	Land and Water Conservation Project
MENA	Middle East and North Africa (World Bank Region)
MEW	Ministry of Electricity and Water
NGO	Non-Government Organisation
NIE	New Institutional Economics
NWRA	National Water Resources Authority
NWSA	National Water and Sanitation Authority
PE	Potential Evaporation
PPP	Polluter Pays Principle
PRA	Participatory Rural Appraisal
PSP	Private Sector Participation
RASM	Readily Available Soil Moisture
RO	Reverse Osmosis
RRA	Rapid Rural Appraisal
SCS	US Soil Conservation Service
SOAS	School of Oriental and African Studies
SURDU	Southern Uplands Rural Development Unit
TOR	Terms of Reference
TS-HWC	Technical Secretariat of the High Water Council
TSWSSSR	Technical Secretariat for Water Supply and Sanitation Sector Reform
TWSSP	Ta'iz Water Supply and Sanitation Project
UCL	Universtiy College London
UNDP	United Nations Development Programme
UNDDSMS	United Nations Dept. for Development Support and Management Services
WDM	Water Demand Management
WHO	World Health Organisation
WIER	Water is an economic resource
WINER	Water is not an economic resource
WRM	Water Resources Management
WTP	Willingness-to-Pay
YR	Yemeni Riyal (Currency)

Chapter 1 Introduction

A meeting was held in Ta'iz, Yemen, in observance of the World Day for Water, 1998. The meeting was attended by representatives from major organisations associated with foreign aid and development, local community and local and central government representatives, NGO's involved in environmental protection, and, in the name of public awareness, several hundred noisy school children. The meeting was hosted by the relatively newly established national body responsible for water resources. After the meeting, a group of smartly dressed people representing most of these organisations went on a brief field trip in a rather new and luxurious Layla 'alawi (Totyota Landcruiser status symbol, named after a Yemeni politician's daughter who acquired one). The chosen destination was a 400m deep borehole in Habir being tested to determine its safe yield with a view to connecting it to the main pipeline supplying the city of Ta'iz 25 km to the South. After a brief conversation with the engineer responsible for the test, a nearby shallow well dug into the wadi gravels was visited, from which its owner happened to be irrigating a field of tomatoes. Standing in his farm-soiled local dress he informed the group with great conviction regarding the detrimental effect the pumping test was having on his water supply. The group then returned to the Governor's lunch awaiting them in the city of Ta'iz, the 400,000 inhabitants of which, received poor quality water once every 3 weeks from the public utility.

On the way from field to city the plight of the (assumedly) poor farmer was discussed by the eminent experts. Depending on the background of the speaker, discussion topics ranged around how soon the well could be on-line, the need to compensate locals for derogation, the role of appropriate stakeholder representative local institutions, the need to understand the locals' perceptions and social water uses, the application of Islamic law to the situation and many others. However, the discussion seemed to miss the reality. Actually, monitoring of the farmer's well indicated no effect after extended pumping from the test well in terms of water level or hydrochemistry. He was simply being opportunistic. Although the visitors had failed to determine this information, vital as it was to their grand strategising, it was not the central issue. More importantly, the visiting actors managed to reach the wrong conclusion by following the scripts and narratives their disciplines had taught them, resulting in their missing the 'big picture' of the links the common subject of water must form between those disciplines if water resources management is to be effective. The incident described above not only contains in microcosm some of the multi-faceted aspects of water resources management involved in the area of Ta'iz, but also, and, more importantly, the need for the managers to have a multi-faceted grasp of their task.

1.1 Purpose and Scope of the Thesis

A central hypothesis to this study is that an integrated, interdisciplinary approach to water use is needed if determinants of allocation are to be understood and sustainable measures introduced. The water stressed situation which has evolved in Ta'iz between 1965 and 1995 provides an example with which to test that hypothesis. The Ta'iz data are also used to examine critically:

a) the relevance of demand management,
b) the role of social adaptive capacity,
c) the relative importance of economic and political factors,
d) the contribution of plural legal and institutional frameworks
e) the significance of virtual water and population growth, and
f) the potential for sustainable development in the allocation of water in the context of severe water stress in a Southern state.

The water resources of a specific area (Wadi Al Hayma, 16 km^2) are evaluated within the context of the record of abstraction for domestic use and, using satellite imagery and water balance modelling, for agricultural use as well. The environmental cost of the depletion of the main aquifer in Al Hayma is evaluated in terms of projected lost agricultural production that would be incurred in enabling aquifer recovery. The returns to water from industrial use are analysed numerically and contrasted with those from agricultural use for the wider (930 km^2) Upper Wadi Rasyan catchment. [The locations and areas of Wadi Al Hayma and Upper Wadi Rasyan included in this study are indicated in Figs. 3.1 and 3.2.] The environmental impact of industrial and urban domestic water use is also qualitatively assessed. The politicisation of water allocation between agricultural and urban domestic users and the potential for conflict are critically examined. The dependence on virtual water to meet the food needs of the increasing population is quantified. The plural institutional and legal frameworks are appraised from the perspective of whether they contribute to providing or preventing equitable water allocation. The efficiency of the water markets and whether their provision is equitable are critically examined and the volume of water transacted on the market, and its quality and price are evaluated quantitatively. The capacity to adapt to water shortage across the spectrum of social scale from individual households and businesses to the government is portrayed statistically and through an examination of specific allocative issues respectively. A review of past and present economic development efforts permits a critical assessment of sustainable development models and the potential for environmental protection and equity provision.

1.2 Thesis Outline

No doubt the literature would be more replete with the useful lessons learnt from failures if professionals were not so economically and politically insecure. In many fields the study of failures offers the greatest opportunity for understanding processes. Ta'iz is an example of failed water resources management. The author of this study was privileged to be able to observe the consequences of that failure. The fieldwork spanned the period 1995 to the end of 1998. Although the 'water crisis' peaked in the summer of 1995, it continues to this day and yet higher peaks may lie ahead. Some causes of the crisis are traced from 1960's roots, although an earlier beginning is explored to explain some of the deeper causes.

Many factors have contributed to the water problems of Ta'iz and the 'knock-on' effects of those problems have been numerous and diverse. An analysis of the problems, their causes and effects demands an integrated, holistic examination of their linkages. The locals and the passing observer view the 'whole picture' as it faces them. Specialists from the disciplines of hydrogeology, agriculture, development, economics, politics, environmental and any other field involved notice the colour of their discipline that contributes to the painting. The policy maker also wants to see the whole 'water colour' and needs to understand the linkages between the various aspects of it that would traditionally belong in different academic pigeon-holes. The thesis attempts to examine the nature, extent and origins of the shortage. Attempting to integrate the different fields which contribute to the Ta'iz water crisis provides a unique opportunity to examine the linkages between many diverse physical and human aspects of water resources management in the context of extreme water shortage.

After a review of related literature, the physical water environment that Ta'iz impacts, and affects Ta'iz, is investigated in terms of water availability and quality in chapter three. The development of the most important aquifer to Ta'iz is examined in detail and a reconstruction of the causes of its demise is attempted. The social response to water availability and use is considered against the underlying economic realities in chapter four. These two chapters provide physical and socio-economic 'maps' of the shortage. Because different methodologies were used to create the 'maps' of the shortage, each methodology is described in its relevant section, and there is no single 'methodology' section. In chapter five, the concepts and principles discussed in the literature are used as filters for looking at the Ta'iz 'maps'. The 'maps' are also used as a means of testing and revising the concepts and principles. Chapter five is structured on the basis of the proposed causative sequence described below, but in the direction of symptom to cause rather than vice versa. The Ta'iz experience is considered in the context of the apparent contradiction of sustainable development. Chapter six concludes the study by considering the appropriateness of the integrated approach and asking whether the lessons learnt from Ta'iz could be of value to other population centres facing similar crises.

1.3 Initial Concepts

The lateral and vertical distribution of people vis-à-vis water provides a means of attempting the contradictory; the compartmentalising of something which is inherently holistic, that is, water.

The Lateral Distribution of Water and Humans: Urban – Rural Distinctions
At the most basic level, *homo sapiens* interacts with the environment extracting needs and returning waste:

Air, Water, Food
←=========
Man Environment
=========→
Waste Products

Human communities, seeking to enhance their comfort, shelter, convenience and security, tend to concentrate in settlements. These settlements must look to ever increasingly technological means to provide man's needs (and wants). The location supplying the basic needs typically lies outside the settlement, and the 'footprint' of supply and environmental impact spreads as the settlement grows. In terms of water this is probably better termed a maldistribution of people than of rainfall (Turton,1999a) and results in a rural – urban (and even North South) distinction:

Urban	Rural
Resource Demand Centre	Resource Supply Footprint
Waste Supply Centre	Waste Disposal Area*
Industrial Activity	Agricultural Activity
Urban Domestic Supply	Rural Domestic Supply
Increasing Livelihood Provision	Declining Livelihood Provision

Result: Population Pull ←======= Population Push =Urbanisation

* The urban area can also be one of waste disposal, but the 'footprint' of environmental impact by waste may spread beyond the area occupied by the urban waste producers (Serageldin, 1994;5).

Lundqvist (1998;Table 1) makes a similar urban-rural distinction using the terminology of industrial-mechanical and biological-landscape, differentiating waste disposal (externalities) as being diffuse and concentrated respectively.

The Vertical Distribution of Water and Humans:

Since water is unbreathable for humans, when they need water they have to lift it. The movement of resources and waste, for example of air, water and food is largely determined by their physical state, thus gaseous fresh air and Chernobyl clouds are at the mercy of the weather to drift where they will. Solid food products and waste tend to stay where they are put, but liquid water supplies and polluted waste-water flow down-hill under gravity unless impounded by technologically adequate means.

The primary dynamic acting on water is the physical one of gravity. However, 'water flows up-hill to money and power' (Reisner,1986). In attempting to reverse gravity-flow, human demand (an 'anthropocentric' dynamic, or 'egocentric' dynamic when want exceeds need) is met by technological innovation. As well as a preference to be upwind, upstream and as far as possible from a landfill site, Yemeni settlements, unlike temperate climate settlements, tend to be located in mountainous areas and are often on the mountain ridges. This may be for defence reasons and also to keep away from the dangerous flash floods of the wadis. The result is the need for a lot of water to be lifted. (Allan,1994a notes a similar population / water elevation separation on a larger scale in the Jordan catchment). The rainfall distribution also results in communities on the mountains being nearer to the ultimate source, that is the rain, and enjoying the economic advantages associated with being upstream users rather than downstream users (Varisco, 1983). The poor, who often seem to be located at the downstream end and are missed out by the ethnocentric dynamic, are sometimes provided for by religious or areligious equity-driven do-gooding. This third, least evident, and therefore weakest dynamic perhaps could be called 'good' or 'theocentric'.

Dissecting the Holistic for the Purpose of Analysis

For water resources management to contribute constructively to the establishment of an economy developing in a sustainable manner, the unenviable task of policy formulation and decision making must weigh a host of variables, some of which are inherently in tension. The need for holism in determining those weights is self-evident, but the variables still have to be isolated to be weighed. As a starting point primary aims must be distinguished from secondary and ends from means. The following table summarises some basic aims in providing water:

Problems / Aims		
Adequate Provision	Environmentally Sustainable Provision	Equitable Provision

In providing water there are two ways of making it go further. One is to make it produce more of the same (productive efficiency) and the other to produce something else of greater value (allocative efficiency). 'The same' is typically defined as within the same broad sector, agriculture, for example, rather than the same item, potatoes, for example.

Overall Methods / Means: Increased Water Use Efficiency	
Productive Efficiency	Allocative Efficiency

Various mechanisms contribute to both allocative and productive efficiency, though engineering ones tend to be directed more at the latter and fall in the category of supply management measures (that is, which increase the supply). The dynamics acting on water provision are depicted as:

Determining Dynamic	Gravity	Money	Power vs. Equity Coercion vs. Co-operation
Context	Physical	Economic	Cultural / Socio-Political
Mechanisms	Engineering	Signals	Legal Framework – 'Rules'
Enablers	Projects	Markets	Institutions – 'Players'

These forces operate within, and help to shape, a context which is not static and in which various allocative trends or processes are taking place. The removal of water subsidies, creation of water markets and establishment of reallocative water transfers are economic measures which can help reduce demand, but which all require political facilitation. Political enabling, in turn, is conducted by institutions directed and supported by a legal framework. This sequence may be depicted as:

Political =>	Legal =>	Institutional =>	Economic =>	<= Social =>	<= Physical

For example, the outer layer of this sequence, the environment, is perhaps the easiest to observe and measure. Abstracting resources from it and returning waste to it is the sphere of human activity, which is in turn influenced by underlying economic realities. In a democratised society, such as the UK, the economic realities of water transactions, for instance the magnitude of one's water bill, are meant to reflect rates set by the relevant institution, for instance the water authority or water company. Thus the institutional layer underlies the economic. That institution has a legal mandate, for instance from OFWAT, which is in turn established by a legal framework (the next layer), which itself came into existence through the deliberations of an elected political body (the core). The extent to which this sequence of causation allocates water, and thereby the benefits of water use, equitably or for the perpetuation of power asymmetries is a key issue.

The sequence is used here merely to provide a means of examining a whole. Some of these categories are rather loose, may overlap to an extent, and may be short-circuited. In some instances the occurrence of feedback suggests the relationships between them are interactive (such as those in power responding to the needs of the electorate). For the purpose of this discussion 'physical' refers to the quantity and quality of water, that is, the water environment, with which communities interact. Together with economic signals, or their absence, these environmental constraints largely determine the hydraulic activity limits of those communities (for instance limiting the extent to which the desert can be made to bloom).

When compared with other rather unidirectionally changing trends and processes that typify the South, some of which are listed below, the mechanisms and contexts in which the compartments of the sequence operate are much more static :

Trends / Processes
Population Increase
Urbanisation
Technology / Communication

These trends have been evident in Yemen, particularly during the past thirty years. During this period economic development has entered a water resources management arena in which the various contexts, mechanisms and trends mentioned above are already operating. As a consequence, economic development which seeks to modify the status quo is itself modified by the limitations of that arena.

Chapter 2 Hot Water Topics: What the Papers Say

This chapter examines the thinking of those who publish their thoughts on water resources management within the various traditional academic compartments or epistemic groups. As discussed in the introduction, this method is put forward as a basis for examining the situation in Ta'iz, Yemen. Since there is overlap between the compartments, the headings are not intended to be water-tight. After considering the need for an integrated, holistic approach and a brief look at the 'global water issues picture', the discussion moves from an examination of the role economic principles play in the allocation of water resources, to the political. The contribution of political ecology, beliefs and knowledge to the political debate is considered. Between the economic and the political are the 'transmission gears' of institutions empowered by a legal framework. The discussion then looks at the sustainable development contradiction. Each facet presents some 'current thinking' amongst the international community which provides both a context against which to compare the Yemeni data in chapter 5.

2.1 Holism, Interdisciplinarity and Integration

A review of the literature suggests the need for a holistic approach when considering water resources management issues is not new. Since 1990 the term integrated has replaced 'holistic' in water resource studies, however integration of a partial analysis is inadequate and both terms are necessary. McSweeney (1998) describes water as "a transient resource" which "transcends the boundaries of every living thing on the planet", and disparages the tools of "our 'atomistic', fragmented and departmentalised academic disciplines" with which we analyse water and water management. One example of discipline myopia is the tendency for some to emphasise water volumes and water quality, whilst others focus on water quantity and price. Reality is a combination of all three. As Berkoff (1994;xvi), after mentioning its economic value, completes the vital trio stating, "water quality should be considered simultaneously with water quantity".

Significant problems arise when holism and integrated are omitted. Allan (1996b;117), citing the example of the international legal community's tendency to base their rules on principles of hydrology and environmental science, that is, closed watersheds, rather than on the political realities of open problemsheds, points out that hydrological systems are subordinate to national political economies. He suggests that this very stance of the legal community contributes to the problem of not solving water allocation in the Jordan basin. Another example is that of the technical modifications intended to solve problems of efficient operation of irrigation systems in the Nile Delta. Radwan (1994;57) suggests the technical interventions not only may not achieve the desired improvement, but may even impair it. The reason, he suggests, is that the efficiency problems are related to the social mechanisms governing the irrigation system.

Although not explicitly mentioned in the conference statements of New Delhi, Dublin and Rio, their scope assumes an holistic approach. Participants call for a 'comprehensive' framework and analysis encompassing the relationships between the (physical) ecosystem and (human) socio-economic activities (World Bank 1993;10), or the integration of social equity as well as economic efficiency (McSweeney,1998). In the light of water's 'unitary' nature, the need for integrated resource management in order to meet national economic, social, security and environmental objectives (Berkoff, 1994;xi) is clearly stated. The holistic hypothesis is therefore not new and integrated approaches to water are at least paid lip-service throughout the literature (eg Keenan,1991;34, Delft Declaration,1991;Annex Point 2). However, in practice, other situations may occur:

a) To simply ignore the interdisciplinary nature of water resources management planning:
in particular, ignoring the non-engineering aspects of the plans (Therkildsen, 1988;15) was the traditional stance.

b) Omitting disciplines from an 'interdisciplinary study':
such as the absence of team members with expertise in physical aspects of water management from 'interdisciplinary' field studies of urban water and sanitation utilities (Cowen,1994;27).

c) To have the wrong discipline tackling the wrong aspect:
such as engineers busy constructing water supply schemes but ignoring the fact that intrigues and conflicts over water rights will determine whether those schemes will ever be operable (Morris, 1991;75), or sociologists choosing drilling materials which resulted in the water supplied becoming saline (Carl Bro International, 1988;5.2.2).

d) To conduct an 'integrated' study which is not interdisciplinary, when interdisciplinarity was called for:
such as omitting the water resources assessment in an 'integrated' rural development plan (CPO et al 1976 in MacMillan,1976).

e) To fail to distinguish between interdisciplinary and integrated.

The latter is, perhaps, the most common mistake and can result in a "series of largely unconnected reports or studies" achieved by "long, drawn-out multidisciplinary research in which each discipline wanders off into the minutae of its specialized by-ways, leaving gaps, and rendering more difficult tight integrating analysis needed to generate good recommendations for action"(Chambers and Carruthers, 1986;10,1, see also Therkildsen, 1988,15 and 82). The Wadi Rima project, Yemen may well fit this category. 20 professionals worked for 2 years to make recommendations to increase water capture. The implementation resulted in a reduction of cropped areas downstream, up to 2/3 sharecroppers being driven off the land and only slightly more water being captured (Morton, 1994;35).

Why should we be blind to our lack of interdisciplinarity and integration? Some are quite disparaging about the trespassing of experts into fields other than their own (Uphoff, 1986;2). Others think that this is precisely the problem, suggesting "a balanced pluralist approach, empirically based and with a wide span in both political economy and physical ecology is more likely to fit the reality" where "pluralism recognises multiple causation" (Chambers, 1983;44). Similarly: "It became clear that the poor performance of many irrigation systems in terms of productivity and equity was .... due to the tunnel vision of traditional irrigation science" (Oorthuizen & Wester 1994;i). Chambers identifies Uphoff's trespassers as a solution: "Narrow specialists can be a liability, and the ideal are multidisciplinary individuals whose horizons are not limited by their own original disciplines." (Chambers and Carruthers, 1986;10).

Perhaps the field of irrigation was one of the first to graduate from the single cause (typically technical, Jurriens & de Jong, 1989;35) to the multiple cause concept of water management problems. Irrigation was then recognised as a physical, human and socio-technical process in which social relations of power and technological development mutually influence each other (Mollinga,1998;12-14, Manzungu,1999;7,11,14). We need to get the engineering, prices and process right (Uphoff 1986;1). Jurriens & de Jong (1989;35 et seq.) also trace a shift in the meaning of O & M from operation and maintenance to organisation and management, reflecting the underlying shift in emphasis towards institutional matters.

The more recent 'arena' model of irrigation planning described by DISWC (1993;4) parallels the broad scope of integrated interdisciplinarity needed in any area of water resources management which:

> "seeks to develop an interdisciplinary perspective ..... by considering the relationship between technology and management... and the integration of

> rural development issues" in which "water management is a form of social interaction of different actors employing different methods, resources and strategies around the issue of water distribution.... in a socio-technical system.. with a spatial hydraulic/social element and a time element that is embedded in the agrarian structure, the institutional infrastructure of the state and state-like institutions and the material infrastructure.. of ecology and technology"(ibid;7)

Beyond the mono-sectoral irrigation literature, in the broader field of water resources management, this multi-faceted arena has been categorised by Van Beek (quoted in Hansma and Hermans, 1997;11) into three systems, natural resources, socio-economic and administrative/institutional systems; a broad grouping of the facets of this thesis.

2.2 The Global Position

2.2.1 Global water statistics indicate the size of the problem

Allan (1994a;4) points out the huge differences in annual human water needs: for drinking, $1m^3$; for domestic purposes, $100m^3$; and in food, $1000m^3$. To meet those needs plus industrial demand, Ohlsson (1995;5) estimates that around one third of the world's 12-14 thousand km^3/yr of non-soil, renewable freshwater resources are withdrawn. He breaks down these withdrawals as 69% to agriculture, industry 21%, and municipal 6%, however, sector consumption is 89% to agriculture, industry 5% and municipal 2%. The huge consumption by agriculture is exacerbated by irrigation. However, 36% of agricultural yields come from the 16% of farmland which is irrigated.

There are really only two ways of 'losing' water, either through evaporation (from which state it will rain on someone else) or through contamination. Seepage of aquifers to the sea and the flow of rivers to the sea are the equivalent of loss through contamination. The assessment of soil-water in global water statistics is referred to by Allan (in prep.). Its under-utilisation can only occur if evaporation is taking place instead of evapotranspiration. Fallow ground therefore is a source of water loss to an area. If the soil cannot retain enough water to support the crop for the full season and there is no potential to supplement the water supply then it is difficult to see how the soil water could be utilised. Some water will inevitably be 'lost' to evaporation from the soil. That which is 'lost' through seepage to the aquifer could be reclaimed but only with energy input for lift.

In 1991, Vincent (1991;197) stated that only 1.3Bn of the world population had clean water and 700m sanitation, noting that coverage was especially poor in the Middle East. Serageldin (1994;3) suggested that 1Bn people lacked an adequate water supply and that 1.7Bn were without sanitation. Lundqvist (1998) states that 1Bn are without access to safe water and 800m are without a secure food supply. Although many global water statistics are bandied about, some of which are contradictory, whilst others do not compare like with like, the overall picture of water shortage and an increasing drain on the resource base is consistent. The consequences of shortages are literally a matter of life and death. Within the MENA area (World Bank designation for the Middle East and North Africa) Berkoff (1994;14) considers that the provision of uncontaminated water supplies could reduce death in rural and urban areas by 30%, and another 20% if sanitation were to be provided. Most of the deaths are amongst the 0-14 year age range who account for 43% of the area's population.

Population growth is the single most important factor affecting the above estimates. Ohlsson (1995;28) estimates a world population of over 10Bn by 2050, 96% of whom will be in the South. Allan (1994b;66) bemoans the emphasis by regional leaders on the water supply deficiency whilst de-emphasising the demographic explosion that is its cause. However, the global picture is not all gloom. Despite a population increase of 23% in the developing world between 1980 and 1990, access to safe water increased from 77 to 82% and from 30 to 63% in urban and rural areas respectively and sanitation coverage increased from 69 to 72% and from 37 to 49% in urban and rural areas respectively (World Bank, 1993;36).

2.2.2 Some attempt to solve the problem

The reason for such increases in safe water and sanitation provision in the 80's was partly due to the efforts of the global development community in response to the 'Water Decade'. The declaration that the 1980's should be designated as the International Water Supply and Sanitation Decade occurred at the UN Water Conference in Mar Del Plata, Argentina in 1977. The conference was described as 'the first of its kind ever held in the area of water' which 'sensitised the world community on the importance of water for development' (Thanh and Biswas, 1990;xiii). This was followed by the UNDP Global Consultation on Safe Water and Sanitation for the 1990's in New Delhi at which participating musketeers aimed at "some" safe water "for all rather than all for some" by the year 2000. Four parts of the conference statement (quoted in Vincent, 1991;212) reflect the state of play in water debates:

1: "Protection of the environment and safeguarding of health through the integrated management of water resources and liquid and solid wastes".

2: "Institutional reforms promoting an integrated approach and including changes in procedures, attitudes and behaviour, and the full participation of women at all levels in sector institutions"

3: "Community management of services, backed by measures to strengthen local institutions in implementing and sustaining water and sanitation programmes"

4: "Sound financial practices, achieved through better management of existing assets and widespread use of appropriate technologies"

Vincent is particularly critical that the statement suffers from "confusing and contradictory rhetoric" and anticipated that it would have no impact. She cites the 'mixed bag' of item 2 measures as "confusing" and item 4 as "contradictory and controversial". However, the points did focus on the main water issues of our times, or at least on those of the changing agenda of the aid fraternity. According to Serageldin (1994;1), the previous 'old agenda' had been about providing household services, whilst this 'new agenda' emphasises environmentally sustainable development.

Other international conferences have also influenced the 'new agenda'. In 1991, the UNDP held the Delft conference entitled A Strategy for Water Sector Capacity Building which dealt primarily with the need for reform in water institutions. The International Conference on Water and the Environment held by the UN in Dublin in 1992 felt that "it is vital to recognise first the basic right of all human beings to clean water and sanitation at an affordable price" (quoted in Lundqvist, 1998;9) and stated the new agenda rather more clearly in what are widely referred to as the Dublin principles:

a) Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.

b) Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.

c) Women play a central part in the provision, management and safeguarding of water.

d) Water has an economic value in all its competing uses and should be recognised as an economic good.

The water resources policy measures of Delft and Dublin were endorsed by world leaders at 1992 UNCED in Rio de Janeiro and were included in the Earth Summit of 1993 (Le Moigne et al, 1994;3). McSweeney (1998;10), summarises Dublin as identifying that water is "to be treated as a scarce valuable resource" and that the conference marked the "introduction of demand management mechanisms". He also describes Rio as "the most comprehensive international environmental and social declaration to date" and as having "equity at its heart", by which he means 'intergenerational equity': that is, not dumping the consequences of our environmental misuse on future generations. Although Rio diluted Dublin it did identify the fundamental dilemma in the regulation of competitive water use: conservation of water as a prerequisite for development versus development threatening water availability (Du Bois, 1992;1).

Briscoe (1994) succinctly describes the 'new agenda' of the international conferences as "no more than the application, to water, of the great ideas of our time, namely democracy and the market" (quoted in Davies and Sahooly, 1996;9). However, whether the slippery concept of equity at the heart of Rio will become the "greatest good to the greatest number of people" (McSweeney,1998) is questioned in Orwellian style by Allan (1994a;3) when he asks "equity for whom" and "on what scale"?

2.3 The Value of Water

2.3.1 The value of water

The value of water to a man dying of thirst in the desert is very different to the large negative value of water to the engineer trying to dewater foundations. McSweeney (1998) asserts that "things only have a value when their existence affords a utility to some person". The potential for ownership imparts value and value arouses the desire to own. The capacity of water to flow and to dissolve substances which pollute it make it respectively difficult to own and urgent to use. Classical (Rogers,1992;7.14) and neo-classical (Burrill,1998) economics equate value with price. Apart from the simple model of water having different values to different individuals, Burrill distinguishes a societal value for water (ibid.). She discusses many 'difficult to price' aspects of water. These include the health, sustenance and pleasure aspects enjoyed by society as a whole, the 'knock-on / trickle-down' value of water to those associated in a secondary way to water (such as food provision, water tanker mechanics etc), the future value of water and the value to non-users. Allan (1994b;99) comments on the failings of leaders, legislators, officials and engineers to understand the value of water. Our value systems are based on our perceptions, and Rogers (1992;7.27) points out the different perceptions of water by individuals, as opposed to groups who collectively make decisions about future uses of water. The latter, he suggests, adopt the common social misconception that water is a pure public good, whilst the former are more likely to understand water as an economic or private good.

Distinguishing between public and private goods (Pearce,1993;3) is related to their subtractability and excludability (World Bank, 1993;81). Subtractability means that if one person consumes the good another person cannot, and excludability means how easy or difficult it is to prohibit access to the good. Drinking water of essence is subtractable within quality constraints in that it cannot be drunk again without treatment. Similarly, a tanker of water is more subtractable and easier to exclude people from than an urban water supply and is thus considered more private and less public. The subtractability/ excludability aspect is directly related to the natural monopoly (and hence greater economies of scale) characteristic (World Bank, 1993;83, Berkoff, 1994;23) of infrastructure-rich, and hence capital investment-rich, pieces of plumbing such as urban water supplies and sewerage systems. This lends the plumbing a certain predetermining allocative logic (Falkenmark and Lundqvist, 1995;204).

Some have said that "water is no longer free anymore" (Delft 1991;19). Of course, it never was, as water auctions in Oman going back to pre-Islamic times (Wilkinson, 1977;113), and many other situations, testify. However, the rainfall-rich, traditionally engineering-orientated, North (Ohlsson, 1995;5) is waking up to the fact that water is an economic good (Berkoff, 1994;21). Its value must also include its opportunity cost (Winpenny, 1994;83, Rogers 1992;7.15, Berkoff, 1994;21). That is, its price must reflect the lost opportunity for use by one potential user when it is used by another. Ideally, the incorporation of opportunity cost should ensure that water gravitates to the highest value use, and, according to Rogers (1992;7.15) should reflect 'willingness-to-pay'(WTP). For many in low-income countries, their WTP is a trade off between time spent collecting water and money (Pearce, 1993;78). Allan (in prep;5.21) contrasts users' willingness-to-pay and their capacity-to-afford, where "affordable means the price acceptable to current users which, if left unchanged, brings a political dividend, and if exceeded generates opposition and dangerous political stress".

How demand is expressed by users and how it is determined by providers are other major questions with which economists and sociologists grapple. Although 2% of disposable household income is the rule of thumb maximum limit for water supply and 5% is unacceptable (World Bank quoted in Allan,in prep;5.22), WTP's of 8% (Ukundu) or even 10-18% (Nigeria) can occur, especially if bought from vendors (Rogers,1992;7.20, Pearce,1993;78, World Bank,1993;49), with poorer sectors often paying higher proportions of their incomes. The switch to vendors typically reflects the declining reliability of the piped supply (Littlefair,1998). Not that the consumers are willing buyers but are trapped into market participation by their predicament (Allan,in prep;5.30). The fact that agencies have noted consumers' willingness to pay a high price for water and are promoting private sector participation in water supply may prove unfortunate for the consumer in the near future (Allan,in prep;5.33). In areas of water shortage, such as Ta'iz, it is argued, principles of 'suppressed demand' apply, that is people do not purchase simply according to price. Similarly, the study of Mu et al (1990, quoted in Rogers,1992;7.20) in Kenya demonstrated that price and income had little effect on consumption but did reflect the source (which usually reflects quality) chosen. Roger's claim that demand is specified by two numbers; quantity and price (1992;7.20) needs correcting to three, so that quality, at least, is included.

2.3.2 Demand management

Before discussing demand management, it is worth asking what demand is. Merrett (1997;55) contrasts the engineer's concept of consumption, the economist's effective demand and the user's concept of need. Lundqvist (1998), equates demand with purchasing power, suggesting demand can be changed by changing the price of water (price elasticity of demand, Winpenny,1994;76). Rogers (1992;7.20) and Lundqvist (1998) also contrast demand with need, asserting that need is "a requirement for water which exists independently of economic or political status and...cannot be manipulated" (ibid.). The more 'need status' a product, such as water has, the less price elastic and less amenable to demand management it becomes.

Following in the footsteps of the power industry (Brooks,1995;46), part of the water industry's 'new agenda' is summarised under the heading 'demand management'. The 'old agenda' was perceived as centred on engineering measures to increase supply for anticipated future demand driven by changes in population, standard of living (and expectations), sectoral allocation and distribution efficiency (Allan,1994b;87). Increasing supply to cope with future demand is termed 'supply management'. Demand management, on the other hand is the manipulation of the forces driving demand by "the use of price, quantitative restrictions, and other devices to limit the demand for water" (World Bank, 1993;5). Brooks describes this change in approach as an emphasis on end-use rather than on sources of supply (1995;47). Berkoff (1994; 37) defines supply management as activities required to locate, develop and manage new sources, and as actions that affect the quantity and quality at the entry point of the distribution system. He sees demand management as comprising actions that influence the use or wastage of water after this point which, ideally, should promote more desirable levels and patterns of water use.

Although Berkoff (ibid.) points out that supply and demand management roughly separate engineering from social and behavioural sciences, there is a problem with the technological innovations and distribution efficiency measures as at least some of these effectively tend to increase supply rather than reduce demand, and, as Merrett points out, the estimate of demand is increased if distribution losses are included as part of consumption (1997;12). A solution for the urban supply instance is to move Berkoff's supply/demand divide from the entry point to the distribution system to the entry point to the private property it serves, which is also the public/private watershed on the clean water side.

Other demand management anomalies include the farmer with more land than water. Any increases in water use efficiency simply increase the land area he can cultivate, and, providing there is a market for his produce, the efficiency measures have effectively increased his supply, not reduced his demand. Also, despite Lundqvist's observation that demand management is particularly needed where low efficiency and low-value production prevail (1998) there is a greater need to reallocate water from low to high value uses even where efficiency is high if we are to avoid being efficiently unsustainable (ibid;9, Pearce,1993;47).

An assortment of demand management devices appear in the literature (Winpenny,1994;42 et seq., Lundqvist,1998, Merrett,1997;64-65) and may be grouped in various ways e.g.:

a) water market creation and water reallocation to facilitate transfer to higher value uses;
b) market incentives such as tariff structures and disposal/pollution charges aimed at 'responsible water use';
c) technological innovations designed to reduce consumption, and related distribution efficiency and re-use measures such as leak detection;
d) educational methods such as public awareness campaigns;
e) birth control, or at least, children by choice.

Of these devices, a) is an allocative efficiency method, whilst the others, in the sense of resulting in less demand by the same sector are productive efficiency measures. Aspects of a) and b) are discussed below.

i) Water Market Creation, Reallocation and Virtual Water

A major facet of the demand management portfolio is the development of water markets (World Bank,1993;47). Although some deny the significance of water markets and others question their legal viability (Dellapenna,1995;153,Falkenmark and Lundqvist,1995;178), they do exist, and often dwarf their public counterparts (Serageldin,1994;15, Wilkinson,1977;113, Crane,1994;71). It is not inconceivable that they will, with appropriate technological and institutional arrangements, one day operate on an international scale (Becker et al, 1996;19), as the market responds to reallocate from abundance to shortage and from low to high value use. Many types of water market are envisaged (Winpenny,1994;54-65, Berkoff,1994;37), however there are problems involved in establishing them:

a) economic - overcoming the natural monopoly and economies of scale aspects (World Bank 1993;27);
b) physical - moving this bulky material over physical relief;
c) legal - legitimising the transfers; and
d) political and institutional - having the will, and capacity to permit, monitor and regulate (Berkoff, 1994;37).

At the institutional level, 'private sector participation' (PSP) initiatives in running, or becoming, water utilities (Brook-Cowen,1997) may help overcome the failure to see water as an economic good which has resulted in the utilities' "vicious circle of poor quality and unreliable services that result in customers' unwillingness-to-pay, which, in turn, generates inadequate operating funds and a further deterioration in services" (World Bank,1993;9).

Another major method of demand management is the reallocation of resources to higher value uses, which Winpenny (1994;27) argues reflects a shift in demand (ibid;83). Traditional views, based on the tangible evidence to the individual user of increased commodity production, focus on efficiency of production. In contrast, Allan (1994a;7) points out that efforts should not just be made to increase production within a particular use, but that it be ascertained as to whether some other use might yield greater returns (measured in monetary or livelihood terms). Efficiency gained through reallocation of water to a higher value use is called 'allocative efficiency', or 'more jobs per drop' as opposed to the traditional ‘productive efficiency’ or ‘more crop per drop’ (Allan,in prep;5.15). Morton (1994;20) sees the only possibility of allocative efficiency if there is “perfect competition in an undistorted market”. He points out that markets are usually distorted. Also, reallocations accrue high ‘transaction costs’, that is, the time and effort required to inform and establish contracts for actors (Falkenmark and Lundqvist, 1995;204) and the time and effort used in information gathering, bargaining, decision making, monitoring, enforcement and collecting (World Bank, 1993;47 and Easter,1991;9). In contrast, supply management measures incur low transaction costs, but high production costs (ibid.). For there to be a net gain from any transfer the marginal cost of the water, plus the opportunity costs to the loser plus the transaction costs in the new activity must not exceed the costs in the existing use, where costs are measured in economic and livelihood terms.

Most significant in terms of the volume of water used and the returns to it, is a shift in allocation from agriculture to industry (Coopers and Lybrand, 1992; 214). Some might argue that the decline in per capita grain production and irrigated areas (Ohlsson, 1995;8) should not be exacerbated further by water transfers to industry. However, even the transfer of at least a few percent, of the 90% of water currently consumed by agriculture, to industry would help countries to earn hard currencies with which they could replace food deficits by purchasing staples. Food staples have been termed ‘virtual water’ because of the water needed to grow them. For instance, 1000 tonnes of water are required to grow one tonne of wheat (Allan, 1996a;113). He argues that a country with a water deficit but which uses a significant amount of water in growing food can import the food instead and thus meet its water-for-agriculture needs with the virtual water embedded in the imported food. Local water is then freed up to be reallocated to higher value uses. Higher value uses can then generate the capital needed to buy the food from outside. The low price of world staples means that grain importers have been advantaged. The practical problem of reallocating bulky water (Ohlsson, 1995;17, World Bank, 1993;84) is thus overcome in the case of virtual water imported in staples, although it remains in the local inter-sectoral water reallocation. One problem with depending on virtual water is the lack of guarantee that virtual water will remain cheap. The subsidies on staples exported from the USA and EU, particularly enjoyed by Middle Eastern importers for the past 25 years (Allan,1996a;96,113-114) may not last for ever, a scenario which haunts the politicians and the consumer. There are already signs of them becoming more expensive.

The main barrier to reallocation policies is political because they fly in the face of:

a) the food self-sufficiency dogma (Allan,1992;2,9,10, and 1994a;6, Coopers and Lybrand,1992;227),
b) entrenched politics (ibid;253, Allan,1996a;88) and
c) the 'cultural embedment', symbolism and strategic significance of agriculture and land ownership (Naff,1991;116).

The actors subscribing to these attitudes tend to subscribe to all of them and comprise those who stand to loose by reallocation. The actors also tend to be the politically powerful (Allan,1994b;100), and the attitudes are part of the 'social construction of reality' which is so enduring (Thompson,1995;27,32). Thus, although policies leading to efficient water use and re-use may be lauded by the politicians, allocative means are not discussed because they are politically stressful, and the relationship between food and water deficits cannot be debated at all (Allan,in prep). Rajeswary (1992) comments that the Yemeni "government strategy is to optimise the use of limited resources in irrigation and protect aquifers while maximising agricultural production". Yemeni politics both in the North and South before and after unification have laid great stress on agricultural self-sufficiency whilst becoming more reliant on imported foodstuffs (Varisco, 1991). The 'simple truth' of virtual water meeting the food needs and the 'vital lie' of food self-sufficiency, or put another way that water both 'is' and 'is not' an economic good (Allan,in prep;6.1,5.5) are simultaneously faithfully maintained in Yemen. Undiscerning listeners and even certain groups (Patai,1976) may swallow the rhetoric of two opposing principles, but to hold to them both at the policy implementation stage is impossible. Yemeni reality is the effective subsidy of irrigation through low diesel prices to power the pumps (Ward,1998). Tariffs on urban water supplies also reflect political and equity priorities and are also effectively subsidies. Sound prices send constructive signals and subsidised prices destructive signals. The difference between the 'full' value of water, economic and environmental and the price paid by the user is a subsidy (Allan,in prep;5.16). If difficult decisions about the allocation and management of scarce environmental capital are to be made, then the political economy has to be flexible and strong to endure the uncomfortable restructuring associated with it (Allan and Karshenas,1996;131, Allan,1996a; 77). The potential for reallocation is made more feasible by a diverse and strong economy (Allan, in prep;5.19,6.5). Like the fear of virtual water drying up or rather getting too expensive, the issue of returns to water may continue to haunt politicians (Allan,1994b;88).

ii) Market Incentives and Pollution

Market incentives to reduce demand for water include the concept of marginal cost pricing. Rogers gives the classical definition; "marginal cost pricing is the pricing of water at the cost of supplying an additional unit of water" (1992;7.28), but he contrasts this with the traditional method of pricing water, which is to use the historical cost (or average cost, Winpenny,1994; 89) that is the cost of water provision up to this point. The difference can be considerable. The provision of the next unit may entail significant capital costs in developing new sources and may be therefore much higher than the historical or average cost. Marginal cost pricing is seen as providing a mechanism for water conservation and generating revenue where price elasticities of demand are less than one, as they usually are (Winpenny,1994;49,89).

Related to the value of both water and the environment is pollution. A groundwater or surface water pollutant has been defined as any substance whose concentration reaches a level at which it interferes with the intended use of the water (Deason,1991;53). Toxins building up in the food chain and water-borne diseases are of particular concern for health reasons (Lundqvist,1998). Falkenmark and Lundqvist suggest water carries out two functions with regard to pollutants; as a diluter and as a transporter (1995;185). Water may also react with pollutants to produce other forms of pollutant or break them down into non-polluting substances.

When discussing the economics of water, pollution, almost euphemistically, seems to be equated with 'externalities' (Rogers,1992;7.21&32, Karshenas,1992;2,6, Pearce,1993;40). The term means that "the unintended real (non-monetary) side effect of one party's actions on another" (in polluting a common resource) "is ignored in decisions made by the" polluter and is thus 'external' to him and 'not his problem' (World Bank,1993;6).

The introduction of water quality standards is a step towards establishing the 'polluter-pays-principle' (PPP). However, in practice, rather than charging for damages caused, standards are set according to the technology of water treatment methods available. Two problems emerge:

a) polluters are allowed to pollute up to a level, that is, pollution has been sanctioned, and
b) there are no mechanisms for reimbursing the damaged party (Pearce,1993;107, Rogers, 1992;7.21).

Although marketable pollution permits have been suggested, the pervasiveness of this 'missing market' and the absence of the necessary legal and institutional frameworks in the Middle East (Karshenas,1992;7, Berkoff,1994;37) result in the PPP primarily existing in rhetoric only (Lundqvist,1998). Were industries to face pollution charges, however, owners would be given an incentive to decrease their water consumption per unit of production (World Bank,1993;12) and industrial water re-use (Ohlsson,1995;9) would be encouraged.

Table 2.1 summarises the relevance and application of the main aspects of demand management at various scales. The aspects are listed in approximate order of increasing contribution to efficient water use:

Type of Provision	Private	Community	State	International
Example	Tanker, bottled, treatment company	Rural supply / irrigation scheme	Urban piped supply	Trade in grain
Water Market Creation	**MOST RELEVANT**	Relevant, but does not necessarily reduce consumption	Most Relevant but Larger Political, Legal and Institutional Problems	In the future?
Market Incentives	**RELEVANT**	Partial Relevance	Relevant but some Monopoly, Legal and Institutional Problems	
Reallocation	Partial Relevance	Relevant	**MOST RELEVANT, MORE PROBLEMS**	In the future?
Virtual Water	Least Relevant		**MOST PROBLEMS**	**MOST RELEVANT**
Family Planning	Least Relevant	Can be Provided	**MOST RELEVANT BUT UNSANCTIONED**	

BOLD = Areas most amenable to change

The table suggests that the most relevant water demand management measures lie on a top-left to bottom-right axis. As the scale increases (from left to right) the measures which would have greater potential impact are more relevant. However, the problems in implementing them also increases and their degree of political acceptability decreases.

2.4 Politically Deep Water

Mollinga (1998;30, after Kerkvliet,1990;11) identifies the water control aspects of irrigation practices as examples of politically contested resource use. Where the capability to secure control over water depends on the agency of others, this power over others becomes domination (Giddens,1976;111). In a water-scarce region such as Yemen, control of water, in terms of its allocation, is open to political contest, and is not simply a matter of allocation to the highest economic bidder. Allan contrasts the opinions of those who think 'water is an economic resource' with those who think it is not (in prep). Those who are supposed to promote a rational view of the simple truth of reliance on virtual water (including economists and scientists) are placed in the former category (ibid.;chapter 5). Those who are more vulnerable to the opinions of their electorate and/or their party (politicians) and who, for food security reasons, pursue the irrational, ideological (Manzungu,1999;13) vital lie of self-sufficiency are placed in the latter (Allan in prep;chapter 6). Allan (ibid.) concludes that although 'water flows up-hill to money', it will flow further up-hill to power (Reisner,1986) and that economic concepts do not have a significant input to the discourse and are only of potential rather than immediate significance (Allan, in prep;5.26,5.32).

2.4.1 Environmental Politics

Redclift (1987;37) identifies a third group who also deny that water is an economic resource: the environmental moralists. On a 'green basis' they argue the protection of the environment for its own sake, irrespective of its elusive economic valuation.

Political ecology, the politics of ecological change (Bryant,1991) or the analysis of how unequal power relations are often linked to conflicts over access to, and the use of, diverse environmental resources (Bryant,1998) combines the concerns of ecology and political economy (Blaikie and Brookfield,1987). Eckersley analyses green concerns as ranging from anthropocentric to ecocentric emphases (1992;8). He traces the shift in attitude from one of pursuit of equity in the distribution of environmental 'goods' and 'bads'. Next, the survivalists see the existence of humanity threatened (Atkinson's starting point of political ecology (1991;4)), and prescribe the surrender of individual choice to a powerful external decision maker. Finally, those who promote the abandonment of the necessity of standard of living improvements at the expense of the environment are termed emancipationists (Eckersley,1992;9-17). The need to do something about declining environmental quality is assumed, and the key issue appears to be whether authoritarianism from above or self-limitation from below are the appropriate mechanism (ibid,24).

Most theorists point out the new political coalitions which specific environmental issues have brought together (eg.Hajer,1995;12) however the political left give more emphasis to the social issues affected by the loss of environmental quality (Atkinson,1991;6) and to causation, including, in the developing world, the legacy of colonialism (Bryant,1998;9), than do others. In the area of North Yemen being considered, the colonial impact on water resources is negligible, however the role of sub-politics, viz. the non-political realms of decision-making, combined with the effects of local micro-powers are highly significant (Hajer,1995;39). Although these local Yemeni politics have been described as the 'local anarchy preventing 'rational' development interventions', Vincent goes on to suggest that 'politics is not anarchy but the art of the possible in the cultures, economies and environments concerned' (1990).

Atkinson asserts that all greens focus on manufacturing industry as the target for 'disarmament' but that ecosocialists see industry more as a symptom of the greater disease: capitalism (1991;5). In either case the call for the Middle East to focus on industrial production to overcome its water crisis by Allan and Karshenas, and the environmental Kuznets curve theorists (discussed in section 5.6) contrasts with the green philosophy. Allan (in prep;6.17) observes that the sectoral reallocation of water involved in industrial production is indeed a highly political act carrying a political price which the policy makers, whatever their political hue, may not be willing to pay. The inherent tension between environmental sustainability and economic development is explored in the conceptual frameworks described in section 2.7.6.

2.4.2 The Role of Knowledge or Information

The problem with environmental knowledge is that it has for too long been solely the domain of scientific (or economic) experts (Hajer,1995;10) to the exclusion of the affected layman and the political decision-maker. Scientists see themselves as the guardians of objective truth (Atkinson,1991;51). Since difficult decisions regarding the allocation of environmental resources have to be made, and power and knowledge are synonymous (Bryant,1998;13 and Foucault in Atkinson,1991;61) the position scientists find themselves in represents a shift in power from those 'in the dark' - the politicians, to those 'in the know' – the experts. The users of knowledge are left to contend over scientific interpretations and meanings. Vincent (1990) identifies four groups of water knowledge monopolisers and manipulators in Yemen: oral historians, water users, those who allocate and those who adjudicate. The last three are the actors in the study of Ta'iz.

'One-and-only-Truth' science causes us to re-examine 'how we know', particularly in the context of the North-South dialectic. Benton and Redclift (in Hajer,1995;14) ask 'do we share an understanding of the global environment in the same way as we 'share' the globe?'. Atkinson (1991;89) questions whether our methods of observation and evaluation yield correct models and suggests that science is a 'cultural project' (ibid.;51), that is, is influenced by the cultural and social filters of those who ask the questions, determine the methodologies, select the observations, interpret the results and frame the conclusions for culturally filtered taskmasters, - all with an eye on where the money for the next research project will come from (Bryant,1998;13). The importance of Southern indigenous knowledge and the need for 'hybridity' with Western scientific knowledge is noted by Bryant (1998;14).

In a very different context to the Yemen (acid rain in the UK and the Netherlands) Hajer (1995) traces the route of an environmental issue from awareness of it to policy intervention. He notes the initial need for an environmental emblem or rallying point that should preferably be observable, although most recent ones (such as acid rain) are not. He then notes how the observations have to be perceived as a calamity, and get reported, though the interpretation may be undermined by nagging doubts of scientific controversy. At this stage the problem has left the locality, left the oral medium (probably to a written one) and possibly been converted into a different language. Unless we are careful, the interests of the illiterate, Arabic speaking local farmer who is most affected by the calamity may have been lost in technically accurate, socially insensitive reporting (ibid;23) and his power to correct the interpretation is nil. If the report of the calamity suits the mileage-seeking of both the current political 'discourse' (Foucault,1971), whose contributors may not have the free will to take a stand, and the whims of the media, a press conference may follow and a political issue may be created (Hajer,1995;20). The emblem may not be the most important and it may not survive the passage to political issue status. If it did, however, there are also hurdles to policy implementation, since policies may not be designed to address problems but rather vice versa (ibid;15). Atkinson should not be surprised to note the fatal procrastination between observation and corrective measure considering the pitfalls of this faltering sequence (1991;7), though non-applied knowledge is certainly useless if it remains so.

2.4.3 Belief Systems

Those sets of shared beliefs and convictions about how the universe is that sustain and justify moral judgements have been dubbed 'cultural biases' by the cultural theory school (Douglas,1978, Thompson,1988;62 and 1995;27) and 'belief systems' by Allan (in prep). The latter (ibid;5.18) suggests that traditional perceptions determine both the value of water and its cultural significance. For Middle Eastern societies with a rich religious heritage, the 'inspired word' holds great power over their adherents. With 482 references to water and 215 to rivers or streams in the Bible and also 60 and 50 references respectively in the Qur'an, strong traditional views should be expected. Many also point out the centrality of water in the economic and ritualistic senses in the desert-derived shari'a (Mallat,1995;3). Irrespective of the position of the shari'a amongst Islamic legal scholars, the man-in-the mosque (and many other societies) expects:

a) water, like rainfall, to be free
b) water to be provided by the state, but to have no obligation regarding its efficient use or good neighbourliness regarding its disposal
c) national food self-sufficiency
d) to procreate and, finances permitting, increase the potential to procreate by having more wives
e) his heart to remain in the soil (Dresch,1989)

Despite Allan's comments to the contrary (in prep;6.14), there is a prioritisation of water allocation in the shari'a, and partly because of this he is correct in concluding that Yemeni political leadership will not be able to address environmentalist or economist calls for reallocation of water. This call is weakened by the influence of traditional belief systems of the land-owning power base of that leadership.

2.5 Water Rights and Legal Frameworks

The rules of the game of water allocation may be divided into two aspects; the rules of the game and the players (Johnson,1996;1,2). This section discusses the former and the next the latter.

2.5.1 What is law for?

Although water law has the task of clarifying and protecting water rights, viz. the right to returns to water and the right to change the water's form, substance and location, Lundqvist (1998) also identifies two contradictory purposes in those rights: one of commercial concern and one of social equity (including third party interests, World Bank, 1993;48). Other purposes of water law might include: encouragement of efficiency of use and, related to it, environmental protection, (Du Bois,1992;7 and Karshenas,1992;18). Legislation is also meant to provide the basis for the operational and regulatory activities of government (Berkoff ,1994;40).

2.5.2 Who owns the water; Private, Common or State?

To address these different roles demanded from the legal framework, Dellapenna gives a helpful model (1995). From the history of American water law development he distinguishes private, common and public property. Initially American law treated water as private property under the principle of 'natural flow' theory whereby any riparian could use flowing water so long as it did not affect downstream users. In order to encourage resource development in mid 19th century in the Eastern USA, the law began to treat water as common property under the principle of 'reasonable use'. More recently, the California drought of 1987-1992 resulted in the establishment of a water bank, which, rather than being a market for water, Dellapenna asserts, was state intervention effectively transferring ownership to the state as the sole buyer and seller.

Each system has its drawbacks. The private system easily results in a redistribution of wealth and rigidity of use and allocation (ibid;155). The communal system can also lead to a redistribution of wealth (Du Bois,1992;11) and makes sources particularly vulnerable to over-exploitation. Because excluding people from access lies between difficult and prohibited, each user seeks to maximise his benefit (for instance by digging a well), with minimum cost to himself (e.g. dropping the water level as a result of his pumping only). As use expands to the limit of the resource, failure results. This is termed a 'Tragedy of the Commons' after the work of Hardin (1968) in which "everyone's property is no one's property" (Rogers,1992;3.1) and certainly, no one's responsibility.

Dellapenna (1995;159) considers putting one's trust in the state to administer water allocation justly through its, admittedly imperfect, experts to be a better model than a market system due to the general absence of the latter (in his perception, though this last assumption will be questioned later). However, Du Bois (1992;11) questions whether state allocation of water might be vulnerable to the powerful, which could result in a similar redistribution of wealth as in the other models. Although Dellapenna seems to downplay this possibility (1995;160) there is perhaps a difference in its likelihood, or extent, between his perspective of the USA and the situation in other countries where the elected are less accountable to their electorate (or at least to the media). The literature is replete with examples of nepotism and other forms of corruption in the government's allocation and management of water resources in other countries such as Nepal (McSweeny,1998), Egypt (Radwan,1994;3), Iran (McLachlan,1988;71), Africa (Du Bois, 1992;11) and indeed Yemen (Vincent, 1991;209).

2.5.3 Water Laws of Islamic Countries - Shari'a, Custom or State?

The existence of three sources of water law in Arab countries (shari'a, customary and state laws) demonstrates an interesting parallel with Dellapenna's private, common or state water ownership trichotomy.

Mallat (1995;4) summarises the main tenets of the shari'a (Islamic law) regarding water:

a) Shafa (drink) - Water is a gift of God and is therefore communal for humans and livestock.

b) Shirb (drink) - Retention, containment or distribution of water creates private ownership rights.

c) Rights of prior appropriation and distribution of surplus.

d) Liability attaching to misuse (e.g. pollution) or withholding water.

Water resources are collective and only when contained, mobilised or conveyed can they become private (ibid.), but for most Yemeni applications, it is only at the point of acquisition that water takes on any value. Thus the communal aspect of the shari'a has been pointed out to be rather minimalistic (Vincent,1990). Also, the shari'a, or more accurately the inventiveness of its interpreters, cannot handle the innovations in the means of access to water (ibid.). The current interpretation on boreholes and dug wells is that they are receptacles. That is, sink a well and the water is yours. However, groundwater does flow, hence a well is not a receptacle but simply a window on the resource. Only when a means of removing the water is in place is there the potential for water moving from the communal to the private domain. The result in Yemen is that valuable resources become private and less useful/inaccessible resources become common or open access (ibid.). A complication with interpretation of the shari'a alluded to above is the existence of different Islamic schools of law. There are several for each religious sect. Two main ones recognise ijma' (consensus) but not qiya (deduction by analogy) Vincent (1991).

Mallat (1995;4) and Coopers and Lybrand (1992;240) note the incorporation of shari'a principles in the Ottoman Majalla of 1858 which still applies in many Arab countries. British, and particularly French, colonialism brought additional water laws to many countries in the MENA region. These sources of law all invest the state with original right (Mallat,1995;4, Berkoff 1994;41). The original right of the state to water is known as 'mubah' or free property which cannot be appropriated, and musha' is a similar category belonging communally to a village or tribe (Mallat,1995;6). Waqf is a category of land and water ownership which is the Islamic equivalent of mortmain or inalienable tenure, designating the property to the specific use it was designated (Wilkinson, 1977;113). It is often bequested to the mosque, sometimes for education or the poor, and sometimes may become state owned. The allocative methodologies of water measurement are usually by time, and, on the basis of a hadith, sometimes by volume (ibid;109, 103).

Customary law ('urf) has operated alongside the shari'a (Mallat,1995;11) and, at least in Oman, is aimed at protecting the essential needs of the community where customary law often supersedes the shari'a (Wilkinson, 1977;121). In countries where the ability of the state to control water allocation is weak and where there is such a rich heritage of existing shari'a and 'urf ,the legal position of state intervention may be rather tenuous (Mallat,1995;7-8). Vincent goes so far as to assert that the shari'a does not include the concept of public domain (1990).

The French cadastre system, the application of Islamic inheritance laws and local custom all permit and may even lead to a tendency to separate water ownership from land ownership (Coopers and Lybrand,1992;242, Wilkinson,1977;105, 212), as it also does in non-Islamic countries (Du Bois,1992;9). The divorce of land and water may result in more efficient use of water, allowing the water to gravitate to higher value uses (ibid., 7).

Iran provides an example of the three types of ownership. McLachlan (1988;90) points out that the technological intervention of the well and pump led to water becoming private whereas the qanat had always been communally owned, and the development of major water undertakings such as dams and irrigation schemes were state owned. The importance of customary water rights in Yemen are brought out by Caponera (1973) and Al-Eryani et al (1995). The most significant local study solely dealing with these issues is of Lahj (Maktari,1971) and studies which mention them include Wadi Dahr (Mundy,1989 and 1995), Wadi Zabid (TESCO,1971) and the Hadramawt (Serjeant,1964).

2.5.4 Law Enforcement and Water Rights versus Rights to Water

Although legal models may provide filters through which researchers try to interpret field observations of allocative practices, the ability to enforce the law is much more relevant to locals, at least in Yemen (Vincent,1991, Coopers and Lybrand,1992;231). It is suggested that the need to resort to legal measures is the prerogative of the those who feel they are deprived of rights, in particular the downstream user (Dellapenna,1994, Johnson,1996;9), whilst upstream riparians may prefer the status quo, as noted even on the international scale in the case of Egypt (Allan, 1996c;112).

Lundqvist (1998;Table 2) makes an interesting comparison between what he terms 'water rights' and 'rights to water'. The former he conceives as a contract of formal rules and regulations which define duties and rights to benefits and do not imply free access, but still cater for third party interests. In contrast, rights to water are perceived as an "unconditional right to demand water services and the authorities/public sector has the duty to make sure that their rights are being met". Lundqvist argues that the latter is a moral argument or attitude with very unclear obligations on the part of the user, and where the providers retain a strong control over supply. This 'rights to water' model is closer to the modern urban water supply where water is supposed to be free to have, use, pollute and dispose, but where these freedoms are only partly enjoyed by the poor (ibid.). Through these contrasting perspectives, Lundqvist underlines the need to re-couple water use responsibilities to rights. Whether the tension between the 'water rights' and 'rights to water' lobbies coincides with the supplier-consumer divide will be examined in the case of Ta'iz.

Table 2.2: Some of the principles and examples of water rights mentioned above may be categorised approximately as:

Ownership	Private	Common	State
User	Individual / Group	Small Communities	Public
modus operandi Johnson,1996;6	Capital Exchange	Customary (viz.: non-market)	Authority and Coercion
Law Basis USA Dellapenna,1995	Natural Flow	Reasonable Use	State Intervention
Shari'a Provision	shirb	shafa	Original Right
Yemeni Legal Framework	shari'a* (Islamic Law)	'urf* (Customary Law) and musha'	State Intervention (Also: Mubah/Waqf)
Yemeni Application	Tubewells? / Bottling Treatment / Tankers	Traditional Agriculture	Urban Supply
Iranian examples Wilkinson,1977	Well	Qanat	Government Dam
Drawbacks	Wealth Reallocation and Inequity	Tragedy of the Commons, Wealth Reallocation and Inequity	Misappropriation by the Powerful

* Some overlap, see text.

Bromley (1986;597-8) identifies a fourth type of resource, not ownership, termed open access, where 'everybody's access is nobody's property'. He distinguishes open access from common property pointing out that the latter has claims to its use, whilst open access does not, asserting that there is no property in an open access situation. Other definitions do not make this distinction (Ostrom,1986;604). Although 'common' may aptly describe easily tangible irrigation schemes, fugitive groundwater is not so tangible to its users and is a more 'open access' resource, characterised by unrestricted entry and unregulated use (ibid.;605). Bromley prefers the term 'regime' to property/resource, since it is the form of management (really institutions) that characterises them (1986;594-5).

2.6 Institutions

2.6.1 Types of Institution

Some authors use the terms institution and organisation interchangeably, or make organisations a subset of institutions (Berkoff, 1994;40), whilst others are more rigid in their definitions. Johnson (1996;1,2), using a sporting illustration to clarify the difference, defines:

a) institutions: the rules of the game (the formal rules, laws, regulations, informal constraints, behavioural norms, conventions) as opposed to:
b) organisations: the players, actors or groups of individuals taking part.

The latter are termed institutional systems by Coopers and Lybrand (1992;105). This study uses 'rules, laws, behavioural norms, conventions, institutions or regulations' for Johnson's 'institutions', and 'organisations, institutions, players or actors' for his 'organisations'. The meaning of institutions in this study (as with most others) will have to be determined from the context. Although this is unacceptable to the purist, it seems to concur with the understanding of most readers, some of whom may have skimmed past this paragraph.

A major debate analyses the roles and relationships of the state, society and the array of formal and informal institutions. Cowen, distinguishes formal and informal 'institutions', on the basis of the clarity of their ownership and control rights, the former having more precise ones than the latter (1994;1). Apart from a few anarchical cases, the social control of states and societies over their people can be placed on a spectrum from 'strong states' and 'weak societies' (such as many late twentieth-century Northern countries) to 'weak states' and 'strong societies' (Migdal, 1988;15). The latter describes many Southern countries such as those in Africa with a "personalised, fragmented power structure" (Therkildsen, 1988;10.2) and could include Yemen.

Migdal defines a strong state as one with "a high capability to extract, penetrate, regulate and appropriate" (1988;15). The state is described as one where, by coercion, leadership follows its own desires, establishes agencies and staffs them to carry out the function of raising taxes and armies, and developing courts in order to shift economic, territorial and judicial control to the state. People are coerced into compliance to, then participation with, and ultimately legitimation of the state (Migdal,1988;18,32). He uses Myrdal's (1968) definition of soft or weak states as "ones in which governments require extraordinarily little of their citizens, and obligations that do exist are enforced inadequately, if at all" (ibid;18). Strong statehood and strong society appear to be mutually exclusive, that is, the scale really spans from state control to society control.

It is suggested that whether a country can (or, dare we ask, should) move towards stronger state control depends on the capability of the state or society to provide survival needs for its people and also on its right to rule (Migdal,1988;10,28,30). The forces pushing towards stronger statehood lie in the state's domestic credibility/legitimacy as revealed in the international arena (ibid;21) and include the state's relationships with potential outside benefactors (ibid;40) and enemies (ibid;24). These forces are perhaps weaker in Yemen than in many countries, but ebb and flow with Yemen's prominence in international affairs. Another issue in the Yemeni context is whether donors are prepared to work with local institutions outside of specific bureaucratic structures (Vincent, 1991) and, perhaps more importantly, whether the central Yemeni government would allow them to. Increasing environmental degradation, it is suggested, will also loom larger as a factor demanding state intervention.

Different models are put forward regarding the role of the state and society in running its peoples' affairs. New Institutional Economics (NIE) gives the state a significant role, particularly as referee (Johnson,1996;4), whilst Common Pool Resources (CPR) theory lessens that role (ibid;8). Social capital theory suggests that whilst vertical networks of social interaction are based on hierarchy and mistrust, forming a poor base for allocating scarce resources, horizontal networks based on equitable membership and common understanding (Lam,1994;16,38, Ostrom,1999;197-9) promote co-operation, civic society and are more accepting of government control (Johnson,1996;12-14). The resistance to state control lies with chiefs of families, ethnic groups and religious organisations (Migdal,1988;28,30), so prominent in Yemen, who question the state's right and capability to rule.

When it comes to the realities of water allocation and management in the Middle East and in Yemen in particular, although there is a need for a strong state if reallocation is to be directed from that quarter (Feitelson and Allan,1998;1,3), public debate is rare (Mollinga,1998;263), and parliamentary tradition is weak to non-existent (Mallat,1995;7). Society is therefore going to continue to play a major role and we can expect water policy initiatives from the centre to be resisted at medium and local levels (ibid;9). Vincent (1991) suggests that in the rural areas in Yemen, the role of non-traditional local institutions is unclear and their absence of authority deprives them of meaning. Local non-traditional institutions can also become prey to traditional inequitable ones if local powerful families become strongly represented on councils and do not have dispassionate interests in water development (ibid.).

It is suggested that the balance of roles between state and societal institutions in water allocation and management problems are primarily related to their scale and function.

2.6.2 A Question of Scale

At the local scale, Bromley (1986;596-7) identifies basic or 'primary decision units' (PDU's), noting that the very essence of common is that more than one PDU is involved. When uniting together for management of water resources under a common property regime, the PDU's form a resource decision unit (RDU), the largest of which forms the upper limit of 'local' (Mahdi,1986;192). In the Middle East, water related problems appear to become more solvable as the number of actors is reduced (Cowen, 1994;6). State interventions are considered inappropriate at the micro-scale, and tend to undermine pre-existing institutional arrangements (Johnson,1996;5). The existence of central institutions can even offer an escape route from the demands of traditional institutions and undermine communal responsibilities (Johnson,1996;23) as it did in Nile Delta irrigation management (Radwan,1994;62). The local indigenous clan system can also work against village community interest (Wilkinson,1977;216).

CPRs become pressured particularly by population growth, mobile populations, poor governance, and market expansion (Johnson,1996;11). These trends, so typical of Yemen today, threaten CPRs which survive better where decisions involve a 'smallish and stable community' (ibid;7). If the problems are bigger than local, or the cause-effect relationship of proposed or existing changes are not obvious to the 'man in the field', then for CPR theory to work and conflicting parties to exercise mutual trust essential for resolution, the activities and motives of the larger broker, or referee, to which they must resort must be transparent (ibid;9). However, they rarely are. In Yemen, even local development bodies (LDA's) with local representatives were emblems of imposition by the state and were typically suspected by locals of corruption (Swanson,1985, Vincent,1991). It is suggested that the institutional difficulties of water allocation and management are felt most acutely in micro-macro linkages (Lam,1994;289) of the middle ground between local (CPR theory relevant) and national (NIE theory relevant) state control.

The scaling up and mobilising of local, societal, institutions in horizontal relationships to regional level needs facilitating (Johnson,1996;17) so that stakeholders meet (Falkenmark and Lundqvist,1995;205), however, if there is no increase in the number of decision makers (Uphoff et al,1990;31) scaling up also increases the principal-agent problems outlined below. Another possibility, at least in theory, is the scaling down of state agencies which could help by respecting and helping maintain the autonomy of existing (local) institutions (Johnson,1996;8). In reality, conflict resolution in the South takes place in the context, not of state rule, but in the multifarious hierarchy of nested jurisdictions and web societies that characterise them (Migdal,1988;39, Johnson,1996;8). Conflicts over water in Yemen are commonplace, and although devastating, they can be the means whereby groups can overcome inappropriate or 'unjust' allocations and may improve interaction and respect (Vincent,1990). The plurality of institutions in Yemen, state and local, may offer the villager more options in conflict resolution (ibid.).

2.6.3 A Question of Function

Apart from scale, the second major determinant of the usefulness of state or local, formal or informal institutions in water management is to do with their operational, regulatory and planning functions. Institutional arrangements have been described as the "transmission gears between policy objectives and field-level performance" (Guggenheim,1991;21) or the "mediating activity between potential and actual performance" (DISWC,1993;3). A bundle of principles and measures occupy current thinking regarding the roles and functions of central / local, government agency / stakeholder, formal / informal, and public / private institutions in water management. These principles include the integration of local participation in management, privatisation and decentralisation (ibid;8).

Participation

The concept of 'the government borehole' village supply (Carl Bro International,1990) captures the problem of lack of 'ownership' of facilities which so easily characterises unsustainable development. Many think that the involvement of the informal, local stakeholders via indigenous (perhaps even newly created) institutions is the solution.

However, incentives to participate depend on the indigeneity of the local institutional context (Cowen,1994;5, Lam,1994;308). Coward specifies the involvement at the level of 'property relationships' that must be created in the community so that facilities become owned by those responsible for their continuance (1986). Practically, and traditionally, community participation is perceived as investment of resources (information, money, labour) which are made through non-formal institutions at a local level (Cowen,1994;3). However, stakeholder participation must also include decision making if resources are to be considered owned. The name of the decision making forum might be 'water user association', or similar, and its role may be multi-functional (effectively local government) or a single (e.g. domestic water supply) function organisation (Uphoff,1986;89). Guggenheim notes the latter usually have the highest rates of user satisfaction, long-term sustainability and cost recovery (1991;22). In the discussion as to whether stakeholder participation can play a significant role in water resource management Cowen contrasts 'participation optimists' who believe non-formal institutions can transmit community demands and mobilise resources commitments in an effective manner, and 'participation pessimists' who favour legal reforms to improve the performance of formal institutions and so do not need to rely on non-formal institutions (1994;26). Improvements involving the commercialisation of the existing institutions seek to reverse the causes of weak institutions listed above, so that performance indicators show an improvement. Measures include management incentives and greater financial autonomy for branches (Coopers and Lybrand, 1993;Appendix 1;8). These measures are currently being implemented in Yemen (Davies and Sahooly, 1996).

Whether non-formal institutions can succeed where the formal ones have not or cannot (Cowen,1994;2) is related to three problems; the tendency for water to be treated as a public good and be prone to free rider behaviour, principal-agent problems of the 'elected' agent or representative looking after their own interests rather than those of their 'electorate', and problems of preference aggregation, that is, how the representative can truly reflect the sum of the 'votes' of his 'electorate' (ibid;4-5). Because the scaling up of water management discussion beyond the very localised encourages principal-agent abuses, Cowen thinks it may be better to switch to improving the formal institutions. This may be a backward step, however, as the development of stakeholder participation can be a valid water management goal in itself (Therkildsen,1988;61). The day when development changes from top-down to bottom-up agendas and recipients become the subject as well as the object of development has not yet dawned (Serageldin,1994;32).

Privatisation and Decentralisation

Centralised institutions have been characterised by bureaucratic cumbersomeness and slow response but also by good potential for co-ordination and integration. On the other hand, decentralised institutions have the potential to be flexible and specialised but prone to poor co-ordination and a redundancy of functions (Guggenheim,1991;21). He stresses that we should recognise that the private sector is usually less concerned about equity, institutional issues and environment than the public sector, and that the handover of water management functions to the private sector must address which functions to hand over and which not (ibid;22). Berkoff suggests that policy, allocation and environment are a government function (Berkoff, 1994;43) and Feitelson and Haddad considered monitoring and resource data base as top priority government functions in joint management of the West Bank aquifers (1998;Table 2). The World Bank (1997 report in Hildyard, 1998;39) encourages weak states to establish a foundation of law, maintain macroeconomic stability, invest in basic social services and infrastructure and protect the environment and the vulnerable.

It is suggested that markets do not function without institutions (ibid;42, Lundqvist,1998). More specifically, this is not true of the water markets of Yemen in terms of formal, visible, institutions, however, informal institutions, although essentially invisible to the observer (Varisco,1983), are present in functioning markets. For equity and environment to be addressed in a water market situation, the World Bank suggests that some form of institution retaining regulatory and allocative jurisdiction, plus the legal framework necessary, must be in place (1993;48).

2.6.4 Institutional paths to more jobs and crops per drop

Network Management

The obligation to provide for the world's water needs through sustainable development of the resource underlines the importance of providing the right economic signals to abstractors and users so that water is allocated to higher value uses. Many of the measures discussed require an institutional framework which will help these policies to become reality. De Bruin and ten Heuvelhof suggest that the three characteristics of stakeholders; their differences, their independent nature but their mutual dependencies, form the opportunity for the government to steer networks of stakeholders towards desired water management goals (1995, described in Hansma and Hermans, 1997;Appendix 2). However, the theory of network management may lose a little relevance at the local level in weak states, such as Yemen, where there is little recognition of a government role (Vincent,1991). At the national level of states which lack a record of open policy discussion, it must be asked 'who steers the government?'

Institutional and Policy Reform

A second path of institutional and policy reform in the change-resistant Middle East region is equally tortuous. Steenbergen (1996;17,18,22) distinguishes first order transaction costs of monitoring and enforcement functions of institutions (mentioned in section 2.3.2) from second order transactional costs involved in transforming those institutions. The enabling factors or pressures for institutional change include democratisation, urbanisation, industrialisation, pressures from outside agencies, environmental degradation and, more importantly, the awareness of the latter (Coopers and Lybrand, 1993;Appendix 1;20). Democratisation may not help the reform process. Kennedy comments that if Californian politicians were to vote for raising water rates above charges for service they would jeopardise their jobs (1991;16), confirming that the role of politicians is to ensure their own survival (Migdal, 1988;23). As a consequence public decision makers do not like to address water allocation (Easter,1991;9). Regarding the importance of public, and particularly politician, awareness of water resources problems in promoting allocative efficiency policies, Berkoff observes that, in practice, water reallocation does not occur by legislation but in response to events (1994;42). These events, typically water shortages and crises can provide 'windows of opportunity' or 'policy windows' (Kingdon,1984, Feitelson and Allan,1998, Johnson,1996;24-25, Mollinga,1998;241,263) such as those in California and Israel (Allan and Karshenas,1996;130) when policy entrepreneurs can promote policy change. However, both Allan (in prep) and Redclift (1987;7) point out that institutional change is slow to too slow respectively. Steenbergen cites the high second order transactional cost of institutional change as a restraint (1996;203), but (Coopers and Lybrand assert that resistance to institutional reform can be changed with information (1993;13). However there are some principal-agent problems:

1. Communication

There is a basic problem of hermeneutics; what do the words of each party mean to the other?, and, if overseas donors are involved, what if language gets in the way? (Clammer,1984;83). This problem occurred in East Ugandan tribes where there was no concept of, and no facility in the language for health, only for lack of disease. This made preventative medicine a very difficult concept to communicate (Carl Bro International,1990;4.10). An agent 'I know better than my principal' attitude can occur and indigenous existing knowledge (Chambers and Carruthers,1986;2) can also be overlooked by developers due to communication problems.

2. Participation, Ownership and Equity

There are informational needs associated with affiliating with an institution (Johnson,1996;9) and informational needs in trusting its decisions. Measurement leads to information and knowledge resulting in power to the one who possesses it (Rondinelli,1983;6). Whether information, such as water quality and rights data (Le Moigne et al,1994;49 et seq.), is viewed as transparent or opaque to the public, is decided by its possessor. Johnson suggests that public officials firstly have only a finite capacity to obtain and synthesise information (termed 'bounded rationality'), and secondly, can misuse the information for their own benefit and at the cost of their constituents (Johnson,1996;5,13). This misuse results in the destruction of the mutual trust required when information is imperfect (Johnson,1996;20). Informational asymmetries regarding the accuracy of data collected by government officials resulted in the inefficient allocation of water between Nile Delta irrigators (Radwan,1994;60). The public may consider that knowledge owned by government should be made available if the former's trust is to be won. That trust will also be won only if the latter has demonstrated a track record that it is worthy of that trust. Although the principal needs to be informed at zero cost about the actions of the agent (Johnson,1996;5), information is never free and there can be a tendency for information to be more costly (transaction costs) and difficult to communicate, the more 'high-tech' it becomes (Easter,1991;9, Le Moigne et, al,1994;49 et seq.).

3. Relevance

Finally, there is a tendency towards institutional irrelevance caused by the gap between the specialised knowledge of the government agency and the 'time and place' needs of their constituents (Johnson,1996;4). In the South, where policy change decisions do not simply belong to the state; the accommodation between the state and other interest groups, their struggles and manoeuvres constitute the real politics (Migdal,1988;30). Means of changing the political will seems to depend on offering incentives of wealth / power, and/or presenting convincing logic (Feitelson and Allan,1998). Whether politicians are convinced to adopt a different policy depends on the information they are presented with. In order for information to be presented, water resource management indicators must first be monitored, data collected and information transferred. Depending, amongst other things, on who monitors, collects, analyses and transfers what, the information can be lies, damn lies or, perhaps, reality.

Table 2.3 Summary: aspects of institutions: local – national scale polarisation:

Scale	Local		National
Migdal (1988)	Society Control		State Control
Political Context	Local Web Jurisdictions		National Parties
Actors	local / stakeholder* / informal / private		central / government agency / formal / public
Actor Focus	Time and Place Needs		Specialist Knowledge
Key Institutional Functions	Resource management including decision-making		Legislative, environment, standards, Monitoring
Participation Advocates	Participation Optimists		Participation Pessimists
Model Relevance	Common Pool Resources Social Capital Theory		New Institutional Economics
Increasing Problems of	Free Rider/ Agent-Principal =============>		/ Preference Aggregation =============>
Participation and Ownership Initiatives	Market / PSP =>		<= Decentralization
Changes needed	Scaling Up of Participation		Scaling Down of Central Authority
Change Mechanisms	Manage the Network		Reform the Institutions
Current Project Emphases	Rural Irrigation and Domestic Supply		Urban Water and Sanitation Supply
Current Proportion of World Bank Lending in MENA (and World)[1]	Irrigation and Drainage 7% (6.3%)		Water Supply and Sanitation 9% (4.5%)

[1]- Berkoff, 1994;Appendix.

*some of the national scale actors are stakeholders, but their stake is smaller

The key environment needing change if institutions are to be reformed so as to facilitate reallocation is the political environment. Changes in political will are likely to have a greater impact on water allocation than institutional tinkering does. Vincent is convinced that Yemen does not need any further organisational innovations in the sphere of rural water supply but does need technical assistance (1991). She also suggests that under the LDA system rural Yemen suffers from unclear organisational arrangements and an absence of authority to give meaning to the organisations (1990). These problems contributed to the current demise of the LDA leaving a hiatus in rural development at present. Rural development contrasts with the current urban water supply arena in Yemen where institutional and policy reform is well underway (Davies and Sahooly,1996).

2.7 Sustainable Development

Development initiatives are superimposed on the economic and political forces which contribute to determining water allocation and the legal and institutional linkages between them. Allan (1996a;81) asserts that the prime purpose of demand management is to allocate and manage water resources in an environmentally and economically sustainable way. Section 2.3 discussed the economic aspects and this section discusses environmental issues and the role of aid.

2.7.1 Environmentally Unsustainable Development to Date

The impact of water lift technologies, which have only become available in Yemen in the past 30 years, have raised farmers' expectations of expanded irrigation (Varisco,1991). However the consequent trend of groundwater depletion is becoming all too apparent. Davies and Sahooly (1996) comment that the annual renewable water resources of Yemen are 125m^3/capita/yr, which is less than 10 % of the regional average and compares with a world average of 7500m^3/cap/yr. Population growth trends alone suggest that the renewable water resources of Yemen will decline to 72m^3/cap/yr by 2025, well below the 100m^3/cap/yr domestic water supply requirement commonly mentioned. National withdrawals are 3.4 billion m^3/yr whilst renewable water resources are 2.5 billion m^3/yr (ibid.). Annual withdrawals from the San'a basin alone were 224Mm^3 in 1994 compared with an estimated recharge of only 42Mm^3/yr (Ward,1998).

Although investment in infrastructure has been a priority of development aid and the development of roads has made water more easily accessible to tankers thus contributing to the unsustainable trend of groundwater abstractions (Vincent,1990), the alternative development of pipelines has had a much greater impact. However, there are economic limits to piped water transfers where terrain increases the cost of lifting the water. Such is the case in Ta'iz where nearly all significant water sources for more than 100km are at a lower level, the only exceptions being in the Ibb governorate.

The extent of the impact of technological innovations through industrial development and the provision of piped water supply schemes and sanitation without adequate waste water treatment is impossible to tell. Yemeni domestic and industrial liquid wastes typically infiltrate to aquifers if they are not intercepted beforehand by irrigation. Water quality and food chain monitoring for pollutants is almost universally absent, particularly of toxins.

2.7.2 The Value of the Environment

Although nature may have previously been perceived as a "stockpile of raw materials to be used by humans for their needs and pleasures" (McSweeney,1998), environmental accounting has been a major issue of the 1990s. If national accounting were to include an evaluation of natural resource depletion, many countries would be in deficit (Coopers and Lybrand,1992;212). There is therefore a need to try to value the environment if development is to be sustainable (Pearce,1993;11,27,63). Part of the problem of valuing the environment is that "its price is not perceived" because it is seen as a public good (Pearce,1993;1). Pearce identifies various separate parts of the total economic value of an environmental asset (ibid;16) and goes on to discuss the total capital of a country as an aggregate stock of human (knowledge, skills etc or returns to education (Dixon and Hamilton, 1996;15)) and natural capital (Pearce,1993;50). Pearce also questions the traditional assessment of national economic fortitude on the basis of GDP because this omits aspects of depreciation of natural, human and man-made (products, infrastructure) capital (ibid.). He suggests GNP comprises net national product less these depreciations (ibid;32&50). Dixon and Hamilton also take social capital into account (1996;16) which they define as "an amalgam of individual and institutional relationships that determine why one society is more effective than another in transforming a given endowment of assets into sustained well-being". Whether average GDP is a sensible starting point in national accounting has been questioned, especially for developing countries, where, due to the high proportion of very low income households and the few high income households, the mean can be very different from the median, the latter being more representative (World Wildlife Fund,1996;25). Another aspect of environmental accounting is that of 'discounting the future', which results in the benefit of the resource being enjoyed now and the cost of its degradation being transferred into the future, accruing (as Pearce puts it, 1993;6) to "generations yet to come" who "have no power at all" to decide otherwise.

2.7.3 Environmentally Sustainable Development

Putting a monetary value on the environment and linking it to the sustainability of development is precarious. Against prospects of Malthusian scarcity (exceeding the limit and facing the cost) and Ricardian scarcity (diminishing returns from overused resources)

(Pearce,1993;1, Rogers, 1992;7.13) an 'environmentally sustainable development' debate is taking place which, in part, revolves around the definition of these terms.

Two different camps may be discerned. The so-called 'deep ecologists' see an inherent value in the environment irrespective of its usefulness to personkind and have a 'strong' sustainability message which requires "no net damage to environmental assets" (Pearce,1993;52, Karshenas,1992;9-10) and suggest that the environment should be protected for its own sake (McSweeney,1998, Rogers,1992;7.23). However, Karshenas considers the deep ecologists to have confused the "determinants of well-being with the constituents of well-being" (1992;9-10), committing himself to determining causation of environmental degradation (which is the crux of the debate, see below).

The 'weak' sustainability camp, says "a country needs to save more than the depreciation on its assets" but will tolerate some damage (Pearce,1993;52), and defines sustainability in terms of 'optimum depletion' and the feasibility of an anticipated 'growth path' (Karshenas,1992;4-5). Their hypothesis is that, although environmental degradation increases with economic development, a point is reached where the degradation trend is reversed (Karshenas,1992, WWF,1996;3et seq., Feitelson and Allan,1998, Allan and Karshenas,1996). The turn is a form of Kuznets curve. Levels of air pollutants in industrialised nations are said to follow the trend of Kuznets curves in which up to certain values of per capita GDP, levels increase, and with further increases in GDP, pollutant levels decline (World Wildlife Fund,1996;18). This is one line of supportive evidence for the 'growth path' hypothesis. However, many key pollutants have not been considered and some environmental performance indicators are still declining in the most industrially advanced nations (ibid.). The problems of time series sampling methodology, statistical significance of results and whether changes in energy sources on air pollutant levels, particularly from coal to oil, during the period would also raise doubts regarding the validity of the theory. Its relevance and validity must also be doubted by the 60% of the worlds population who have not reached any 'turning point' for any variable (ibid;13). A second line of defence is the supposed correlation of 'forced environmental degradation' with economic stagnation in many developing countries (Karshenas, 1992;14,10). However, even if the correlation is valid for the pre-turn Kuznets curve segment, it does not prove that economic development and environmental reconstruction are complementary (the post-turn segment) and neither correlations give proof of causation (World Wildlife Fund,1996;26). Another problem arises from resource renewability; whether natural resource reconstruction is slow (e.g. a depleted aquifer) or impossible (e.g. a polluted aquifer) due to irreversible changes (World Bank,1993;94, Pearce,1993;50). These factors are overshadowed by our uncertainty of the scientific processes involved and our technical ability to correct damage (Karshenas,1992;20).

Despite blaming the plight of low-income countries on their poor endowment of initial natural resources (World Wildlife Fund,1996;8), natural capital appears to be rather evenly spread (Dixon and Hamilton,1996;16). Rather, the difference between low and high-income countries lies in their human resources which have been shown to be correlated with education provision (ibid;17). Education is, therefore, one area for reinvestment of the rents accrued from the environmental damage caused by economic development (ibid;16, Pearce,1993;50, Karshenas,1992;14).

The foundation for forced environmental degradation of population growth, increasing scarcity of indigenously produced food and a stagnant economy, so typical of low-income countries, underscores the most important role for water, livelihood provision (ibid;16,23, Allan and Karshenas,1996;122). Dixon and Hamilton point out that agricultural land is the dominant natural resource of rich and poor countries, but especially for low-income countries, and emphasise the need to manage land sustainably and encourage the growth of rural incomes (1996;18). This is contrary to the desired trend of economic development (and supposedly environmental rebuilding, in the long run) which envisages countries moving from an agricultural to an industrial to a service industry base. (Karshenas,1992;16, World Wildlife Fund,1996; 13, Winpenny,1994;45).

There is an equity question at the North-South level. The world still wants the products of heavy industry and there is at least the possibility that the north`may be 'free riding' by exporting environmentally damaging industrial processes to the south, whilst happily importing the products at prices which do not cover the cost of the environmental damage. (World Wildlife Fund,1996;25, Pearce,1993;75, Karshenas,1992;16,22). There is also a suggestion that this export may be realised, and even sanctioned, at the highest levels (Summers quoted in McSweeney,1998;6).

2.7.4 Roles of Aid and Poverty

What is the role of foreign aid in the context of the aims of economically and environmentally sustainable development in the South? Serageldin (1994;31) suggests helping the poor. This raises the issue of social and ethical sustainability (Du Bois,1992;2). Morton points out the dilemma of trying to pursue economic and social aims in development (1994;55) and Migdal suggests the UN has created a further paradox of hallowing the state by dealing with it, whilst undermining the state by its economic and social programs (1988;13). The very structural adjustments prescribed by the World Bank to strengthen the state can weaken it (Hildyard,1998;49). Vincent (1991) suggests that in Yemen this paradox is further complicated by what is observed as an unwillingness of donors to work with local institutions outside of specific (central) bureaucratic structures.

Falkenmark and Lundqvist (1995;183) find the notion of sustainable development awkward in the context of the pursuit of mere survival by the poor. Whether the poor in any country actually benefit from the economic development associated with Kuznets principles is also questioned (World Wildlife Fund,1996;8). In order to address the problem of poverty, one must examine its causes. Chambers (1983) points out some different views: he suggests that political economists see processes concentrating wealth and power as the cause and seek to change social and property relations, whilst physical ecologists see physical causes. He sees an interdisciplinary vicious circle of powerlessness, vulnerability, physical weakness, poverty and isolation forming a deprivation trap; a vortex pulling down the poor. Karshenas cites population levels relative to the resource base as the cause of poverty, particularly degradation of the environment in the pursuit of maximising agricultural production by the increasing rural population, especially in arid and semi-arid countries. Besides rural poverty, Berkoff also identifies the modern urban areas as Southern poverty traps (1994;37). Whether urban or rural, although McSweeney's warning that the commodification of water may cause the poor to die of thirst is unlikely to be fulfilled, (1998) the potential for them to die from water borne diseases at an increasing rate is more likely.

The literature takes a critical and often cynical view of foreign aid efforts. Morton traces the shift in focus of aid from industrialisation/modernisation, to agriculture and integrated rural development, to the structural adjustment of macro-economics and, most recently, to development of institutional and human capabilities (1994; 13) The dynamic for the changes in focus seems to emanate steadily from northern academia searching for something new to publish rather than from recipients' day-to-day survival needs. For instance, although operation and maintenance are not 'flavour of the month' in development circles, these are identified as key areas at grass root levels, and particularly the absence of (imported technology dependent) spare parts (Therkildsen, 1988;166, Miller,1979;133).

The traditional donor-control oriented, non-adaptive, blueprint method of development planning is severely criticised (Therkildsen,1988). Many see foreign aid as an industry with 'one shot' quantitative targets in which the donor firmly controls the conduction of a blueprint development plan, commissions consultants (usually from the donor country) to conduct data-intense studies. It has been noted that 'long-and-dirty' data intensive studies can 'hide the wood from the trees' (Chambers and Carruthers,1986;1-2). The problem may not be one of generating too many data, but of not obtaining the right data and not integrating it holistically, a task which is certainly made more difficult as field experts multiply. The consultants then make recommendations to purchase technologically inappropriate hardware from the donor country (Cowen,1994;7, McSweeney,1998, Chambers and Carruthers,1986;4, Therkildsen,1988;102,166). This tendency has also been noted in Yemeni rural water supply development (Vincent,1991;204). The donor's interest in aid is only in maintaining the volume of giving and "his interest in what happens to it is relatively small" (Morton,1994;58-9). Chambers identifies another major contributing factor to the non-arrival of aid at the point of need as bias in donor awareness of the needs, particularly of the rural poor (1983). In Yemen, Vincent (1990) questions the large amount of time spent in technical feasibility studies of development schemes compared with the time spent in developing trust, legitimacy and authenticity (that is, enabling local 'ownership'). Government institutions of recipient countries are also happy to keep the aid flowing (Therkildsen,1988;166), particularly if it means employment for them and, in some cases at least, an opportunity for nepotism and the skimming off of benefits (Johnson,1996;7, McSweeney,1998) euphemistically known as 'rent seeking' in the literature (DISWC, 1993;8, Cowen, 1994;5), but perhaps better labelled corruption or at least rent collection. This item, which can be a significant part of the aid budget (ibid.), belongs in Morton's 'forbidden territory' list of untouchables along with taxation and law and order (Morton, 1994;48,50) which donors are not allowed to question. The charicature representation of rent-seeking officials and opportunistic farmers may be rather one-dimensional when compared to the full array of incentives which they face (Mollinga,1998;21), but at least we should face this major one.

Morton reduces Chamber's development biases to one: "a bias towards the short term" (Morton, 1994;37). The foreign aid expert envisaged by Morton (1994,43-44), Chambers (1983) and Clammer (1984) appears to be 'Superperson' with an interdisciplinary background, great powers of integration, a grasp of the local language and can keep motivated during their long term posting despite knowing their counterpart has no intention to take their 'expert' advice. Certainly commitment and continuity of development programs, and particularly staff, are vital if programme impacts are to become sustainable, but one wonders if such staff exist, could be afforded or are likely to stay when they realise what is expected of them. They do not appear to stay in Yemen (Vincent, 1990 and 1991).

Urban Water Supply and Sanitation.

A specific issue in the field of sustainable development, though bridging other fields as well, is the provision of urban water supply and sanitation. Allan (in prep;5.9) suggests 'It is a generally accepted development goal that the basic needs of about $100m^3$/c/yr should be made available to individuals and communities at prices consistent with the economic capacity of the respective communities'. However, there is some debate over the validity of encouraging development of urban water supplies and sanitation. Falkenmark and Lundqvist suggest there is greater political pressure for urban supplies as opposed to rural supplies (1995;188) which is related to tarmac/capital development biases. The provision of piped water supplies is questioned because of the high cost (Rogers,1992;1.3, Berkoff,1994;35), particularly for urban provision. Urban supplies cost more because the distribution systems connect every house rather than just providing standpipes and the cost of fitting the distribution system around the existing infrastructure of roads, pavements, telephone and electricity cables in the urban environment. Sewerage provision is questioned even more (Serageldin, 1994;1,3,Fig5,15). However, Serageldin's internalisation of the externalities by local groups paying for the sanitation necessary to remove sewage from their immediate area which they then export to the larger urban district ends up with the pollut<u>ed</u> paying at the final stage of removal from the area unless the formal institutions cover this cost (1994;Figure8). Contrary to Serageldin, others insist that if water is supplied, sanitation must also be supplied (Rogers,1992;7.34). The poor are particularly prone to poor sanitation provision (Pearce,1993;79) and the subsidies inevitably built into water and sanitation systems consistently benefit the rich, not the poor. The literature disagrees over the willingness of users to pay for improved services, some saying they are (World Bank,1993;15) and others saying they are not (Pearce,1993;77).

2.7.5 Why aid now focuses on institutions

The failure of institutions to provide adequate water management despite significant inputs of infrastructure from outside has contributed to the current shift in development emphasis to institutional and human capabilities (Morton,1994;13). Weak institutions characterised by overstaffing, inadequate pay, declining skills, poor working environment, lack of job satisfaction have been identified as the cause (Berkoff,1994;37, Falkenmark and Lundqvist,1995;178, Coopers and Lybrand, 1992;235, Delft,1991;19). Worsening performance indicators of increasing unregistered connections, unaccounted for water and number of jobs per connections are added to the picture (Serageldin,1994;11), and increasing insecurity of deliveries is thought to lead to irresponsible use by customers with the supplier blaming the user (and becoming customer desensitised) and vice versa (Lundqvist,1998;11).

Berkoff (1994;42) traces the typical historical development of water entities from the first water agencies through their amalgamation into an overarching body. This body is delegated functions before it has the mandate, skills or resources to manage (Guggenheim,1991;22, Berkoff,1994;45), its legal validity may be precarious (Mallat, 1995;7) and it has a secretariat that is weakened by opposition from line agencies (Berkoff,1994;45).

Development agencies have not always helped in the reform of institutions. Often the development plan is prepared outside the recipient institutional framework (Therkildsen, 1988;chapter 6) which can result in failure to understand and allow for institutional features (Coopers and Lybrand, 1992;108). The assumption that the lack of recipient capacity to plan and implement can be substituted by the provision of technical assistance staff diverts attention from domestic institutional capacity building to the production of new schemes (Therkilsden,1988;17). Donors by-pass institutions in their development planning and implementation, which results in non-integration and unsustainability (ibid;3.6,102), and rather than contributing to capacity building, donor technical assistance staff become performer/substitutes instead of teacher/mobilisers (ibid;18-19). There is therefore now a development emphasis on improving institutional human resources capabilities so that indigenous decision making quality, sector efficiency and managerial performance are improved (Delft,1991;19).

2.7.6 Conceptual Frameworks of Sustainable Development

Two basic and contrasting models of sustainable development are apparent in the literature:

a) The environmentalist view: economic development and environmental sustainability are not compatible.

b) The Ekcurve theorists / Karshenas view: economic development and environmental sustainability are compatible.

The first places economic development and environmental sustainability at opposite poles with sanctioned discourse and policy possibilities, at whatever level – national, local etc, held in tension between them. Figure 2.1a adds another axis between internally and externally derived dynamics, such as belief systems and foreign aid respectively for example, which hold discourse and policy in tension in another dimension. For illustration, various activities or initiatives which have occurred in the Ta'iz area are plotted in the quadrants defined by these axes. It is suggested that the more socio-politically acceptable water resources management initiatives usually reflect internally derived preferences and economic development than environmental and externally derived dynamics.

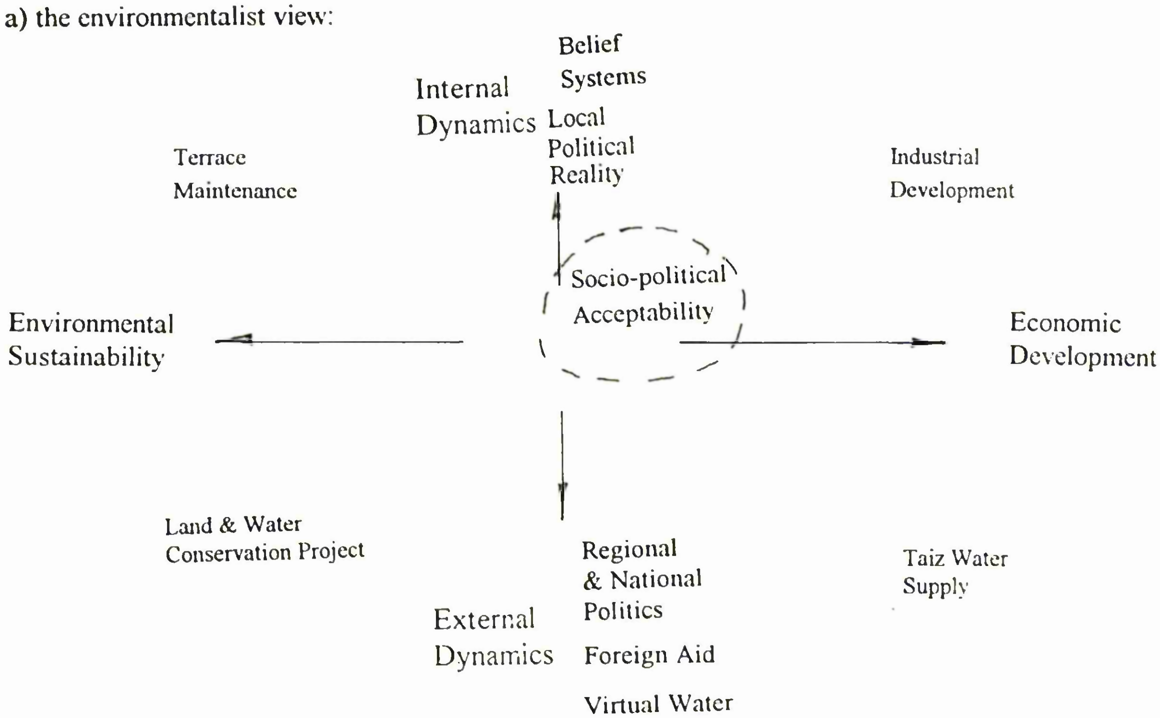
Figure 2.1b is a reworking of Karshenas (Allan and Karshenas,1996) and the Ekcurve model in which economic development and environmental sustainability in the form of 'capital' are plotted on perpendicular axes, that is, as though they were compatible. The Yemeni reality of no apparent turn in the curve, economic progress for the 'haves', declining economic capital for the 'have nots', and declining environmental capital for both is superimposed. Since 60% of the world economies lie somewhere between these two paths they are termed 'Southern Reality'.

2.8 Summary: key themes relevant to Yemen

The literature recognises the need for a holistic view of water management, however examples of this approach are rare. The importance of considering whether there is sufficient water (quantity), whether it is adequate for the intended use (quality) and whether it is affordable to the all users (price) is not new, although these aspects are seldom seen simultaneously in specific situations. The Middle East is recognised as a water scarce area, in global terms, and Yemeni water as the scarcest of the scarce for a region with such a high population. The following chapter examines that scarcity in the Ta'iz area.

As well as physical reasons for water scarcity, this chapter has discussed some of the human factors. As a starting point the literature points out the failure to perceive the economic value of water that forms the basis for implementation of demand management measures rather than simply increasing supply as populations increase. Some authors suggest that one of the reasons for failing to perceive the economic value of water is the presence of political motives. These motives are identified as particularly apparent in the reticence to reallocate water from agriculture to domestic and industrial uses and the failure to recognise the contribution of virtual water to meeting the food deficit. The use of information and knowledge in achieving political aims has been noted and traced to underlying belief systems. The role of plural legal and institutional frameworks in implementing politically determined policy raises the issue of bottom-up vs. top-down initiatives, and underlines the strong society / weak state Yemeni context. Some, particularly those working in Yemen, have recognised the importance of local, mostly small scale, rules and players if water use is to become more allocatively efficient and equitable. Models of sustainable development provide a conceptual framework against which to examine the impact of water use on the environment in and around Ta'iz and the role of the development agencies.

a) the environmentalist view:



b) the EKcurve / Karshenas view

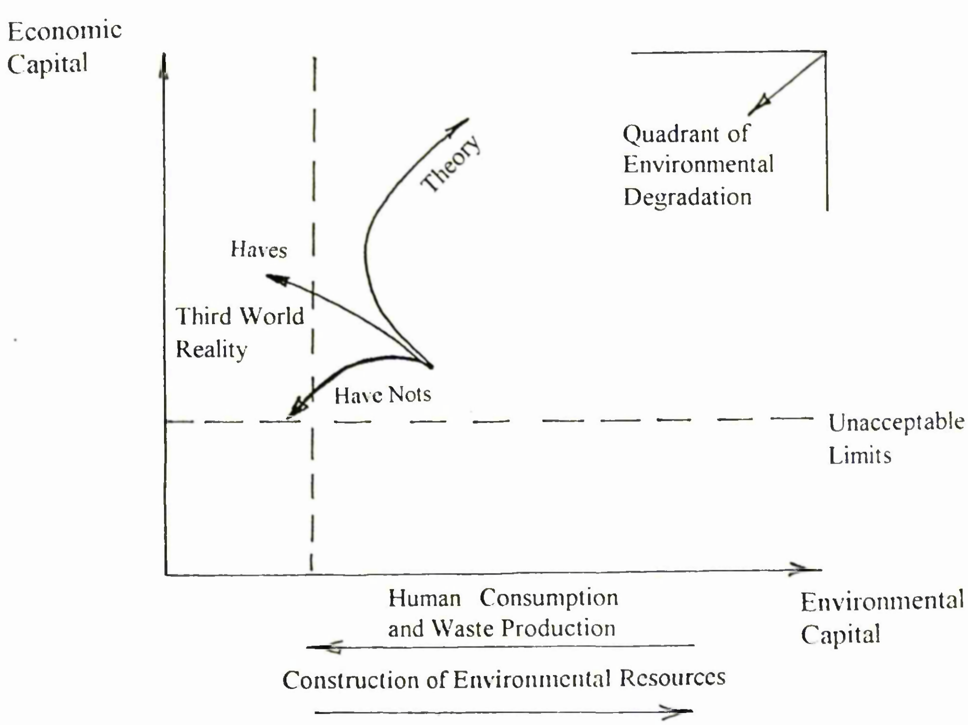


Figure 2.1 Perspectives on Sustainable Development

Chapter 3 Autopsy of an Aquifer

'if groundwater abstraction for the city remained at the (low) 1995 level
and if irrigated agriculture ceased
....the Al Hayma basin would recover after ten years
and the Miqbaba basin after five years.'

3.1 Introduction

The Ta'iz study area is an extreme case of environmental degradation and provides a unique opportunity with which to put some empirical flesh on the theory discussed in the previous chapter. The demise of the water supply of Ta'iz has centred on two main water resource problems. Firstly, the resource base has been declining, and secondly, that resource has become increasingly polluted. The major part of this chapter investigates the declining groundwater levels in the main aquifer serving the city, that of Al Hayma (Figure 3.1) in order to:

a) provide a better understanding of the natural water movement processes,
b) assess the relative significance of different human water use activities,
c) determine the physical causes of the crisis,
d) define the sustainable yield of the aquifer and
e) predict how long it would take the aquifer to return to its starting condition if only current minimal abstractions for the city were to continue.

The latter point permits evaluation of the cost of reversing environmental degradation in section 4.1. The problem of declining surface and groundwater quality is described and its causes are identified in section 3.7. Section 3.8 concludes the chapter with a summary of the environmental impact of water use and abuse in the Upper Wadi Rasyan catchment (area defined in Figure 3.2).

Groundwater Development: Historical Background

Since the 1960's, the water supply of Ta'iz has been derived from groundwater sources located successively further north of the city. The earliest wellfields were developed close to the city (Hawban / Hawgala, Figure 3.1) but were of low quality water. Water quality has deteriorated further because the wellfields are located downstream of the city and receive effluent from it. Development then shifted to the Al Hayma valley 12 km to the north. As this source was exhausted, the conveyor was extended further north to the Habir area where the

Tawilah Sandstone was hoped to provide some relief to the water shortage. Exploration further afield continues to today. A summary of these events follows (Box 1):

Box 1: History of Hydraulic Events in Ta'iz

Early 1960's: Hawban and Hawgala fields developed and Kennedy scheme developed to supply Ta'iz (low quality water) by USAID.

1967 USAID leave, Kennedy scheme starts to deteriorate

1975 JM Montgomery report identifying other well potential wellfields and recommends Al Hayma – Miqbaba

1976-81 Investigation of Al Hayma wellfield (Miqbaba – As Sahlah) recommends utilisation of all groundwater in Al Hayma including the complete cessation of irrigated agriculture. Tipton and Kalmbach (1979) recommend compensation of $10M to farmers (which was never paid). Awareness of the impossibility of simultaneous use by agriculture and Ta'iz city.

1982-3 Commissioning of Al Hayma wellfield.

1987: Al Hayma wellfield running dry. Emergency measures include reconnection of low quality Hawban Hawgala fields and emergency drilling of six more wells in Al Hayma.

1989: Attention turned to Tawilah Sandstone in Habir, immediately to the north of Al Hayma and negotiations for exploratory drilling began with shaykhs of Habir / Dhi Sufal. Some wells drilled in Dhi Sufal, Al Qa'idah, Al Janad (No production wells).

1995-6: Water supply in Ta'iz reaches once per 40 days, EC >1500μS/cm. Emergency drilling in Ta'iz city by instruction of the Governor. Negotiations with shayxs of Habir / Dhi Sufal over six wells to be connected to an extended Hayma – Ta'iz conveyor. Six wells drilled, three connected (from West Habir).

1997-Present (1999): Declining yields of three West Habir wells and Ta'iz city wells. Exploration by NWRA of Wadi Warazan, Wadi Al Ghayl / Bani Khawlan.

Sources: Leggette, Brashears and Graham (1977 and 1980), Montgomery,James M (1975), Adel (1986), Dubay,L (1993), Dubay,L (1989), Dubay,L (1996), Tipton and Kalmbach (1979), CES (1997).

Groundwater Development: Hydrogeological Background

The Al Hayma aquifer comprises a sequence of alluvial materials of all grain sizes but predominantly sands and silts. The alluvium was deposited in a north-south trending fault-controlled depression in the volcanic bedrock, which reaches depths in excess of 80m. To the north of the valley lies a major east-west fault which forms the northern limit of the graben (Figure 3.1) and the base of the horst slope from which the alluvium was, and continues to be, derived. The relatively high permeability of the alluvium, in contrast to the volcanics, underscores its importance as a water resource. The Al Hayma valley constitutes the largest underground storage facility for water in such proximity to the demand centre of Ta'iz. The valley floor covers 16 km^2, excluding As Sahlah (Figure 3.7), and is the downstream point in a catchment of 231 km^2 of mountainous terrain. The potential of the Tawilah Sandstone, which underlies the volcanics, at least in some areas, is unproven. Although it outcrops at the base of the horst, the Tawilah Sandstone has not been reached by any borehole in the graben.

3.1.1 Outline Methodology

The analysis of the alluvial Al Hayma aquifer is based on the principle that all water inputs to the valley must equal the outputs, plus or minus any change in groundwater storage:

Rainfall + Runoff = Outflow + Evaporation & Evapotranspiration + Abstraction for City +/- Change in Storage

Runoff is that into the valley from the surrounding hills and, like outflow, may have surface and sub-surface components. Evaporation and evapotranspiration mainly comprises that from soil and from plants. Consumption by the population comprises less than 0.2% of the total water budget. Change in storage is the net result of subsurface inflow and outflow and infiltration both from rainfall events and 're-infiltration' from irrigation. The change in storage is observed through hydrographs.

In order to address the five points listed above, a number of models have been developed to simulate the terms in the water-balance equation so as to reproduce the observed decline in water levels, that is, change in storage in the Al Hayma valley, over the period abstraction for the city has been taking place. This constitutes the period 1983-1995. Because each of the terms have varying margins of error, the rationale behind the modelling has been to eliminate scenarios and assumptions which cannot reproduce the historical trend.

Table 3.1. Summary description of the function, inputs and outputs of each of the models:

Function	Inputs	Outputs
3.3 SCS / TS-HWC Runoff Model - Daily data from 1983 to 1995.		
To generate runoff volumes to Al Hayma.	Airport Daily Rainfall, SCS Land Use Types	Daily flows from tributaries and flanks to be applied to central wadi course and edge areas of Al Hayma (as mm)
3.4 Penman-Monteith Evapotranspiration Model - Daily data from 1983 to 1995.		
To estimate the amount of water required by each crop from abstraction above and beyond that provided by rainfall and runoff and, where water input from the latter two exceeds demand, to estimate the infiltration.	Airport daily mean dry and wet bulb temperatures, sunshine hours, Airport and Usayfra wind run. z-d and crop heights. Output from Runoff.	Net infiltration and abstraction for locations receiving central spates, flank spates and just rainfall for the appropriate cropping pattern (m^3 per 100m x 100m grid square per season. Dry season Oct-Feb, wet Mar-Sept)
3.5.1 Steady State Groundwater Flow Model (GWVistas/Modflow) 1976 pre-development calibration		
To match groundwater heads in 1976 as an essentially pre-development steady-state condition and compare runoff indicated by the groundwater model with that by the runoff model.	Aquifer geometry, hydraulic conductivity, subsurface tributary and outlet constant heads, net recharge derived from evapotranspiration model.	Calibration of flows and heads
3.5.2 Transient Water Balance Model a)		
To run a mean rainfall year (1987) five times, incrementing drawdowns to examine whether the scenario being considered could approach matching the observed hydrographs.	Satellite image determined irrigation areas for 1986. Output from evapotranspiration model for 1987.	Calibration of hydrographs. Assessment of flows.
3.5.2 Transient Water Balance Model b)		
To match the complete observed hydrograph record from 1983 to 1995	Satellite image determined irrigation areas for 1986 and 1995. Output from evapotranspiration model for 1983 to 1995.	Calibration of hydrographs. Assessment of flows.
3.6.2 Recovery Model		
To predict how long it would take the aquifer to recover to approximate pre-development levels if the city continued to abstract as in 1996 and there was no irrigation	Satellite image determined irrigation areas for 1995. Output from evapotranspiration model for 1987.	Predictive hydrograph

Although it is not possible to arrive at a unique solution, the error margins of individual variables when considered together (sensitivity analysis) still permit an evaluation which addresses the five points . The methodologies for determining the inputs to the models are described in each of the following sections. After a discussion of the origin of the rainfall data (section 3.2), section 3.3 attempts to model the runoff to the Al Hayma valley, 3.4 the evapotranspiration from the valley with changing irrigation and cropping practices. Section 3.5 attempts to reproduce the observed hydrographs by a series of groundwater models and 3.6.1 to predict the aquifer recovery period. Table 3.1 gives a summary description of the function, inputs and outputs of each of the models.

3.2 Rainfall

The area lying within the previous political boundaries of North Yemen may be roughly divided topographically into three zones running north-south: the western coastal strip (or Tihamah) flanking the Red Sea, the central highlands, and the eastern slopes descending towards the desert of the Rub' Al Khali. This topographic division largely determines the rainfall distribution, with very little rainfall in the Tihamah and the eastern desert. The central highlands receive most of the rain, which increases southwards, reaching a maximum of over 1000mm/yr in the vicinity of Ibb, only 35 to 40 km north of Ta'iz.

The northward movement of the inter-tropical convergence zone, sometimes referred to as the Red Sea convergence zone (Gun and Abdulaziz,1995;21-22 and WAPCOS, 1996;2.1), in early summer (April-May) and its southward movement in late summer (August-September) results in increased precipitation at these times (Williams,1979;3-6). Precipitation during this bimodal rainy season is in marked contrast to the dry season (October-March) of prevalent north-east trade winds, and in many areas, including Ta'iz, to the noticeably drier months of June-July (Figure 3.3).

The main meteorological stations currently operating are located at Usayfra (monitoring period 1979-present) and at the new Ta'iz airport (1976-1979 and 1983-present). Coupled with data from a few, more minor stations, a tentative rainfall distribution map has been proposed (Figure 3.2). It should be pointed out that the interpretation of any of the climate data is dependent on the quality of the data. Measurement and recording errors, and periods without readings are present in the data sets. Also, apart from a few months during 1977 and two months during 1989, there has been no monitoring of climatic variables in the Al Hayma valley itself. However, the TS-HWC (DHV, 1993) note that for Yemen as a whole:

> "Daily rainfalls observed at any one station are effectively samples from a statistical population of rainfalls that is constant irrespective of position, altitude, or any other physical variable"

and DHV 1993 goes on to point out that the difference in rainfall between locations:

> "is caused by the number of rain-days, not by the daily rainfall amounts".

On this basis, and in the absence of more comprehensive rain gauging, rainfall data from other nearby locations has been used in estimating the runoff and evapotranspiration described in the following sections.

Ta'iz airport is the nearest station only 8 km to the East and with a similar elevation (1450m) and aspect to Al Hayma. Usayfra is the second nearest, 12 km to the south and of a lower elevation (1200m). The airport daily meteorological data have been used in calculating evapotranspiration and runoff over the modelled period, however, data had to be generated for the wet months of August 1990 and May-July 1994 which were missing from the record. These periods were generated by applying typical rainfall frequencies and amounts for those months on a pro-rata basis, relative to the annual total rainfall observed at Usayfra.

Although some have suggested that there may be longer term trends in annual rainfall variation (for example, Zagni, 1996), the short record available for the area does not appear to support such a view (Figure 3.4).

3.3 Runoff

'During 1995 it is estimated that 85% of the year's rainfall in Ta'iz
occurred during a period of only 12 hours
if the periods of the most intense rainfall were summed.'

3.3.1 Methodology

The pattern of rainfall, with high intensity convectional storms during some afternoons in the rainy season, is particularly important in analysing both the runoff to the study area and the evapotranspiration. During 1995, it is estimated that 85% of the year's rainfall in Ta'iz occurred during a period of only 12 hours if the periods of the most intense rainfall were summed. In these circumstances, the analysis of evapotranspiration and runoff based on 10day, monthly, or longer averages must be questioned. The approach here has been to use daily data.

Apart from a few months of stream gauging in 1976 as part of the resource assessment from the Al Hayma valley for the development of the public supply there has been no other stream gauging in the area. One of the main methods used in assessing runoff where there is no stream gauging is the SCS method (Rango,1984, Mockus,1972 and Noman,1982). This method is also recommended for use in Yemen in a modified form developed by the Technical Secretariat of the High Water Council (TS-HWC) and is documented in DHV (1993). The SCS method assumes that rainfall is initially abstracted (Initial abstraction, Ia) by interception, infiltration and surface storage before runoff begins, as a set proportion of the total maximum retention of the watershed (S) such that:

$$Ia=0.2\ S$$

The relation of these two parameters to the rainfall (P) and the runoff (Q) is:

$$Q=((P-Ia)^2)/((P-Ia)+S)$$

And, where Ia=0.2 S:

$$Q=((P-0.2S)^2)/(P+0.8S)$$

S is determined from:

$$S=((1000/CN)-10) \times 25.4^*, \qquad (^*\text{ conversion from inches to mm})$$

where CN is a curve number devised on the basis of different soil types and land uses.

Although originally developed on Eastern USA catchments, TS-HWC (DHV, 1993) have suggested values of Ia and CN applicable for Yemen. In order to test the relevance of either method, monitoring of wadi flows during storms in Ta'iz area on the slopes to the south of the graben has been carried out. Although the monitoring was not possible in the wadis discharging to the Al Hayma valley (located on the slopes to the north of the graben), they are similar catchments in terms of topography, altitude, land use, soils, rainfall amount, intensity and frequency. The difference in aspect does not seem too important since the local prevailing winds during the rainy season are westerlies, and sometimes easterlies.

During the rainy seasons of 1995 and 1996, thirteen wadi flows from ten rainfall events were monitored. Flow estimates comprised rudimentary measurement of the stream cross-section and the velocity of floating objects at regular intervals during the storm. Locations were chosen where the wadi bed profile was relatively smooth and constant. Allowance for drag was made by taking a mean velocity of 75% of the observed surface velocity (van der Gun pers comm.). Rainfall measurement was by rain gauge mostly located within the catchment. Due to the absence of other rain gauges, it was not possible to carry out rainfall averaging methods over the catchments, such as Thiessen polygons, although it should be noted that the catchments are adjacent and of similar aspect and elevation. The catchments are shown in Figure 3.5 and a representative hydrograph in Figure 3.13.

Table 3.2. Curve numbers derived from the SCS method and those proposed by TS-HWC as applicable to Yemen:

Land Use Classification*	SCS ** Description	SCS Soil***	SCS** Curve Number	TS-HWC** Description / Type / Ia value	TSHWC Curve Number
Uncultivated, steep slopes	Bare Ground	D	90	Steep slopes with bare rocks / P1 / 0.15	90
Uncultivated, lower slopes	Bare Ground	C	88	Low slopes with bare rocks or thin soils /P2/0.2	85
Terraced steep slopes	Row Crops Contoured and Terraced	B	72	Terraces on slopes / P5 / 0.3	65
Cultivated Wadi Floor	Row Crops Contoured and Terraced	A	64	Terraces in wadi beds or on plains / A2 / 0.3	65
Urban Area	Residential	B	74	Flat areas with impermeable soils / P4 / 0.2	75

* adapted from Dar al Yemen, 1997
** DHV, 1993 and Rango 1984
*** matched with soil types given in Dar al Yemen, 1997

The curve numbers were converted for antecedent moisture condition according to the previous 5 days rainfall and the season, according to Tables 2.4 and 2.5 in DHV, 1993.

The observed and calculated wadi runoff / rainfall ratios are contrasted in Figure 3.6. The rainfall events were typically intense, with a distinct start and finish and the lag time between commencement of rainfall and the peak flow was of the order of 15 to 20 minutes. Although the ratio determined by calculation was greatly different from the observed data in some instances, these instances tended to be for the lower rainfall events where a greater margin of error might be expected due to the rain gauge being distant from the storm centre. For the purpose of adopting a method to simulate runoff, it is more important that calculated and observed runoff are closer for the higher rainfall events, as was the case. On the whole the TS-HWC values were closer to the observed than the SCS ones. This is thought to be because land type descriptions, and therefore land type areas, in the TS-HWC method more closely approximate the field condition. The TS-HWC CN and Ia values have been used in preference to the SCS ones in calculating runoff to Wadi Al Hayma.

[The SCS model and its application by TS-HWC are regarding runoff. The use of it here is to determine runoff from the surrounding wadis and slopes to the Al Hayma valley. Perhaps, more correctly, this should be termed runon, however here it is referred to as runoff. Sub-surface outflow through the Miqbabah gorge is referred to as 'outflow' in this chapter.]

3.3.2 Runoff to Wadi Al Hayma

Runoff to Wadi Al Hayma is observed as occurring in three different ways:

i) inflow at specific points where there are known wadi flows (within the period of resource development / modelling viz. 1983-1995) and which form a linear source along the length of the wadi bed as spate flows.

ii) inflow at specific points where major subsurface inflows occur at the entry points of major tributaries to the valley.

iii) runoff from a large number of small wadis on either side of the main valley where the water harvesting system spreads the runoff over the fields along the main valley perimeter. This is said by locals to extend approximately 200 to 300m into the main valley.

The three types are shown on Figure 3.7. The wadis, Rahabah and Hama'ir discharge minor surface flows to the Al Hayma valley. Wadis Tanif, Ja'ashin, and Hajib have been observed by locals to discharge as surface flows into the Al Hayma valley, though the flow frequency has been noted to decline during the modelled period (see section 3.5.1). These wadis receive water from the elevated high rainfall area to the north. It is estimated from rainfall distribution maps (Dar El Yemen,1997 and Gun and Abdulaziz,1995) that rainfall over these areas is approximately 60% higher than in the Al Hayma valley. The boundary is placed along the E-W fault line at the northern limit of the graben, which marks the major change in slope.

In generating rainfall data for the Al Hayma catchment as an input to the model, the following assumptions have been used:

a) that, because the nearest rainfall station (Ta'iz airport) occupies a similar altitude and aspect to Al Hayma, its rainfall record can be taken as representative of the Al Hayma valley. This is not to say that rainfall occurred in the valley catchment on exactly the same days and by the same amount as occurred at the airport, but that the monthly totals, frequency and duration of storms will be similar. This forms the basis of the daily rainfall applied to the valley floor in the model.
b) on the basis of the TS-HWC and DHV observations quoted above regarding rainfall, runoff to the catchment from north of the graben has been generated by adding 60% more days of rain to the airport record. These days have been added randomly but in an identical distribution in terms of season (Figure 3.2) and amount. Runoff from areas south of the fault has been generated using the Ta'iz airport rainfall record.

In addition, runoff observations in the catchments around Ta'iz suggest that in the model:

a) daily rainfall below 6mm (Figure 3.8) should not contribute to runoff (DHV 1993;5) and therefore should be excluded.
b) for catchments of the order of tens of km^2, such as those being considered, that a maximum runoff/rainfall ratio of 10% occurs (Figure 3.9).

In order to assess the validity of the last point, as part of the model sensitivity analysis, two variants have been considered:

a) runoff without a maximum cutoff,
b) a runoff maximum of 10% of the rainfall

The main reason for the decline in the frequency and amount of spates reaching Al Hayma in recent years is considered to be the significant increase in groundwater abstraction for agriculture in Wadi Hajib, and the associated change in land use, and for the Ta'iz municipal supply below Wadi Ja'ashin (viz. Wadi Al Minqa'ah). Although this is part of the point the model is attempting to analyse, in the case of Wadi Al Hayma, the observation by locals of declining spates into Wadi Al Hayma must be built into the model inputs.

The model developed by SCS also assumes that the whole of the catchment received the rainfall of that day and that the antecedent moisture condition was the same for the whole catchment. In reality this is not the case and some of the runoff absorbing zones DHV (1993;16) will do exactly that, and absorb the runoff from other parts of the catchment before it reaches the exit point. The curve numbers 'lump' together an overall average runoff/absorbtion property for the catchment being considered. In summary, effectively the development of the water resources has increased the water absorbing capacity of the catchments with time and changed their curve numbers. Because no calibration for this is available, the calculated runoff from wadis Tanif, Ja'ashin and Hajib to Wadi Al Hayma in this analysis have had to be altered so that they occur only during maximum spate periods. The largest spates in the field occur in August and May. Runoff in the model to Wadi Al Hayma from these wadis has only been permitted in August, when the model usually generates one or two spate periods of a few days.

Table 3.3 summarises the 1983-1995 mean runoff (m^3/day) to the Al Hayma valley from the main tributaries and from the flanks as determined by the different methods used in the runoff model:

Runoff Type	i & ii	i & ii	i & ii	iii	iii	
Wadi Model Variants	Tanif	Ja'ashin	Haji b	West Flank	East Flank	Total*
a) SCS-TS-HWC	5000	5600	4100	2300	1400	21200
b) 10% max Q/P	1700	2000	1500	800	500	7500

*also includes some minor tributaries

These values are compared with those determined from the sensitivity analysis of the steady state groundwater flow model (section 3.5.1).

3.4 Evapotranspiration

3.4.1 Choice of Evapotranspiration Model

Doorenbos and Pruitt (1977;Table 1) and more recently, Shuttleworth (1990, cited in Wallace, 1991;141) have summarised some of the methods used to determine evapotranspiration rate. The methods may be divided into direct methods (using lysimeters, evaporation pans), and a range of highly empirical to very complex physically-based formulae. Each method has its advantages and drawbacks, but underlying all of them is the problem of Actual Evaporation falling below Potential Evaporation estimated by the method due to restricted uptake of water by the plant root system (an area still not clearly understood, Monteith, 1991;20). Essentially the methods of measuring evapotranspiration directly require equipment not generally available (or in some states, such as Yemen, poorly maintained), the empirical methods have very limited applicability, and the physically-based methods require equipment which, although used in a research context, is not found in routine meteorological station monitoring. The best compromise of applicability, accuracy and data requirement is in the less complex physically-based formulae.

Since the FAO recommendation of 1990, the Modified Penman method of Doorenbos and Pruitt (1977) has been superseded by the Penman Monteith method (Monteith, 1965) as a basis for calculating reference crop evapotranspiration. Both these methods involve an energy input term and an aerodynamic term. The latter method uses a more physically-based estimate of resistance to energy and water vapour flux, simulating evapotranspiration as though it were from one 'big leaf', representing the crop canopy.

The changes in crop water requirements, and hence 'losses' to evapotranspiration and evaporation from plant and soil as the plant develops were 'built into' the Modified Penman method via empirical crop factors rather than through the physically-based resistances. The crop factors also relate the crop water requirements for various crops to that of a 'reference crop' of 8 to 15cm grass not experiencing water shortage. More recently, the 'big leaf' concept has been questioned and the importance of evaporation from bare soil in between the plants which significantly changes the aerodynamic properties of the 'field' has been recognised. This has led to a proliferation of resistance terms in the formulae to cover soil, stomatal, canopy and aerodynamic resistances (Shuttleworth and Wallace, 1985;842).

Complex multi-layered models applicable to detailed research at the individual field scale, and smaller, have been developed, but these methods require sophisticated research equipment for the lab/field measurements (Wallace, 1991;140).

3.4.2 FAO Penman Monteith Model Parameterisation

The derivation of the Penman Monteith equation for the estimation of evapotranspiration is described in Monteith (1965, 1991), and in Monteith and Unsworth, (1990;247 et seq.). The FAO Irrigation and Drainage Paper No. 56 'Crop evapotranspiration' incorporates crop coefficients which aggregate the physical and physiological differences between crops relative to a reference crop of standard surface resistance (Allen et al.1998;iii).

Table 3.4. Values used for the location-specific variables/constants of the Penman Monteith equation and the basis for their selection in the Ta'iz context:

Parameter	Description	Value / Unit	Basis
alpha	albedo	0.23	Allen et al 1998;23
a	Constants in equation for atmospheric emissivity	0.34	Rhebergen & van Waveren 1990 for Yemen highlands cited in Al Derwish, 1995
b		0.044	ditto
a'	Constant in equation for net long wave radiation	0.2	Al Derwish, 1995
C	Surface soil heat flux = C (net radiation)	0.3	Fuchs and Hada, 1972 cited in Al Derwish, 1995
P	Atmospheric Pressure +/- 5 mbar	858 mbar	Ta'iz airport measurements
r_s	Surface resistance to heat and water vapour fluxes for well watered vegetation	70 sec/m	Allen et al 1998;22

Daily measurements of mean dry bulb temperature, mean wet bulb temperature, wind speed and sunshine hours were provided from the Ta'iz airport meteorological station. Saturation Vapour Pressures were calculated from the wet and dry bulb temperatures using the method described in Abbot and Tabony (1985).

Other parameters and their units used in the Penman Monteith equation are described in various places such as Monteith and Unsworth, 1990;247 and Shuttleworth and

Wallace,1985;842. However, the evaluation of r_a, the aerodynamic resistance to heat and water vapour flow also requires site-specific inputs:

$$r_a=[\ln((z-d)/z_o)/k^2u]^2 \quad (sec/m)$$

Where, from Monteith and Unsworth, 1990:

k	is the von Karman constant = 0.41
u	is the wind speed (m sec^{-1}) at the measurement point (typically 2m above ground level)
z	is the reference height (m), that is, the height of the measurement point above the ground
d	is the equivalent height (m) for the conservation of momentum such that
$d+z_o$	is the height (m) of zero wind speed

Typical relationships (ibid;117 and Allen et al 1998;21) are:

$d=0.65$ x crop height (m)

$z_o=0.123$ x crop height (m)

Ta'iz wind speeds were checked independently and were 50% lower than those measured at the airport and were closer, but higher than those measured at the Usayfra meteorological station. Ta'iz airport is more exposed than the Al Hayma valley or the Usayfra site. Although wind measurements at both are at 2m height, the Usayfra site conforms better to the intended application of the Penman Monteith method. Modelling has compared both airport and 50% airport wind speeds.

3.4.3 Soil Moisture Content: Model Methodology

The absence of data regarding soil moisture content with depth at different times since rainfall or irrigation precludes the use of a zero flux plane model. The simpler FAO readily available water (RAW) model (Allen et al,1998;161 et seq.), more commensurate with the available data, is used here. For the summer crops, it is assumed that for the medium silty loam soils of the Al Hayma valley (Dar El Yemen, 1997;27) the total available soil moisture content is 14% (Smith, 1992;36 and Allen et al 1998;144). Applying the effective rooting depth (ibid. 61 and Allen et al,1998;163) for each crop type at each growth stage gives the RAW for the crop.

3.4.4 Irrigation

Current cropping patterns of the major crop types are given in Table 3.5 together with crop coefficients used. Crop coefficients were calculated on the basis of Allen et al (1998;chap 6).

Table 3.5 Cropping Patterns, length of season (days) and crop coefficients ($K_c$ini, mid, end) for major crop types.

Winter Irrigated	Summer Supplementary Irrigated	Summer Rain-fed
Potatoes: 120-125 days, (0.5,1.2,0.8) Tomatoes: 180 days, (0.6,1.2,0.815) Maize: 145 days, (0.6,1.275,0.57) Qat*: 365 days (0.65)	Maize: 140-145 days, (0.7,1.3,0.58) Sorghum / Millet 125-130 days, (0.7,1.1,0.5) Qat*: 365 days, (0.65)	Sorghum / Millet: 125-130 days, (0.7,1.1,0.5)

* A cash crop bush, similar to privet, the leaves of which are chewed by many Yemenis each afternoon because of its amphetamine / stimulant properties.

Rainfall seasonality results in maximum irrigation occurring during the dry winters and supplementary irrigation in the summer. In the case of winter irrigated crops, it has been assumed that the crop water requirement is met, and the FAO Penman Monteith method has been used in calculating the reference crop evapotranspiration.

It should be noted that the 'rainfall' used in evapotranspiration calculations is the recorded rainfall, whilst irrigation is an effective irrigation. Effective irrigation is defined as the water pumped for irrigation less that portion which recirculates to the aquifer, which can be, and has been, ignored in terms of the total water balance. As an approximation it is assumed that evaporation from channels is similar to that of the evapotranspiration from the crops they irrigate and is proportional to the area they occupy. The estimation of irrigated areas by satellite imagery discussed above includes the channel area. This is also effectively one of the assumptions in the image analysis; that the growth of natural vegetation around the channels contributes to the image and the registering of an 'irrigated pixel'. This assumption together with the occurrence of high infiltration rates result in small evaporative loss contributions to field application efficiency (though there are large infiltration 'losses') and no further calculation for irrigation losses has been made.

Summer Rain-fed Crops

The FAO RAW methodology has been used with both irrigated and rain-fed crops. Inputs from rain and daily abstractions by crops from the tank are dealt with as described in the previous paragraph except that the only input is rainfall.

Winter Irrigated Crops

The rare occurrences of rainfall in the winter have been evaporated from the non-irrigated areas (that is, bare soil areas) in the model at a rate proportional to the reciprocal of the square root of time after an initial two day period of evaporation at the potential rate for wetted soil (Monteith, 1991;14 et seq.) which is assumed to be at 90% of the potential rate for an open water surface calculated using the Penman method (Wilson, 1990;51). It is assumed that the RAW for bare soil is 35mm (equivalent to 14% porosity over 0.5m depth, which compares reasonably with Smith, 1992;61, and Monteith, 1991;15). Although these are very rough approximations, the number of uncropped periods in which there are more than two successive rainfall days are very few. Thus large changes in the assumed values of the variables mentioned above have a small effect on the volume of water available for infiltration in the model.

Supplementary Irrigated Crops

With supplementary irrigated crops, it is important to assess the amount of water from the farmer's contribution via irrigation and that from rainfall and runoff. These amounts are summed separately in the evapotranspiration model.

Qat Irrigation

Qat crop water requirement calculation is problematic. Qat has been considered analogous to citrus fruit in calculations (Zagni, 1996), however, local irrigation practices indicate that the plant can survive on much smaller quantities of water and in the dry winter season almost 'hibernates' if it is not irrigated. Farmers will typically irrigate in order to obtain one crop in the lucrative winter months. This usually comprises three irrigation turns at around 10 day intervals with a maximum of 10 to 15 cm application each turn, applied directly to a basin surrounding each individual bush. It is unclear if qat receives supplementary irrigation in the summer. Many farmers comment that they obtain three crops per year, one in winter and two in summer. This would coincide with the bimodal summer rainfall. However it is unlikely that with irrigation facilities to hand (which nearly all the Al Hayma valley qat farms have) no supplementary irrigation takes place. From discussions with farmers, it has been assumed in the model that three crops per year are irrigated/ supplementary irrigated; one in winter, one in early summer and one in late summer. It has been assumed that three turns are applied to the winter crop, and that a significant rainfall event in both of the summer rains triggers the farmer to aim for a crop which then needs a further one or two irrigation turns, depending on whether the date of the next rain is before or after the 10 day irrigation interval.

Results

Evapotranspiration by different crops (Table 3.6) has been calculated using wind measurements from both Ta'iz Airport and 50% of that rate, as discussed above.

Table 3.6. Mean crop evapotranspiration (mm/day) calculated for the full season:

	Airport Wind,	50% Airport Wind
Supplementary irrigated sorghum/ millet	5.26	4.58
Rainfed sorghum/millet	2.05	2.00
Summer maize	5.89	5.15
Winter maize	3.53	3.26
Potatoes	2.67	2.52
Tomatoes	3.65	3.38
Qat	2.20	2.14
ET_0	4.76	4.24

ET_0 values calculated by the pre-FAO 56 Penman Monteith method in other studies have ranged from 5.8 (Zagni,1996, Ta'iz Airport), to 4.0 (Dubby and Taher,1998, Al Hayma).

3.4.5 Irrigation Trends

In order to assess the evapotranspiration throughout the modelled period, it was particularly important to determine the extent of irrigation activity over this period. Interviews with local farmers suggested that irrigation activity in the central portion of the Al Hayma valley peaked in the mid-80's, after which, according to the farmers, increasing abstraction by the water authority for the Ta'iz municipal supply began to deplete the aquifer significantly. Subject to availability, financial budget, and the absence of cloud, Landsat TM data were selected for the peak central valley irrigation period (1986) and for recent times (1995). Summer (June and September) and winter (January) data were obtained for both dates so that rainfed (summer image) and irrigated areas (summer and winter images) could be distinguished. The recent data facilitated field checking of current water use during the summer and winter seasons of 1996. From the Landsat data, various images were produced by SOAS researchers and graduates undertaking projects in remote sensing. Three main assumptions are involved:

a) In January, all vegetation is irrigated.

b) Pixels with a high response in TM4 (Very Near Infrared) and a low response in TM3 (Red) are vegetation.

c) Pixels classified as 'irrigated' are 100% irrigated – that is, there are no part-irrigated pixels (pixels cover a horizontal land area of 30m by 30m).

Four main images were produced. Although Bands 1,2,3,4,5 and 7 were available, the two vegetation indices (NDVI and TVI) use TM4 and TM3 bands only, the latter taking into account soil brightness. The other two methods, Principal Component Analysis and Tasseled Cap Analysis are statistical analyses which look at interband correlations. All four techniques produce different estimates of irrigated area, the variation being +/-20% of the mean. The main reason for the difference is the thresholding process. A threshold digital number is selected 'manually to a level which selects as much of the area where vegetation is thought to be without selecting too many pixels outside this area which are considered noise'. Although the statistical methods are considered more 'scientific', field checking suggested they produced too dense a level of irrigation. The NDVI appeared closest to the field situation and the TVI image appeared too 'sparse'. These observations could not be verified by detailed field/image correlation however. The NDVI image was selected for identifying irrigated area for input to the water balance model. The total irrigated area in the modelled part of the Al Hayma valley by the NDVI method was 3.7km^2 for 1986 and 4.3km^2 for 1995 indicating a 16% increase in irrigated area over the modelled period as well as the more obvious huge upstream shift in irrigation (Figure 3.10).

Table 3.7. Approximate irrigated crop portions in the Al Hayma valley derived from discussions with farmers and used in the evapotranspiration model (area divisions are shown in Figure 3.7):

Area in Al Hayma	Summer (Supplementary)	Winter
Top 1986 & 1995	50% Qat, 25% Sorghum/Millet, 25% Maize	50% Qat, 50% Maize
Upper 1986 & 1995	50% Sorghum/Millet, 37.5% Maize, 12.5% Qat	50% Potatoes, 25% Maize, 12.5%Tomatoes, 12.5% Qat
Central / Lower 1986	50% Sorghum/Millet, 50% Maize	75% Maize, 12.5% Potatoes, 12.5% Tomatoes
Central / Lower 1995	50% Maize, 25% Qat, 25% Sorghum/Millet	37.5% Maize, 25% Qat, 25% Potatoes, 12.5% Tomatoes

The summer images and the field checking indicate that the whole valley is cultivated in the summer, thus areas not cultivated during the winter are assumed to support rain-fed sorghum/millet during the summer. The proportions of these crops applied to the irrigated areas identified by the satellite imagery are used to calculate the areal distribution of evapotranspiration with time which forms an input to the groundwater models in section 3.5.

3.4.6 Model Checks

a) Modelled and Observed Irrigation Frequencies

The extent to which irrigated crops fall below the threshold (Allen et al 1998;169) is a useful check on the model, since, assuming farmers recognise when the crops need irrigating, this should happen rarely and to an insignificant amount.

Table 3.8 indicates the proportion of the growing season of each crop in which the soil water content falls below the threshold in a mean rainfall frequency year as determined by the evapotranspiration model:

Irrigated / Supplementary Irrigated Crops	% of season below threshold	Maximum deficit below threshold (mm)
Sorghum / Millet	8	10.1
Winter Maize	10	9.2
Summer Maize	8	10.0
Potatoes	50	18.8
Tomatoes	18	10.6
Qat	42	55

Table 3.8 suggests that the combination of irrigation intervals noted in the field (and used in the model) and soil moisture availability / rooting depths advised by Allen et al (1998) and Smith (1992), that were used in the model, appear reasonable. Potatoes appear either to be irrigated too infrequently or the suggested soil moisture availability / rooting depths are too low, or both. Certainly the limitations for irrigation imposed by the system of turns does result in periods of stress especially in the summer if rains do not fall in adequate amount, and, more importantly, frequency.

b) Total Amount of Water Needed for Irrigation

The amount of water which the model predicts should be applied by irrigation provides a rough check for comparison with the amount the farmers could use based on the number of wells and the typical yields. The UNDDSMS well inventory located 123 dug wells and 5 private boreholes in the modelled area, many of which are now dry. The anticipated yield of these particularly during the early stages of the development of the resource would have been of the order of 6-10 lit/sec suggesting a maximum total possible yield of 34,000 to 56,000 m^3 per 12-hour day. The irrigation demand suggested by the evapotranspiration model for the total irrigated area in the valley (discussed later) could, in broad terms, have approached a maximum of 15,000 m^3/day in the dry season and 6,000 m^3/day in the wet season. It would therefore appear that there was sufficient pumping capacity to provide irrigation for the demand indicated by the evapotranspiration model even allowing for small irrigation efficiencies.

Irrigation rates predicted by the evapotranspiration model and also runoff quantities added to the rainfall and applied to the runon areas in the transient water balance model require high infiltration rates if the fields are not to be flooded for long periods. The mean measured infiltration rates (Dar El Yemen, 1997;28) are 180mm in a three hour period and can approach twice this amount. Typical furrow depths observed in the field are of the order of 150mm. This is adequate to infiltrate nearly all of the model-generated irrigation depths. Even excessive over-irrigation or the maximum, 400mm model-generated irrigation depths, could therefore be infiltrated within three hours. The maximum runoff (spate) depth from the entire thirteen years of data is 1m. The high observed infiltration rates could also cope with this amount within a day especially when it is considered that the wadi bed materials will have even higher rates.

3.5 Groundwater Flow Modelling

In this section groundwater flow modelling attempts to match the observed hydrographs. A unique solution of the water balance equation is not possible due to error margins in the variables. However the five aims mentioned at the beginning of this chapter can still be addressed within those error limits.

Table 3.9: Variation in evapotranspiration and runoff inputs to the groundwater modelling:

Scenario	Model Used to Generate the Scenario
Wind velocity data are used from: i) Ta'iz airport, and ii) 50% of this velocity	Evapotranspiration
Runoff is calculated by: i) the SCS-TS-HWC method ii) As above, with a maximum of 10% runoff/rainfall ratio	Runoff

3.5.1 Steady-State Groundwater Flow Model

The first step towards matching the observed hydrographs involved attempting to reproduce the groundwater heads when the Al Hayma alluvial aquifer was essentially undeveloped. The widespread development of well construction and pump installation was triggered by the flow remittances from Saudi Arabia, which began in the mid-70's (Figure 3.17). A groundwater head map was produced from 1976 data as part of the investigation into the Al Hayma valley as a supply source for the city of Ta'iz (Leggette et al, 1981). The 1976 head distribution was matched by constructing a steady-state model using the GWVistas-Modflow software. The development of the inputs to the model is described below.

Aquifer geometry was determined from the extent of cultivated land on the alluvial floor of the valley indicated by the Directorate of Overseas Surveys 1981 maps and the satellite images of the area. The base of the aquifer was determined from borehole information and from the results of a resistivity survey carried out by (Leggette et al, 1981) and matched to the borehole data. The survey and boreholes were located in the central part of the valley and the lower (Miqbaba) part. The level of the base of the aquifer in the upstream, northern part of the valley was estimated by extrapolation. The valley was modelled as comprising one aquifer (the alluvium) because the volcanics are much less permeable (the mean permeability of the volcanics is around 300 times smaller than that of the alluvium, Dar El-Yemen, 1997;91).

Permeability of the alluvium was determined by those who conducted borehole pumping tests at the time of their construction by Jacob and Theis recovery analyses. The occurrence of some discontinuous silty and clayey bands presumably led them to use confined methods, although a semi-confined method may have been more appropriate. No observation well data were available, however, storage data are not required for the steady-state analysis. Values of hydraulic conductivity from the more reliable pumping tests ranged from 333 to 3m/day with a mean of 42m/day and a median of 29m/day.

Wadi inflows were represented in the model by constant heads. Although the software has the facility to model stream flows, the extremely ephemeral nature of the wadi flows precluded their representation by this method in a steady-state analysis, and instead, flows from constant head sources located at the entry points of tributaries to the Al Hayma valley were used in calibration. Constant heads were located between ground level and the base of the aquifer. In attempting to calibrate heads and flows in the model it was found that the heads could not be varied by more than +/- 2.5m and in the case of the major wadis by not more than +/- 1m without the model failing to converge. This relatively tight control meant that the resulting wadi flows did not vary greatly. The occurrence of a marshy area at the narrow outlet of the central part of the valley was modelled as a drain with a water level equivalent to ground level.

Recharge was applied using the rainfall of 1987 (0.00126 m/day, the closest year on record to the mean of the modelled period) to all the cells in the model. The valley perimeter cells also received the extra equivalent rainfall contributed as runoff from the east and west flanks in accordance with farmer's observations. The rainfed crop and bare soil evapotranspiration and evaporation were deducted from the rainfall to give net recharge. As a rough estimate at this initial stage of analysis, the evapotranspiration from a 300m-wide strip potatoes and maize irrigated for three seasons per year and extending the full length of the wadi was deducted in the calculation of net recharge. Again this was an approximation of the farmer's observations regarding the extent of irrigated agriculture prior to significant well construction.

On the basis of Table 3.9, two main scenarios were explored:

a) a driest case in which evapotranspiration was based on the wind velocities recorded at Ta'iz airport and a runon from the eastern and western flanks based on the SCS-TS-HWC model but with a 10% maximum runoff/rainfall ratio,

b) a wettest case in which evapotranspiration was based on 50% of the wind velocities recorded at Ta'iz airport and a runon from the eastern and western flanks based on the SCS-TS-HWC model.

Table 3.10 gives the net recharge (m/day) contributed to the valley as runoff from the eastern and western flanks (+ denotes net water gain, - denotes net water loss):

Case	Flanks (882 cells)	Central Zone (742 cells)	Balance
Dry: Airport wind velocity and SCS-TS-HWC	+0.00018	-0.00054	-0.00015
Wet: 50% Airport wind velocity and SCS-TS-HWC with 10% max Q/P ratio	+0.00049	-0.00041	+0.000079

Groundwater heads and wadi flows were used as model targets. The target head distribution was within 5m of the observed 1976 levels over the full 240m range in head values from the northern to the southern end of the valley (Figure 3.11). Wadi flow targets were within the range given in Table 3.3. Recharge was varied according to Table 3.10 and intermediate cases were also considered. Wetter cases failed to reach a solution and dryer cases caused the model to 'run dry'. Permeability was varied to determine the limits in which a solution could be obtained with a water balance of better than 0.01%. The head convergence criterion was 1mm.

Table 3.11: Steady State Model Sensitivity

Scenario	Dry	Intermediate	Wet
Solution & Balance	OK	OK	OK
Permeability m/day	10-100	20-25	34-38
Comment on heads and flows	Best when K=15 to 20	Best when recharge=0.00007 m/day	Flows too high

A net recharge of minus 0.00007 m/day +/- 15% and a permeability range of 20-25 m/day gave the best fit. Over this range the modelled outflow from Miqbaba varied from 4100 m^3/day to 11300 m^3/day. For comparison, the average flow from Miqbaba monitored by Montgomery (1975) in 1974 was 5,600 m^3/day, and by Leggette et al (1981) was 10,400 m^3/day. [Their records had to be extrapolated assuming a declining flow during the dry season.] Leggette et al acknowledge that their readings were in a period when groundwater levels were particularly high (1977-1980), whereas this model was being calibrated against 1976 levels.

Table 3.12 gives the range of wadi flows (m^3/day) determined by the steady state model for the 'best fit' range of recharge and permeability and the 'target' flows generated by the runoff modelling (Table 3.3):

Wadi Flows	Tanif	Ja'ashin	Hajib	Miqbaba	Total Inflows**
Target	1700-5000	2000-5600	1500-4100	5600-10400*	6200-17500
Steady State	2018-4200	1900-4000	900-1900	4100-11300	6034-12300

* observed flows, ** including minor wadis

The steady-state analysis suggests that the driest case analysed was 'too dry' and the wettest 'too wet'. The best fit solution lies between. The two combinations of Ta'iz airport wind data with the SCS-TS-HWC runoff method, and 50% reduced wind speed with a 10% maximum runoff/rainfall ratio in the SCS-TS-HWC method also lie between the wettest and driest cases and are considered in the transient water balance modelling.

3.5.2 Transient Water Balance Model

Recreating the field observed hydrographs by modelling requires a time-series analysis such as that provided by the transient methods available in the GW Vistas-Modflow package. It was decided, however, not to use this method for two reasons. Firstly, because of the problems of cells 'running dry' (as has happened in reality), large head differences occur in adjacent cells during successive iterations, resulting in the model failing to converge. Secondly, abstractors export water to different parts of the basin. Thus, although wells in the deeper, central part of the valley remain operative for longer, the farmers away from the centre import water because their wells have run dry as the aquifer was depleted. In trying to model this, a dry cell ceases to function and cannot receive recharge or lose abstraction even though these processes are taking place in reality. Because of the problems of cells 'drying up' and farmers importing water, a model was adopted which summed water inflows and outflows on a basin scale.

Rather than the constant head representation of wadi inflow runoff used in the steady state model, the transient model applied the runoff water to the areas described as receiving spate flows by the farmers. These areas are different for the dry and wet season both in the field and in the model. For the modelled period (1983-1995), the area receiving spates has decreased from that in the 1970's when there had been little groundwater development. In particular, groundwater sources had been developed immediately prior to, and during, the modelled period in the Ja'ashin catchment for irrigation and the city supply, and in the Hajib catchment for irrigation. In Wadi Hajib this has resulted in a notable decline in the number of spates reaching the Al Hayma valley. In Wadi Ja'ashin there was an almost immediate interruption of the perennial flow and only very major rainfall events result in spates reaching the Al Hayma valley today. As mentioned above, in an attempt to model this decline in the number of spates, only the runoff from the wettest month (August) has been used in the model for these two wadis.

Water levels have been monitored for the modelled period in wells clustered in the central Al Hayma basin and the Miqbaba basin (Figure 3.7). Because the limited areas of water level monitoring coincide with the two areas which have a basin geometry with a lip at the exit, a model comprising the two basins with a small interconnecting channel and a large input channel was developed (Figure 3.12). It was assumed that the basins were horizontal with a horizontal piezometric surface equivalent to that at the geometrical mid-point of the basin. It was also assumed that the level of the 'horizontalised' basin outlet lip is at the same level below the mid-point basin start water level as the actual outlet lip is below the starting water level at the outlet. A third assumption was that any excess water in channels (that is, which has not been used by the crops) drains to the basins. This last assumption is not valid because the water takes time to drain into the next basin and during this period is effectively in storage and available for pumping to the overlying crops during a period of deficit. However, because the time steps are quite long (annual wet season and dry season) any excess will tend to be drained from the channels. In any case, the amount of water which crops in the channel areas needed in the deficit periods has been calculated separately and is discussed below, where it is referred to as the 'channel deficit'. Changes in groundwater level are caused by volumetric inflows and ouflows, thus outflows from the basins and water levels in the basins are interdependent. By taking into account the changing surface area of the piezometric surface at each time step from the aquifer geometry, water levels and outflows could be calculated iteratively for each time step.

Transient Model A: 1987 x 5

Before attempting to match hydrographs from the full time series, the rainfall, runoff, agricultural and city abstraction data for 1987 (the year closest to the average rainfall) was run for five years consecutively. Model drawdowns were calculated using the 'static' level from the steady-state model. The target five-year drawdown was the average drawdown measured in the observation wells in the larger Al Hayma basin during the first five years of the operation of the city supply. There were three main reasons for choosing the five-year period. Firstly that the period would be long enough for the impact of development of the aquifer to be significant. Secondly it was desirable that the modelling should run from a point prior to abstraction for the city. Thirdly, monitoring in the intervening period was very scant and the five-year period offered the first reliable observed heads to calibrate against.

Although pumping tests may show a semi-confined or even confined response, the draining of the aquifer on a large scale comprises the actual replacement of water by air in the pore spaces and a specific yield value is more appropriate to represent storage. A rudimentary variation in specific yield covering the range indicated by the major soil type (14% to 10%) was used.

Table 3.13. A summary of the analyses and results of the Transient Water Balance modelling of the Al Hayma basin (1987 x 5):

Variables			Al Hayma
Runoff	Wind Run Data	Specific Yield	Drawdowns (m)
SCS with 10% max Q/P	50% Airport	0.1	4.2
SCS with 10% max Q/P	50% Airport	0.14	3.5
SCS-TS-HWC	Airport	0.1	3.1
SCS-TS-HWC	Airport	0.14	2.3
Target five year drawdown:			4.0

Transient Model B: 1983-1995

On the basis of the results of model A (1987 x 5) three scenarios were selected for attempting to match the complete 13-year record (Table 3.14). The abstraction record was not complete for this period, however. The first two years had to be generated by extrapolating back the yields of wells to their commissioning dates and the last five years of data by extrapolating forwards linearly on the basis of declining yields to the date of their eventual failure or their 1995 yields. Irrigated areas were determined for 1983-1987 from the 1986 satellite image and from 1991-1995 from the 1995 image. The intervening period was taken as a 50/50 mixture of the 1986 and 1995 irrigated areas.

Table 3.14. Three scenarios tested by the Transient Water Balance model (1983-1995):

Model	1a	1b	2
Runoff	10% max Q/P	10% max Q/P	SCS-TS-HWC
Wind Run Data	50% Airport	Airport	Airport
Specific Yield	0.1	0.14	0.1

The hydrographs for each method are compared with the target hydrographs for Al Hayma and Miqbaba in Figure 3.14. A mass balance error of approximately +/- 10% might be expected.

Model 2 gave the closest match to the observed data. The other two models 'dried up' in 1991. It should be noted that matching the Miqbaba water levels was particularly difficult. Because of its relatively small size and low storage, slight changes in the amount of water flowing from the input channel to the Miqbaba basin produce a large change in head.

The discussion up to this point has focused on understanding the natural water movement processes. In summary, the SCS method modified by the Technical Secretariat of the High Water Council for Yemen appears applicable in this instance. However, it is not possible to determine conclusively whether a 10% runoff/rainfall cut off should be used or not due to the error margins of the variables.

3.6 Who took the water?

Leggette et al. (1977;8-18) estimated a 'total quantity available for potential export' for the city of 9 Mm^3/yr +/- 20% and proposed an abstraction of 10 Mm^3/yr (and an effective end to irrigated farming) as a 'reasonable objective'. In their estimation, the As Sahlah basin accounted for 2Mm^3/yr of this supply. This leaves 8 Mm^3/yr for abstraction from the area included in this study (Habir to Miqbaba excluding As Sahlah).

From the steady state analysis it is possible to estimate the impact development of the Al Hayma basin has had since the relatively undeveloped situation of 1976.

If no outflow from Miqbaba were to occur, thus negatively impacting agriculture downstream of this point, the potential yield of the is obtained from the sum of the Miqbaba outflow and the evaporative loss from the marsh, viz.: 3.0 Mm^3/yr +/- 15%.

Assuming, like Leggette et al, the complete demise of irrigated agriculture, the potential yield is obtained from the sum of the evaporative loss from the marsh, the Miqbaba outflow and evapotranspiration from crops receiving irrigation in 1976. This yield would be 3.8 Mm^3/yr +/- 15%.

3.8 Mm^3/yr is only 50% of the 'reasonable objective' of Leggette et al.(1977). With hindsight it can reasonably be stated therefore that the failure of the Al Hayma supply scheme was guaranteed at its planning stage.

To assess the relative significance of different human water use activities and to determine the physical causes of the 1995 crisis (and earlier crises), abstractions from model 2 were examined (Figure 3.15). Although the design abstractions for the city supply were never achieved, the over-estimates of Leggette et al. resulted in groundwater mining from the outset. At the commencement of abstraction for the city in 1982-1983 irrigation activity alone in Al Hayma was already affecting outflows from the Miqbaba basin. Right from the outset of the city scheme competition for the dwindling resource between the city and the farmers made aquifer depletion inevitable. Effective complete depletion had occurred by 1991, if not by 1988.

In reality, farmers will not stop irrigating if technology, land and water are available and affordable, and farmers did increase the irrigated area in Al Hayma after 1976. However the abstraction for the city on its own would have exhausted the resource, except it would have taken a little longer if irrigated agriculture had stopped as the original scheme unrealistically envisaged.

[The channel deficit mentioned in Figure 3.15 refers to the excess amount of water which has been drained from the channel areas to the basin downstream, usually in the wet season. If this water had not drained to the basin by the following dry season it could have replaced any irrigation deficit in the channel areas in the dry season. It is considered that during the early 1980's the storage in the channel areas was sufficient to meet this deficit, but that as depletion progressed, the 'channel deficit' has approximated the actual deficit. The 'channel deficit' thus represents an unknown in the model that could be added to the agricultural consumption of water in the earlier years of the model to get a more accurate assessment of the agricultural consumption. In the later years of the model (when the deficit is larger) it contributes less, if at all, to the estimate of agricultural consumption. In any instance, the overall picture of 'who took the water?' is clear.]

3.6.1 Aquifer Recovery: the hydrogeology of potential resource reconstruction

The establishment of a calibrated mathematical model permits the tentative exploration of future trends. It has been used to predict how long it would take the aquifer to return to its 1976 steady-state condition if groundwater abstraction for the city remained at the (low) 1995 level and if irrigated agriculture ceased. Under these conditions the Miqbaba basin would recover after five years and the Al Hayma basin after ten years (both +/- 20%).

The history of the Al Hayma valley water resource has been examined as a case study which provides a necessary introduction and background to the issues of water management in the wider Ta'iz area. The reason for selecting Al Hayma is that the demise of this particular resource has had the single biggest impact on many of the wider water management issues and a better informed discussion of them in the following chapters is possible.

3.7 Water Resources Pollution

'those who destroy the earth'
Revelation 11:18

This section assesses the impact of water use practices in the Upper Wadi Rasyan catchment on water quality. One consequence of falling groundwater levels has been reduced base flows, which in turn has resulted in less dilution of pollutants, that is, higher concentrations in surface and groundwaters.

3.7.1 Methodology

A survey of surface water electrical conductivity (EC) was conducted as part of this study during November-December 1995, September and November 1996 and March 1997. Analyses of groundwater and surface water were also obtained from sampling undertaken as part of the NWRA well inventory (1996) and a study by van der Welle (1997) in autumn 1996. The NWRA well inventory analyses (1996) were undertaken in the NWSA laboratory in Ta'iz and the ionic balance was usually worse than +/- 20%. Only where their analyses were better than this, have they been used in compiling Figure 3.16 Although the level of error in the inventory analyses is unacceptable, for many locations it comprises all that is available and their data are consistent with those of van der Welle. Van der Welle also encountered problems of laboratory analytical reliability and only where the data from her study were considered reliable have they have been included in this discussion. The samples reported in this study were collected at various dates in the hydrological year. However, it should be noted that concentrations generally reach levels around 50% higher at the end of the dry season in February / March than in most of the rest of the year. Sampling was generally not conducted immediately after a rainfall event when concentrations would be appreciably lower than 'normal'.

3.7.2 Polluted Areas

Figure 3.16 indicates that apart from a few upper reaches of streams and Wadi Ad Dabaab the only water courses which flow for more than 6 months per year are heavily polluted. Using the irrigation salinity hazard criteria, Figure 3.16 divides the valleys into those whose groundwater or surface water exhibits a high hazard (750-2250 μS/cm EC) and those with a very high hazard (>2250 μS/cm). This division is even higher than the WHO limit for drinking water of 1500 μS/cm which has been adopted by NWSA. The EC of rainfall in the area has been measured at 20 μS/cm and spring and surface water flows in the mountainous areas are as low as 300 μS/cm. However, all samples from wells and streams in wadi alluvium are above 750 μS/cm. The area of >2250 μS/cm EC is confined to the east to west flowing central zone of the Upper Rasyan catchment.

Dar El Yemen (1997) also noted this central zone as having groundwater containing high concentrations of sulphate, sodium and chloride. Of the ions commonly analysed, sulphate is often indicative of urban pollution and nitrate of agricultural use of fertilisers, but can also be indicative of sewage pollution. High sulphate concentrations in groundwater can also occur naturally through the dissolution of minerals such as gypsum. Apart from three spurious analyses, all the analyses of NWRA (1996) and van der Welle (1996) containing sulphate in excess of the EU limit of 250mg/l were located in the central zone defined by EC >2250 μS/cm. The areas with groundwater of nitrate content greater than the EU maximum of 22.6 mg/l were located both in the central zone and outside it, particularly in the agricultural areas in the western edge of the study area (Wadi Dabaab, Ar Rubay'i and Shar'ab). The distribution of nitrates, sulphates and high EC strongly suggests the presence of urban pollution in the central zone and pollution by agriculture in the areas mentioned.

3.7.3 Pollution Sources

Tying down the specific sources of urban, particularly industrial, pollution is hampered by the occurrence of 'natural' pollution around the 'headwaters' of Wadi Mawsatah that is upstream of any industrial or other sources. This groundwater source flows towards Wadi Hawban and then Hawgala. In 1974, prior to significant industrial or urban development in the Wadi Hawban catchment the EC was already at 3750μS/cm (Montgomery, 1975) though this has been further affected by industrial and urban pollution so that in Wadi Hawban it exceeds 5000μS/cm today.

Domestic Waste Water

Contaminant levels have increased in the Wadi Hawban and Hawgala areas because they lie directly downstream of the city and receive industrial and urban waste that is either not intercepted by the sewerage system, or has leaked from it. Sanitation provision is estimated by NWSA at 48%, although when illegal connections and billing irregularities are taken into account this figure may be higher (Handley,1999a;9). Certainly sewerage provision has not kept pace with water connections (Figure 5.5) and the water shortages in the city further exacerbate the problem by providing less dilution for the sewage which results in greater corrosion of the sewage mains and hence greater leakage of sewage. The sewage which does find its way into the sewerage system and does not leak out ends up in the stabilisation lagoons in Burayhi from whence it flows down Wadi Malih. The net result is that the surface water and groundwater downstream of Hawban/Hawgala and Burayhi are polluted by the city effluent. Farmers use this water for irrigation but can only grow millet because of its high salinity resistance and even then they notice a rapid deterioration in yields and soil quality. In the absence of any other sources, the inhabitants of the downstream areas are forced to use this water not only for irrigation but also for domestic purposes (Photo 1) and even drinking in some instances, knowing full well its origin. Waste water flows from the main city sewers have been measured at 10,000m^3/day in the dry season.

Industrial Waste Water

Table 3.15 summarises the major industrial waste discharges in the Ta'iz area:

Factory	**Treatment**	**Discharge Location**	**Discharge Method**	**Waste Type**
Hawban Factories 1	Activated Sludge	Wadi Mawsatah	Partially submerged pipe	Food Production Waste
Hawban Factories 2	None	Adjacent to Factories	Lagoons and Cess Pits	Sewage and Plastics Waste
Soap and Ghee	New Treatment?	Hidran	Lagoons	Oils and Fats
Paint Factory	None	Adjacent to Factory?	Pit?	Paint Waste
Sheibani Food and Drinks	None	Bir Basha	Pipe	Sewage, Food and Drink Production Waste
Soft Drinks	None	Wadi Dumaynah	Wadi bed to Lagoons	Sodium Hydroxide
Proctor and Gamble	None	Adjacent to Factory?	Pit?	Not Known

Figure 3.16 groups together the industrial complexes of Hayel Said at Hawban (including Nadfood, Genpak and YCIC) and Sheibani (including Food Products and Paradise Juice).

Occasionally, factories, which normally pipe waste away, have been known to dump water in depressions near to the factory when pumping equipment has failed. Heavy metal content (mg/l) of groundwater samples near to three factory discharge points confirms the occurrence of industrial pollution:

Table 3.16 Heavy metal pollution (from van der Welle, 1997):

		Sample location / pollution source		
Parameter	WHO Guideline	Wadi Rubay'i / Paint Factory	Wadi Mawsatah / Hawban Factories	Wadi Hidran / Soap and Ghee
Aluminium	0.05	0.22 – 0.14	0.13	0.19
Lead	0.05	0.14 – 0.13	0.34	0.37
Cadmium	0.005	0.01	0.03	0.03
Manganese	0.05	4.7		
Nickel	0.05		0.08	0.07

The well from which the paint factory pollution was detected, and those immediately downstream of it, are used by approximately 1000 people for drinking water collection. Local inhabitants complain about the odours from the discharge point in Wadi Mawsatah. When they complained previously, the factory extended the discharge pipe to its current position. It would appear that the activated sludge treatment of this waste source is inadequately maintained or is insufficient for the demand load. Although some form of waste treatment has apparently been installed at the Soap and Ghee factory since these samples were collected, it is as yet unclear whether the treatment has reduced the level of pollution significantly. Discharge from the Soap and Ghee factory has been to lagoons perched above a small wadi immediately to the north of Ta'iz city dump (Photo 6). Seepage and evaporation approximately keep pace with supply. There is a seepage face at the base of one of the lagoon dams. Concentrated liquid waste from the city is also tankered to the dump. The environmental damage caused by years of subsurface seepage cannot be undone by whatever waste water treatment is undertaken now. The build up of heavy metals and other toxins in the food chain in the agricultural areas of the Rasyan catchment downstream of the city and the factories has not been investigated.

3.8 Summary: Environmental Impact on the Upper Wadi Rasyan Catchment

Groundwater Levels

The environmental impact of abstraction levels in the Upper Rasyan catchment have been felt most in Al Hayma as described in sections 3.2-3.6. The development of the wellfields in Al Hayma have been felt as far downstream as the sewage lagoons at Burayhi with declining wadi flows and groundwater levels and the resulting drying up wetlands or xazaga. This latter effect has been perceived as a positive one by locals who have been able to increase the area of land available for agriculture. The reduction in wetland has also been accompanied by a local decline in malaria and bilharzia. Groundwater development also affects upstream areas in that agricultural development, in search of dwindling sources of water moves upstream, as the satellite imagery demonstrated in Al Hayma (Figure 3.10).

Water levels have also notably declined in the Hawban area of the Hayel Said factories, lower Wadi Dabaab adjacent to the Soap and Ghee factory and in the area of Ta'iz city itself.

Pollution Levels

Nearly all of the streams in the Upper Wadi Rasyan catchment which flow for at least six months of the year are polluted by, or entirely comprise, domestic and industrial waste water.

Groundwater pollution extends even further (Figure 3.16). Domestic waste water accounts for most of the total pollutant load by virtue of the large volume of untreated waste, a significant proportion of unsewered properties and leaking sewers. Some industrial waste water is known to contain heavy metals but levels are not monitored.

3.8.1 Conclusions

Falkenmark and Lundqvist's (1995) correlation of the regions with the most rapid population growth and stagnating food production, coinciding with extreme vulnerability due to hydroclimatic constraints, aptly describes Ta'iz. That vulnerability is expressed in declining water availability and quality.

Water Quantity

The Al Hayma aquifer took approximately four years to deplete and will take nine years to recover if no more irrigation takes place and the city abstracts current minimal quantities. Section 4.1 attempts to put a value on the loss of agricultural production and livelihoods if resource degradation were to be reversed (section 4.1).

Water Quality

The full cost both now and to future generations of the pollution in the Ta'iz area is, perhaps, impossible to estimate (Allan and Karshenas,1996;125). The loss of soil fertility, the increase in toxin levels and especially heavy metals in the food chain and the legacy of polluted groundwater and surface waters of the area are severe. The impacts of pollution on surface and groundwaters was immediate, and the prolongation of polluting activity over the past twenty-five years has ensured a significant build-up of pollutants in the unsaturated and saturated zones. Although some of these environmental impacts may be reversible, many of them are not (Karshenas,1992;2, Feitelson and Haddad,1998, Pearce,1993;50). Others would take a long time to rectify and need a lot of fresh water to dilute the impacts to acceptable levels. That water is simply not available.

As with many Yemeni urban areas, an environmental 'time-bomb' has been set off which will leave its mark on generations to come. Even the 'reversible impacts' may, in reality, be irreversible due to the deficit of economic capacity and political will. The socio-economic and socio-political aspects that have contributed to this environmental disaster and which might contribute to any resource renewal are considered in chapters four and five respectively.

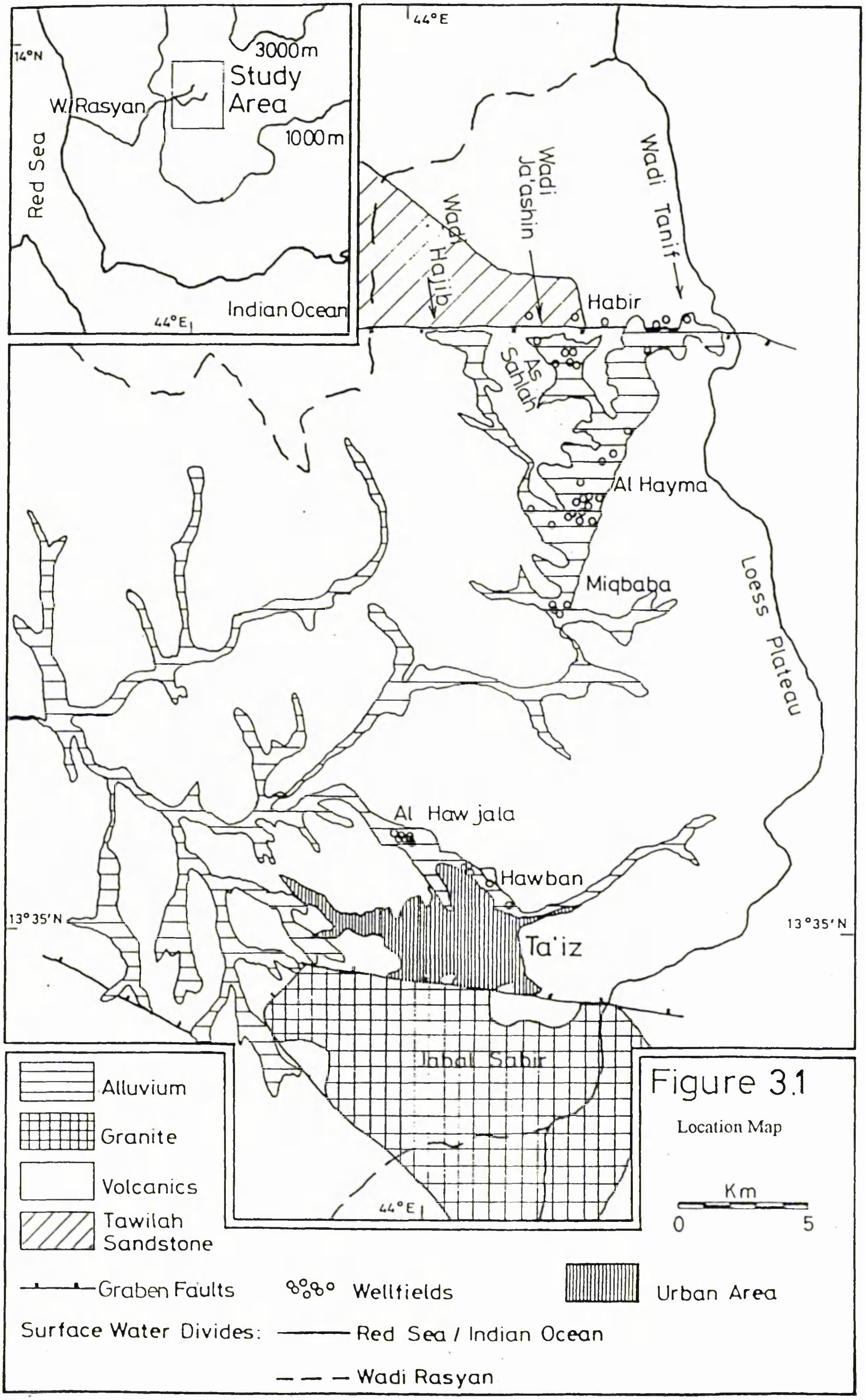


Figure 3.1

Location Map

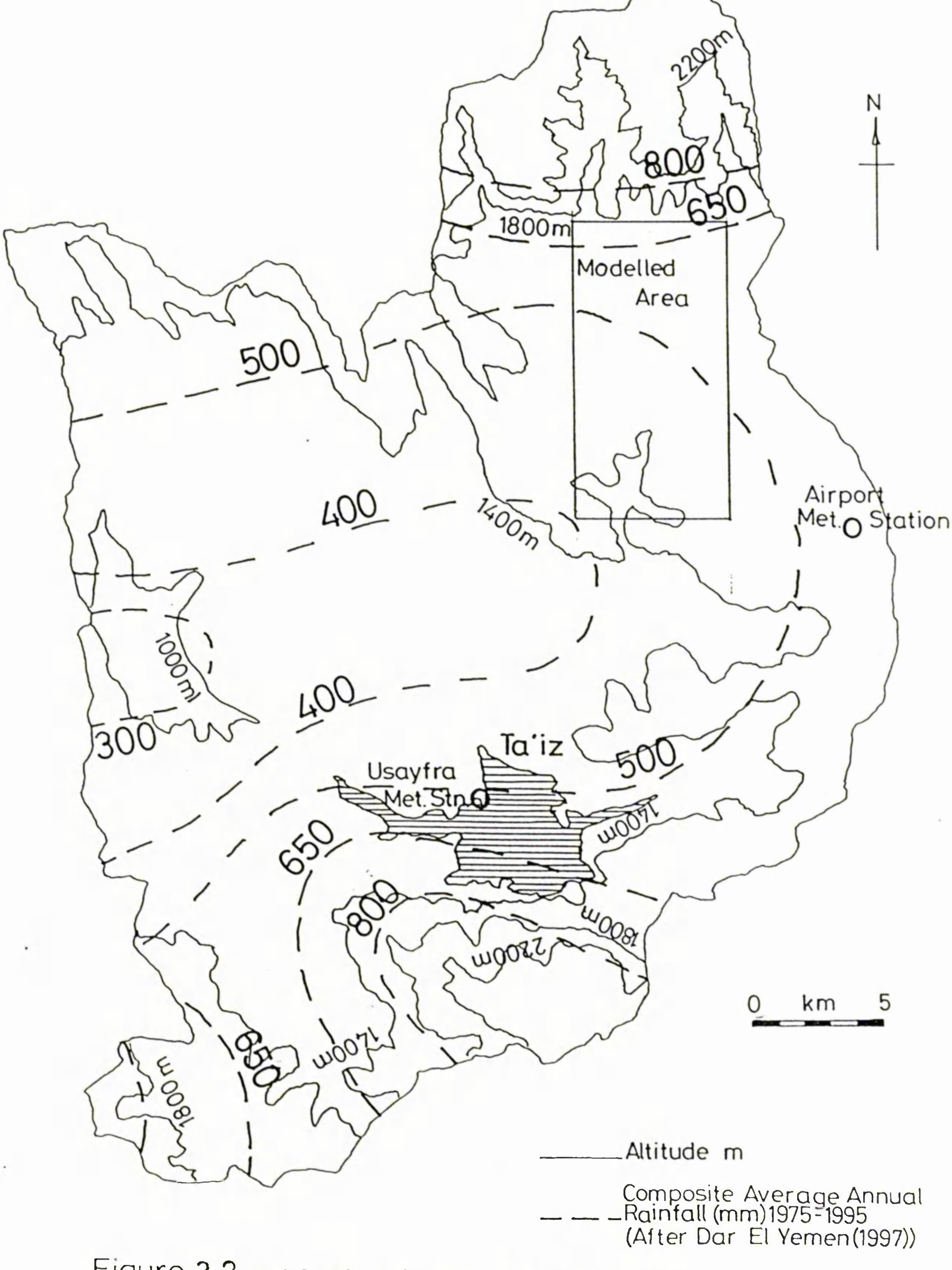


Figure 3.2 Rainfall Distribution - Upper Wadi Rasyan Catchment

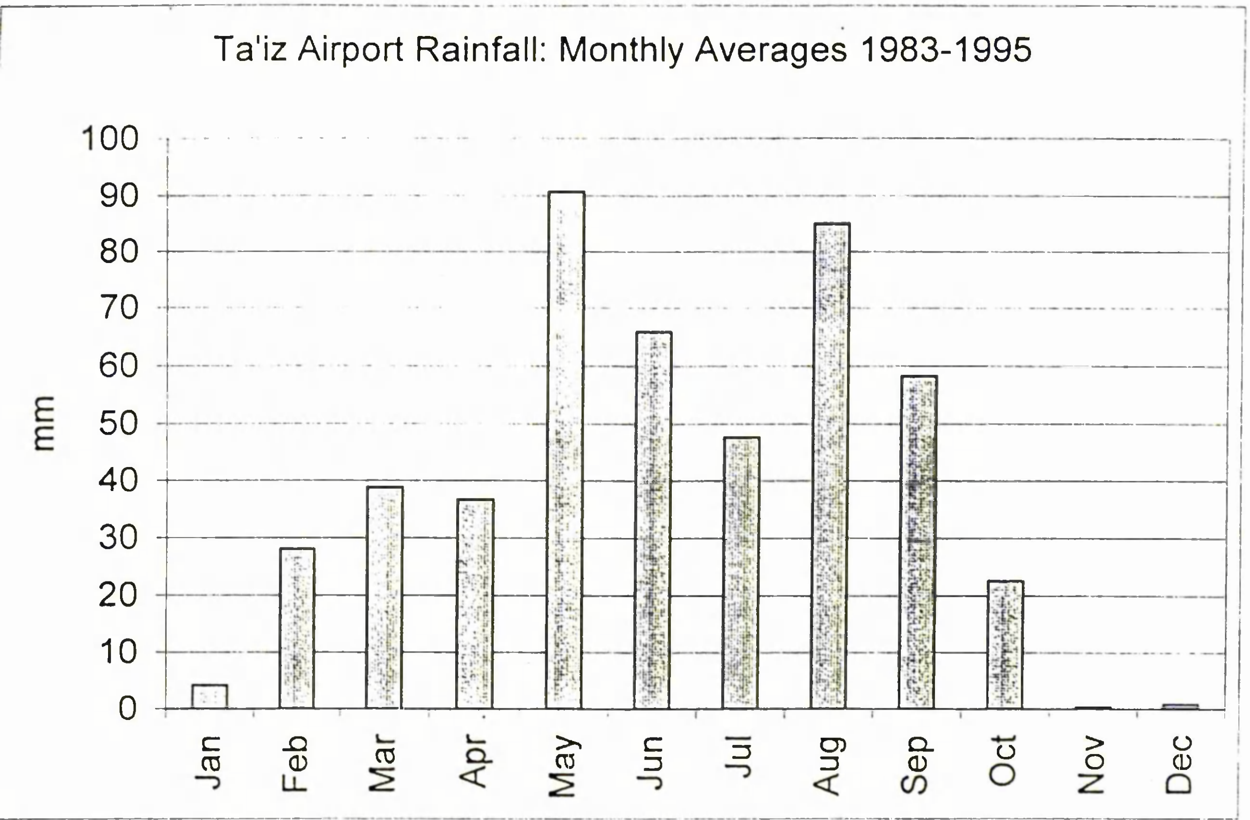


Figure 3.3 Average Monthly Rainfall (Ta'iz Airport)

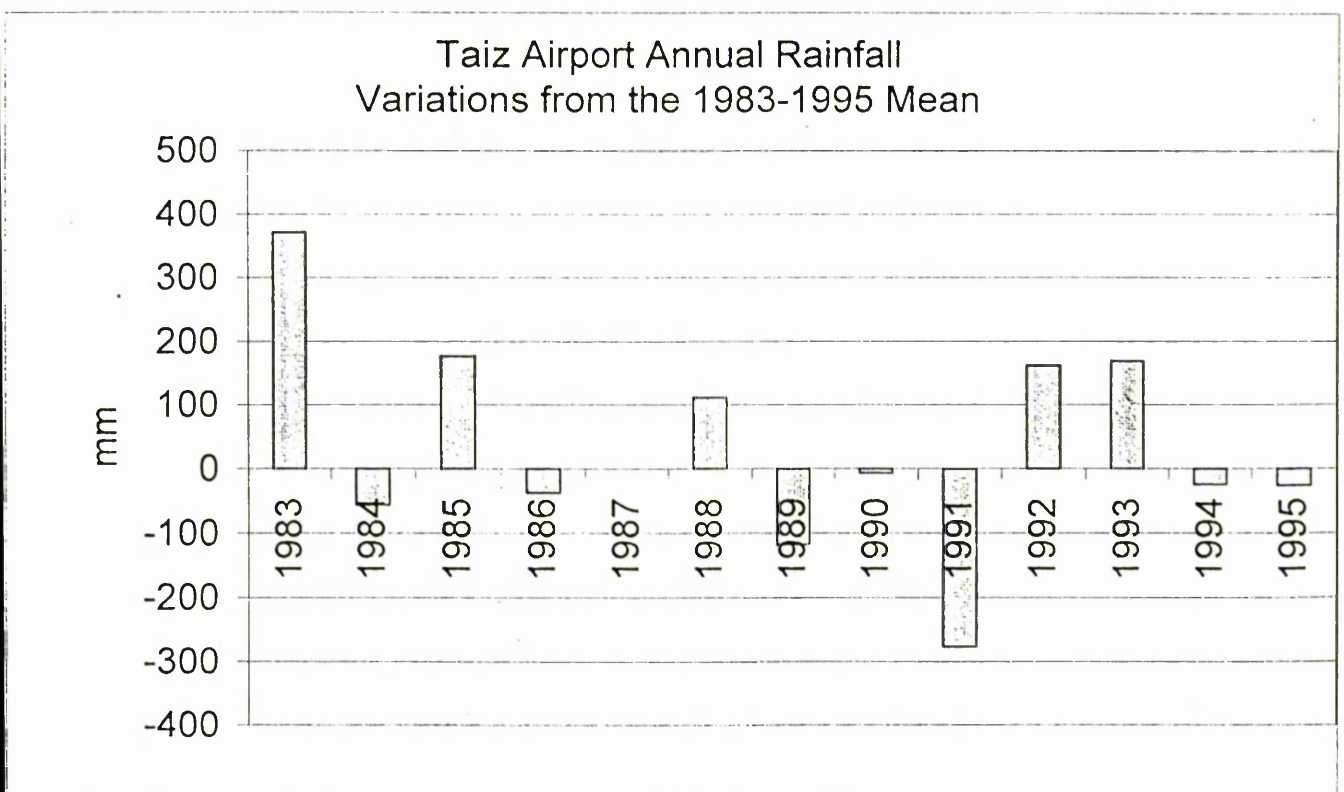


Figure 3.4 Annual Rainfall (Ta'iz Airport)

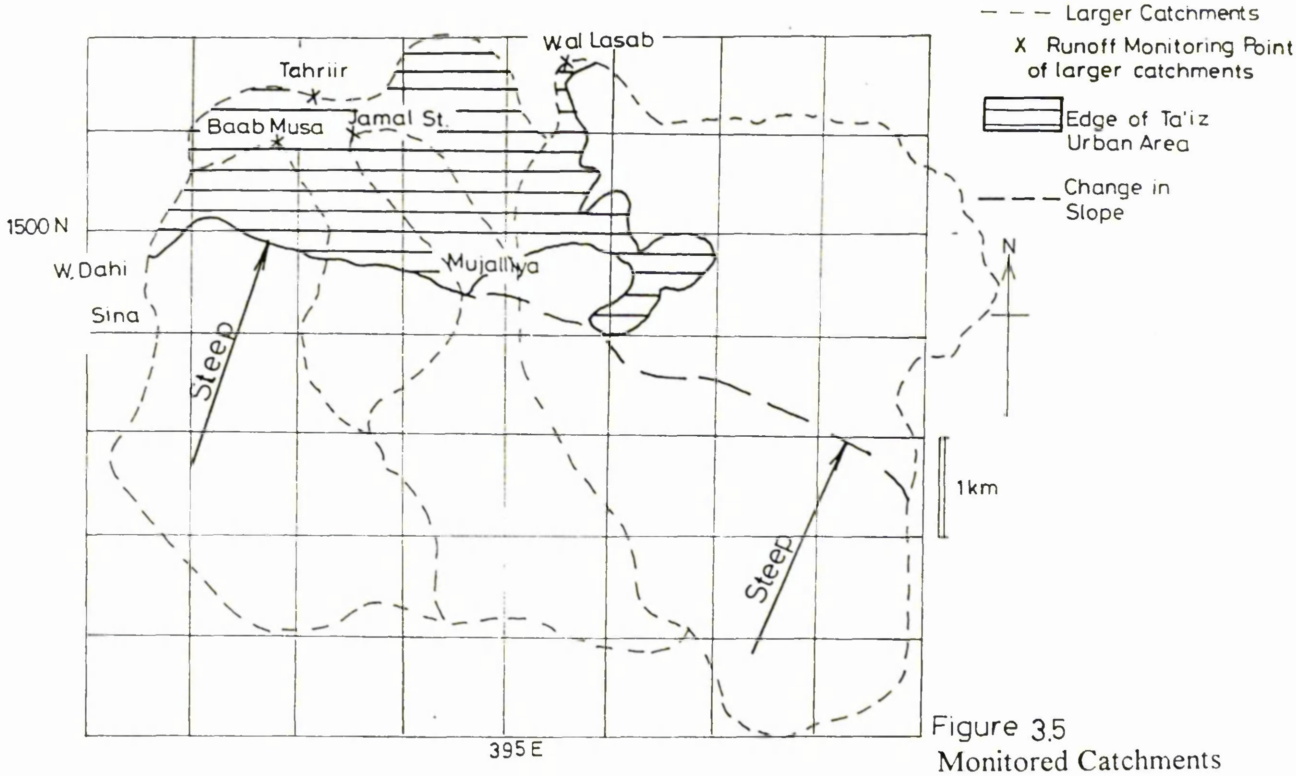


Figure 3.5
Monitored Catchments

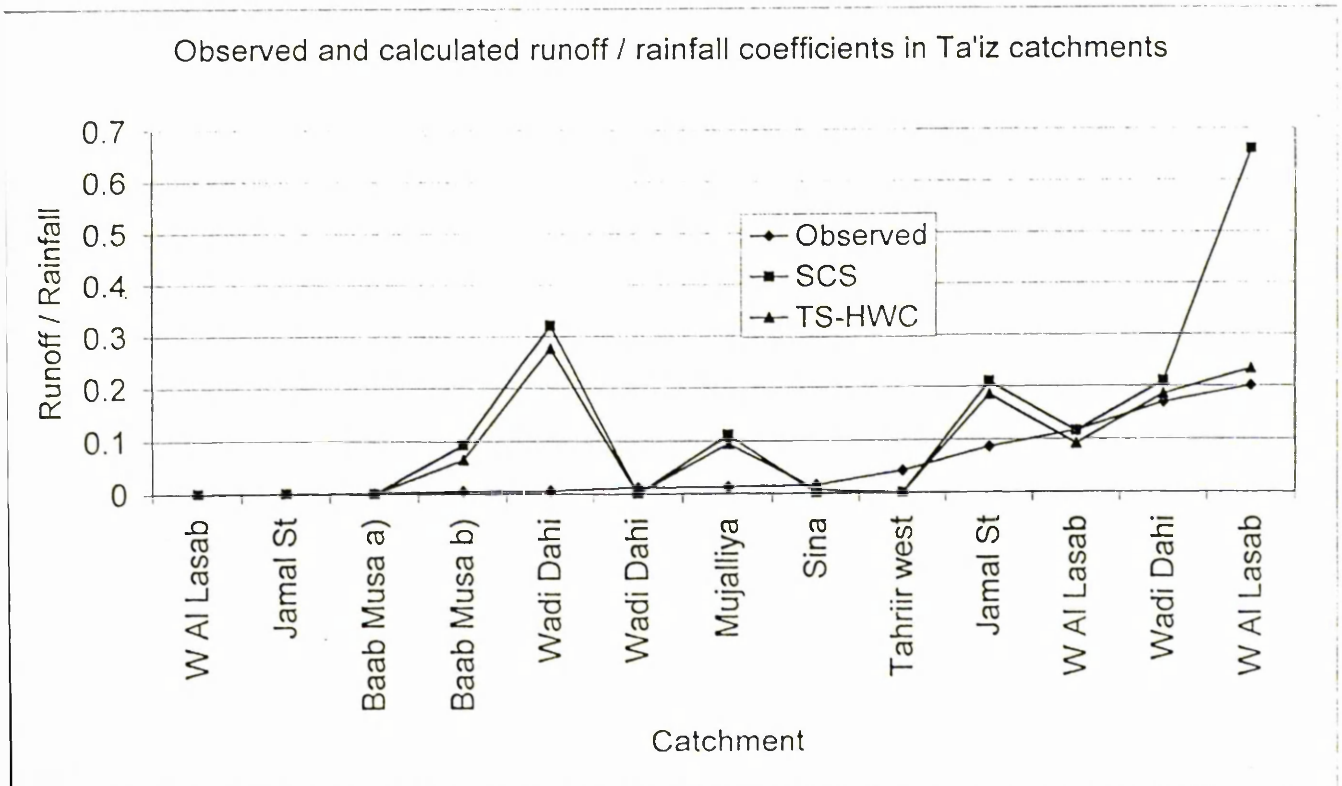


Figure 3.6 Runoff/Rainfall Coefficient Calibration

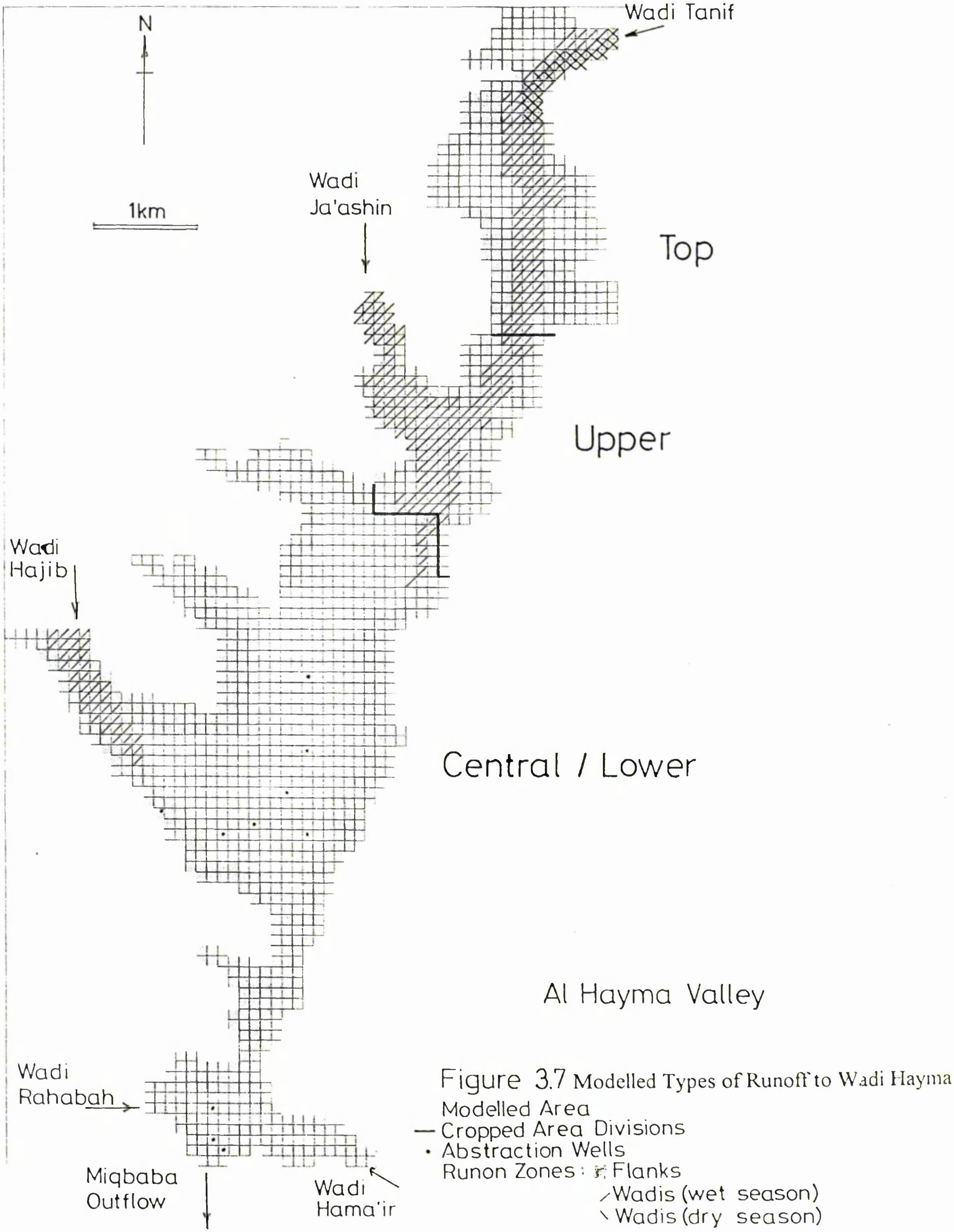


Figure 3.7 Modelled Types of Runoff to Wadi Hayma

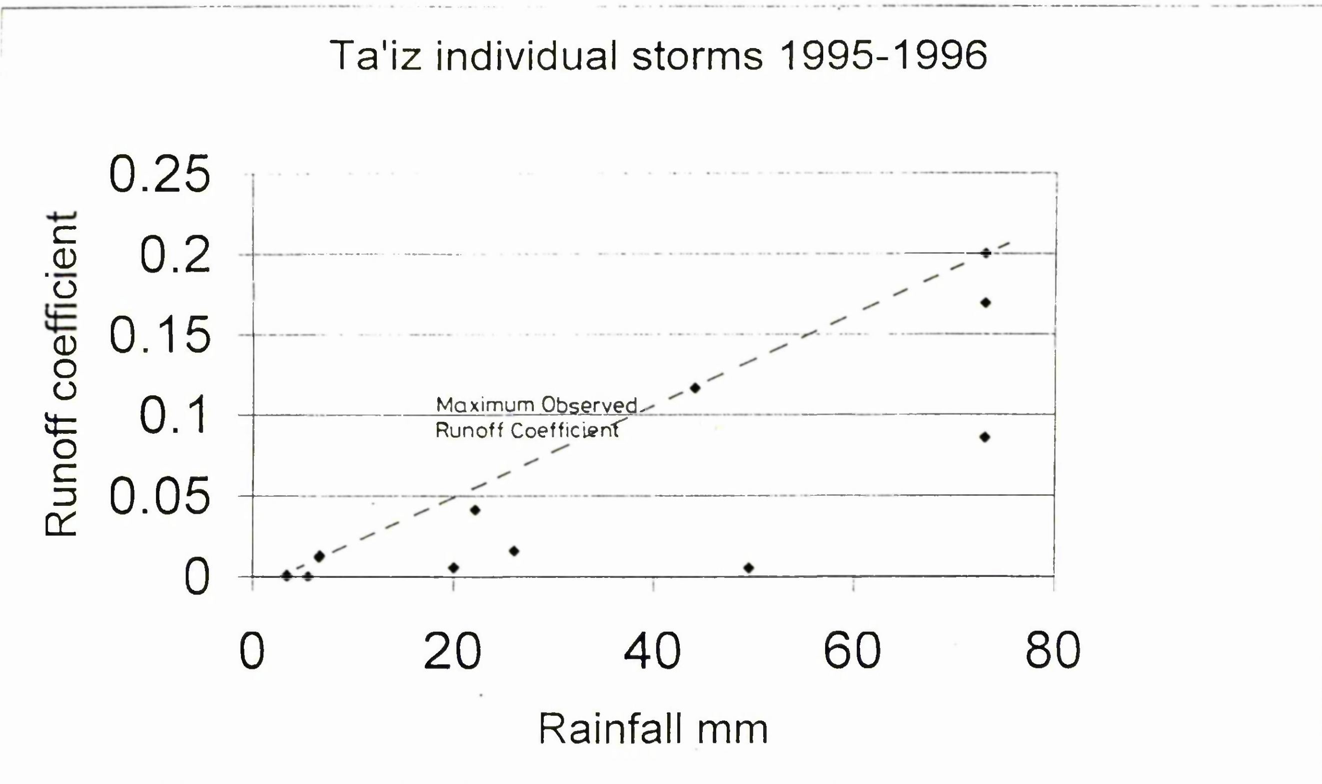


Figure 3.8 Runoff Threshold from Individual Ta'iz Storms

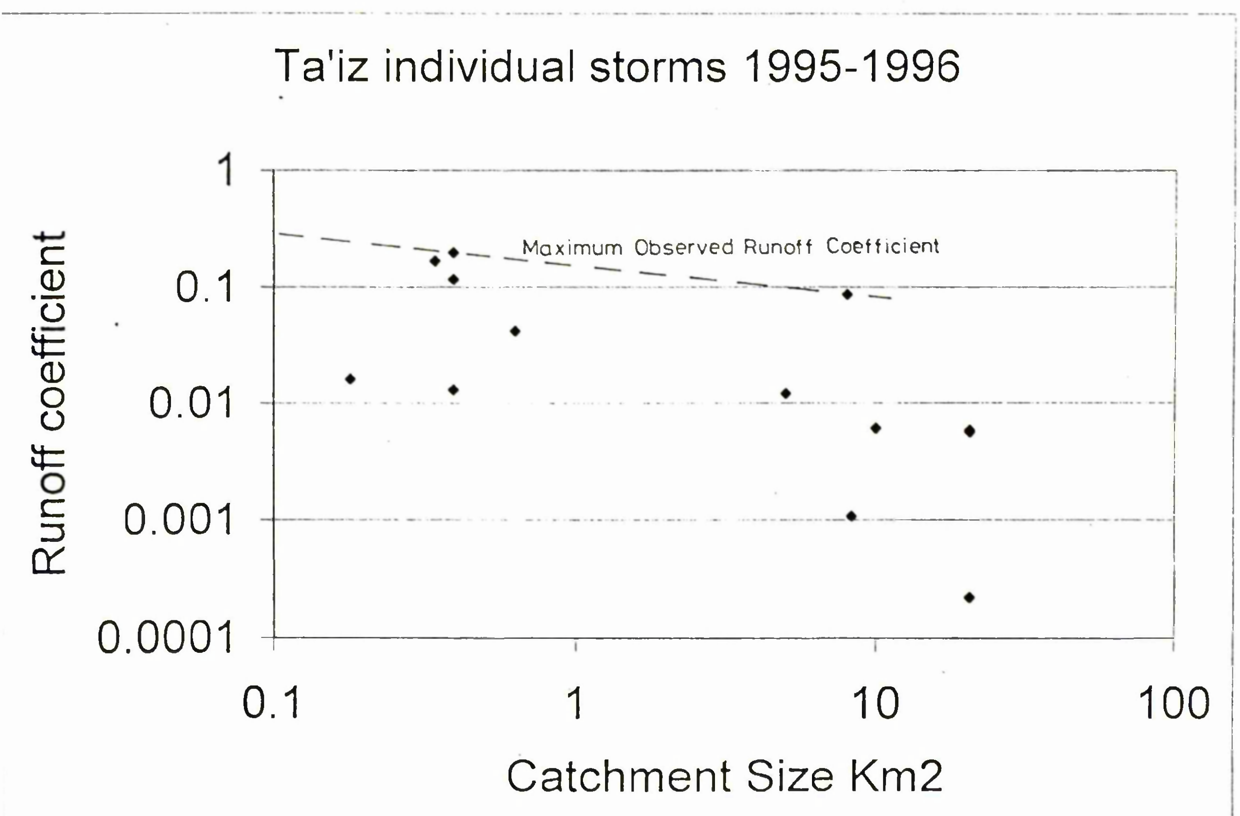
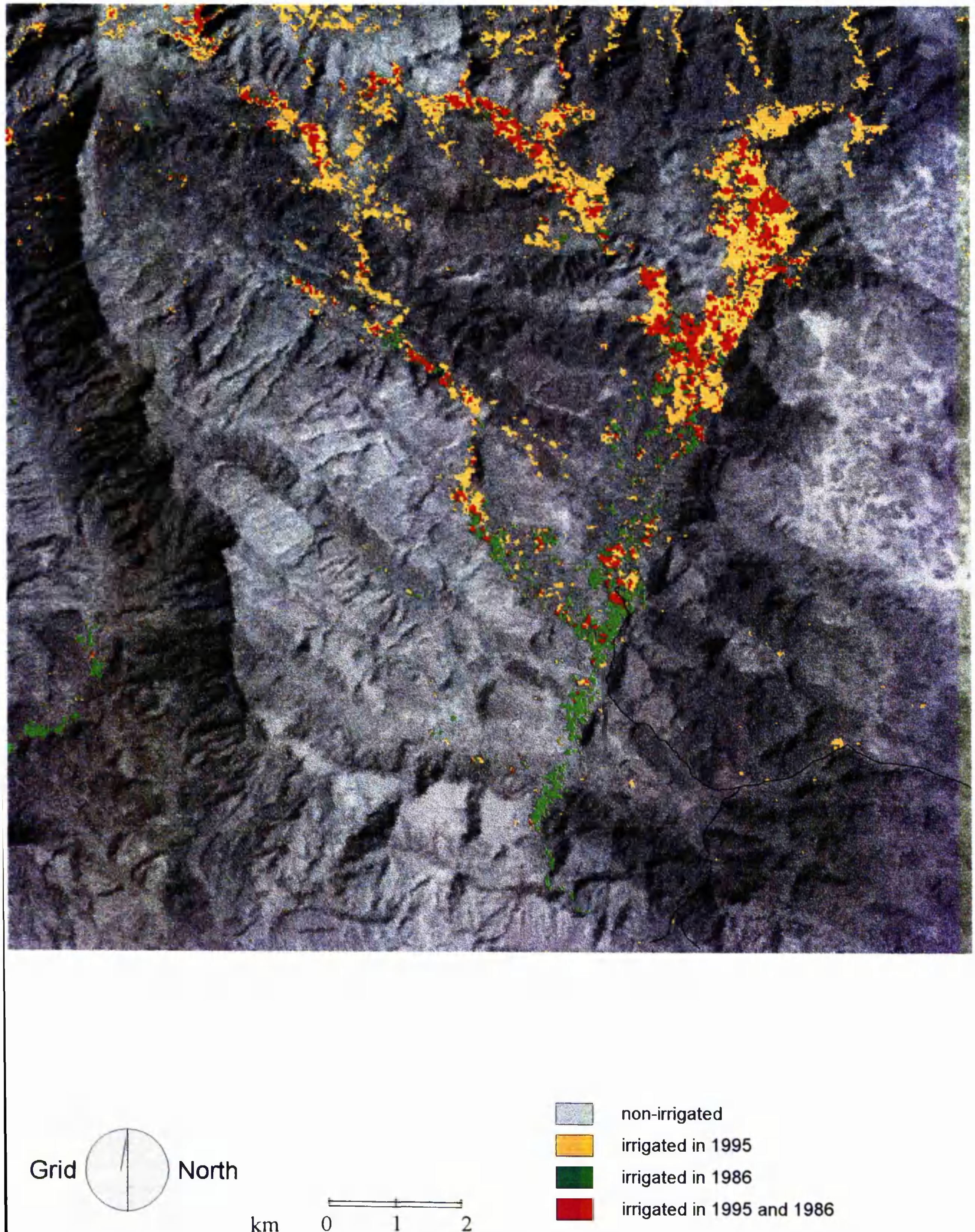
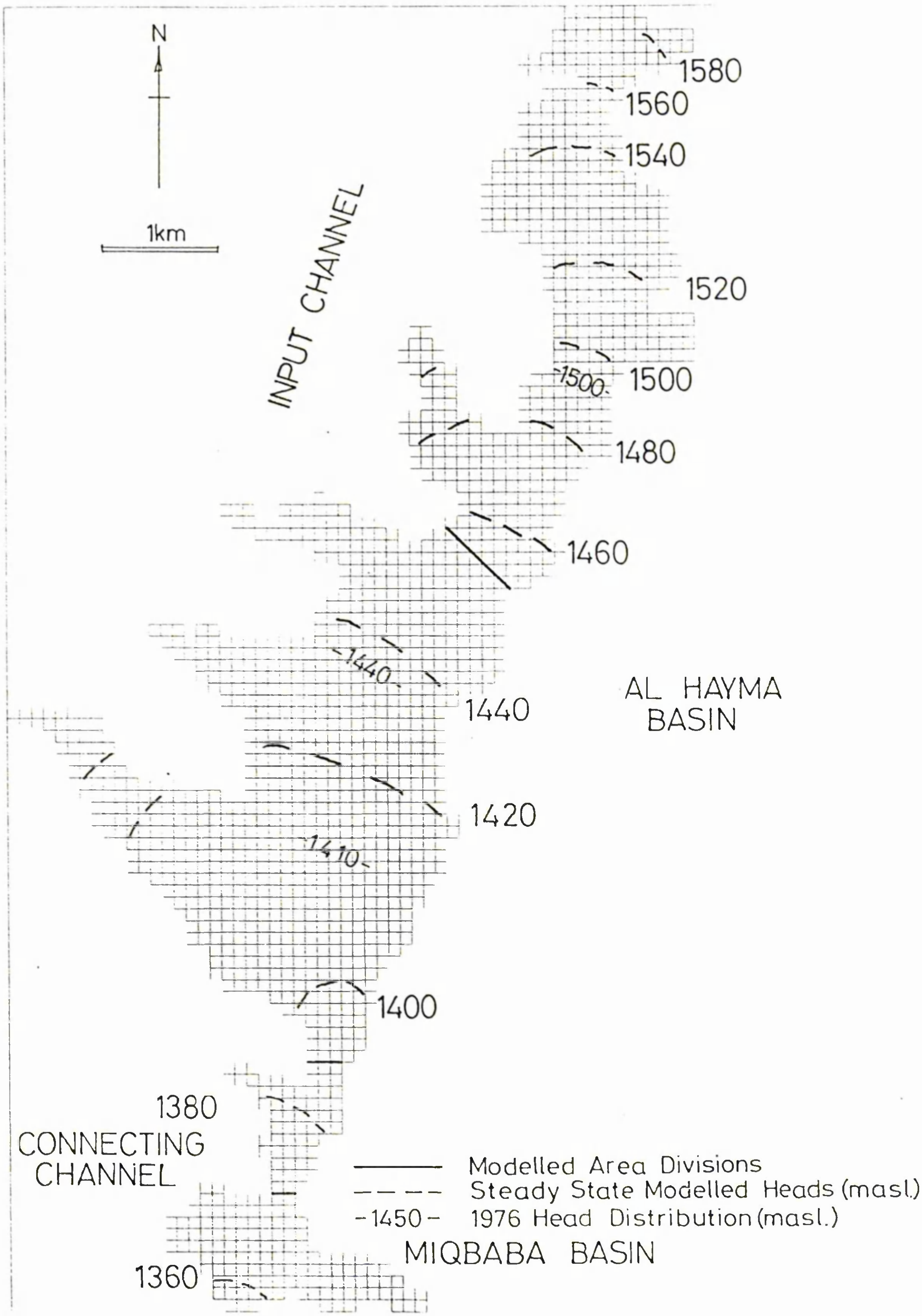


Figure 3.9 Runoff Coefficient / Catchment Size Relationship from Individual Ta'iz Storms

Figure 3.10: Changes in irrigated area in Al Hayma - Habir 1986-1995





3.11 Modelled and measured 1976 groundwater head distribution in Wadi Hayma

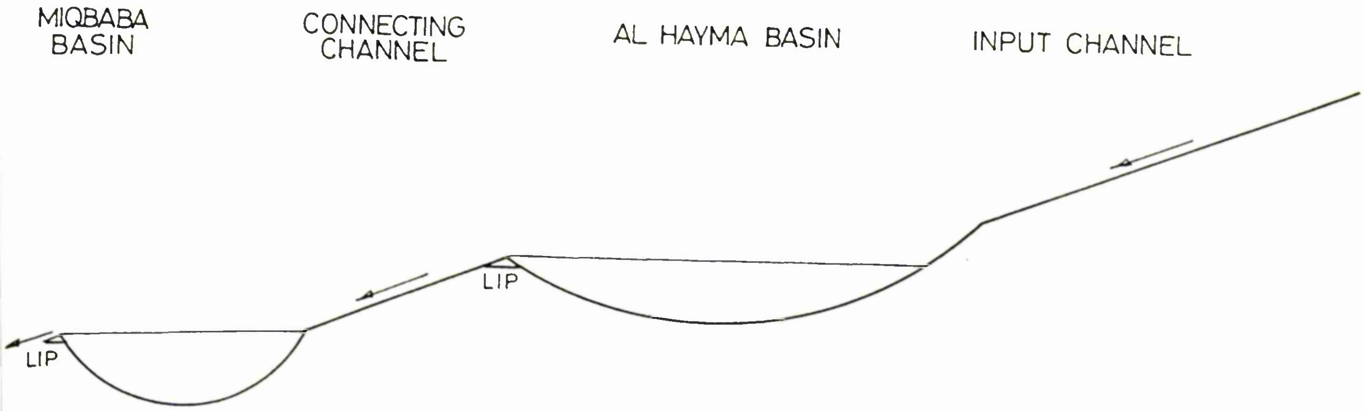


FIGURE 3.12 Transient Model – Channel / Basin Configuration

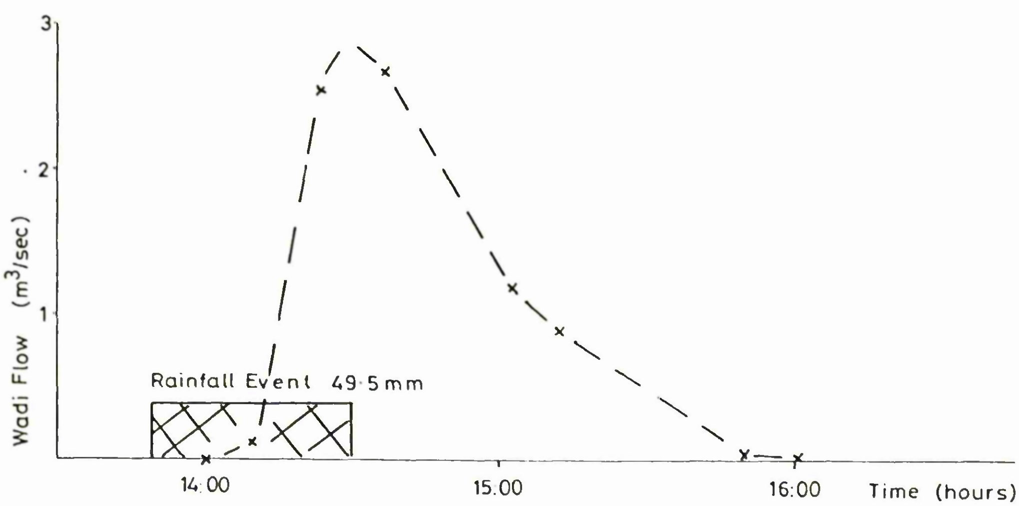


Fig. 3.13 Wadi Al Lasab Hydrograph 4/9/96

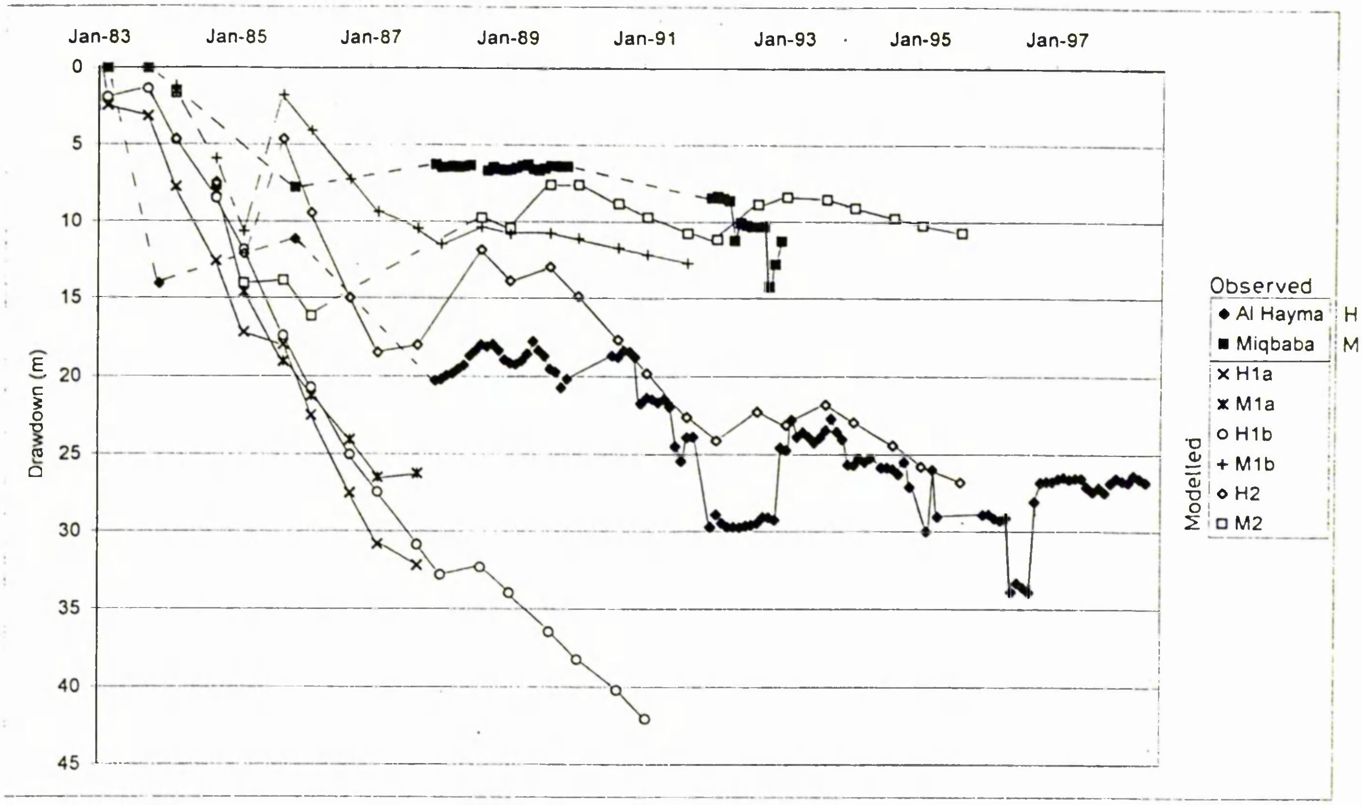
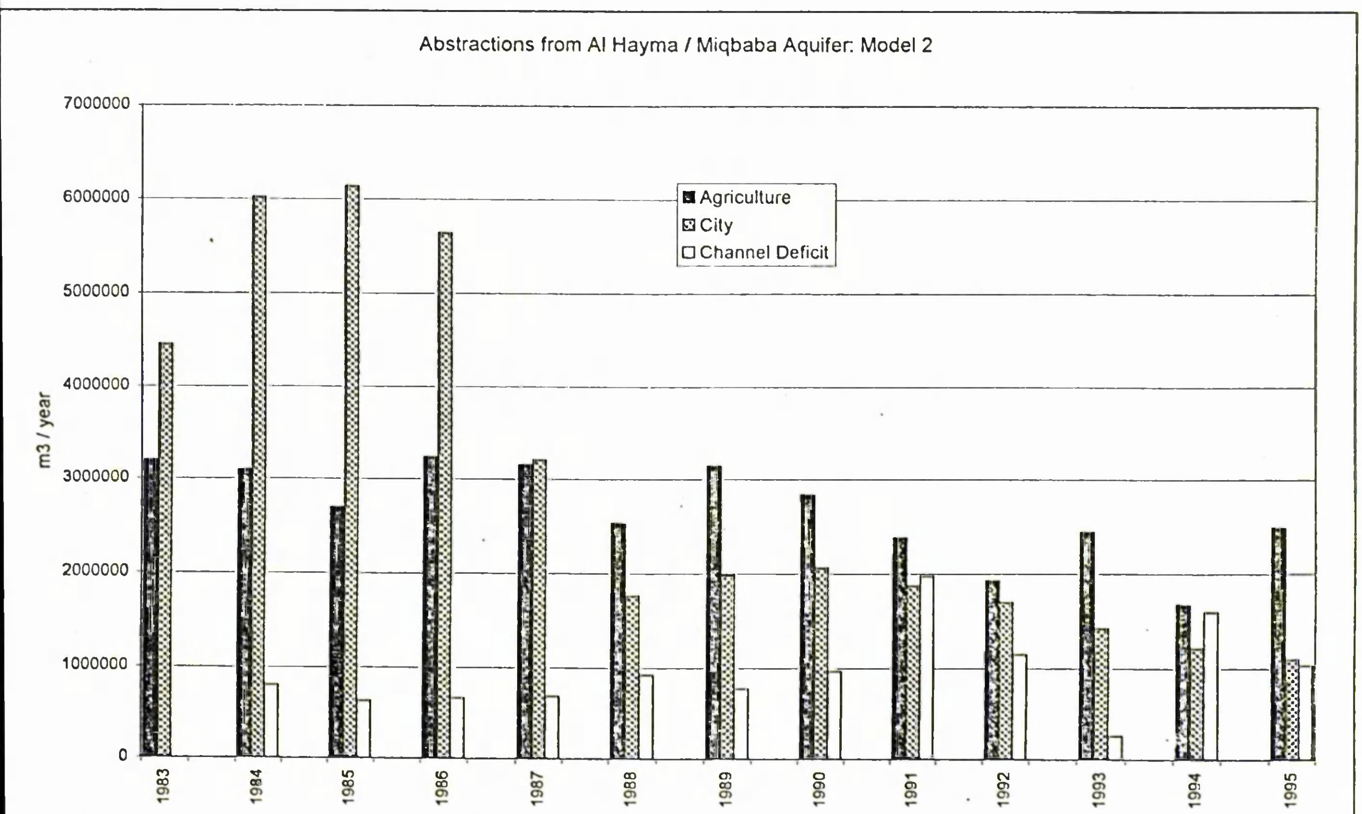
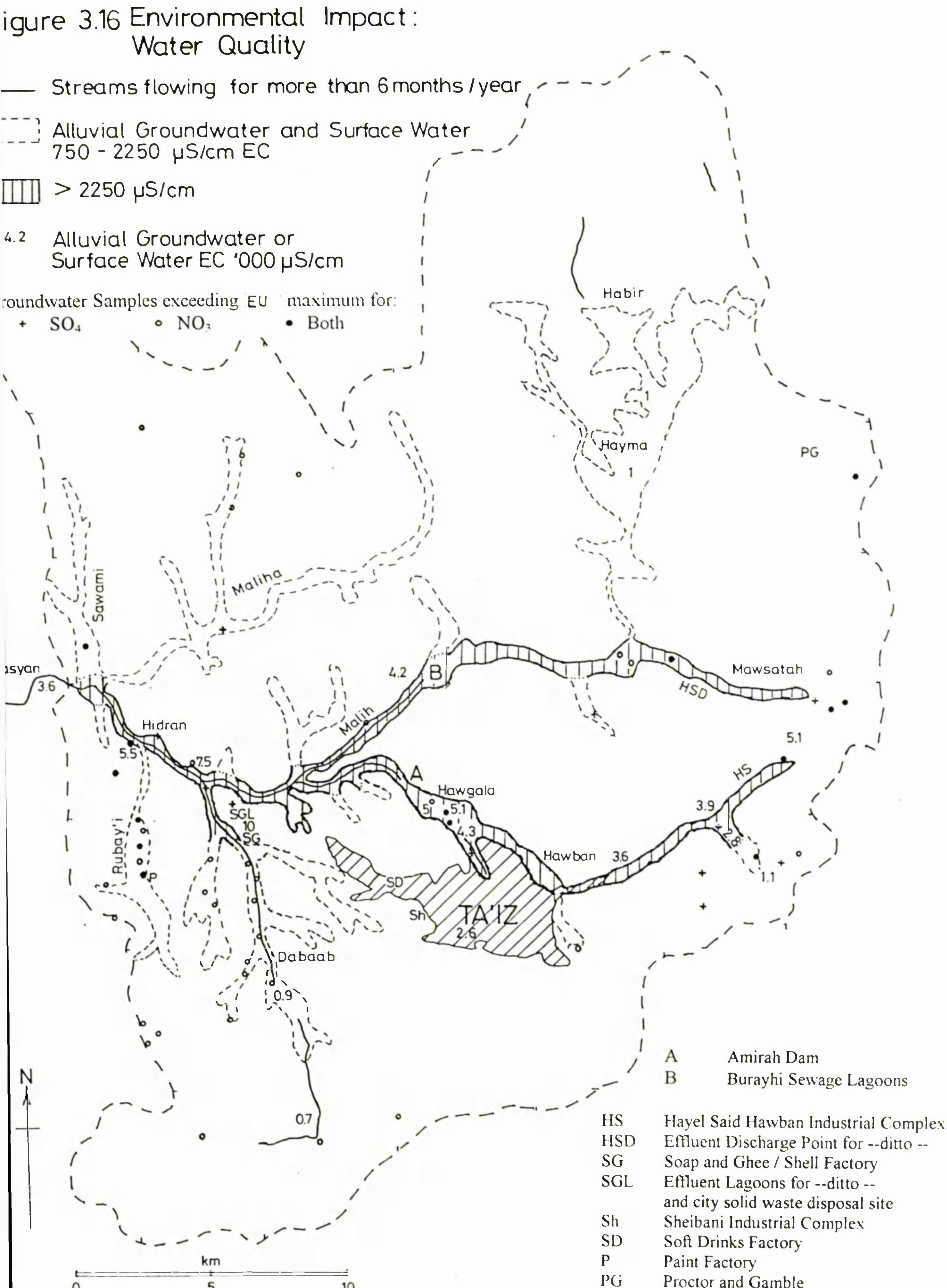


Figure 3.14 Transient Model Calibrated Hydrographs



ig. 3.15 Modelled Abstractions from Al Hayma / Miqbaba



3.16 Upper Wadi Rasyan Environmental Impact: Surface and Groundwater Quality

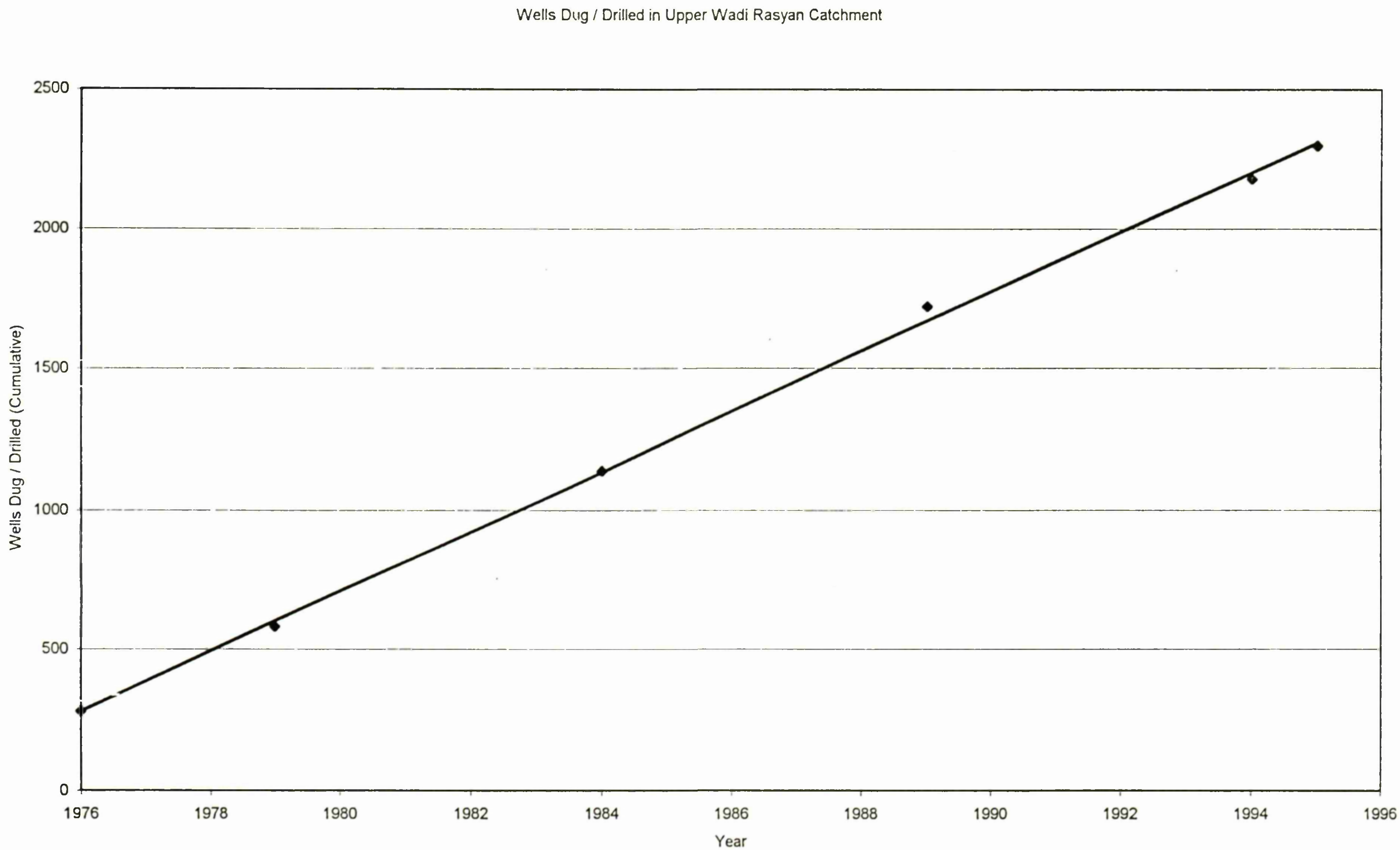


Figure 3.17 Growth in the number of wells drilled and dug 1976-1996 (After NWRA, 1996)

Chapter 4 A Socio-Economic Map of Water Allocation and Use

The depletion of the water resources of Al Hayma analysed in the previous chapter exhibits in microcosm the national picture. The annual renewable water resources of Yemen have been estimated at 2.1Bm^3, or 125m^3/capita/year. This is equivalent to about 10% of the regional MENA average and compares with a world average of 7500m^3/capita/year (World Bank, 1997; Davies and Sahooly, 1996). The reason is not so much climatic (the area has a higher proportion of rainfall than the regional average) as demographic. By the year 2025 it is estimated that population growth will result in renewable water resources per capita of 72 m^3/capita/yr (ibid.). As a reminder, this compares with individual human water needs of around 1m^3/yr for drinking, 100m^3/yr for domestic purposes and 1000m^3/yr to feed her.

In the context of such shortage, it is suggested that the survival of Yemen during the next century depends, not so much on how much water is available, but on how well the scarce water resources are used. This purpose of this chapter is to:

a) evaluate the relative returns to water of agriculture and industry in economic and livelihood terms,

b) describe the socio-economic impacts of the water scarcity and pollution problems described in the previous chapter particularly in the urban area

c) demonstrate the adaptive capacity of households and water-related businesses to the scarcity in the context of equity.

The chapter is ordered in this sequence. The area under discussion in this chapter is Upper Wadi Rasyan (Fig. 3.2) which comprises 930 km2 and had a population of nearly 700,000 at the 1994 census.

4.1 Agricultural Sector Water Use

'She said... "Since you have given me the land of the Negev,
give me also springs of water."
So he gave her the upper springs and the lower springs'
Joshua 15:19

4.1.1 National and Governorate Context

The most impressive feature of the Yemeni landscape is the terracing. In North Yemen this agricultural system dates back to at least 1000BC when, it is thought, 300,000 people derived livelihoods from 20,000 hectares of terraced land. Yemen is one of the few places on earth where rainwater harvesting and runoff agriculture has been practised continuously since earliest settlement (Prinz, 1994).

The shift from rainfed and runoff-fed agriculture to irrigation, particularly groundwater based irrigation indicated in Table 4.1 is very recent, and was part financed by remittances earned by up to one million Yemenis working in Saudi Arabia and the Gulf from the mid-seventies up to the Gulf War in 1990. With so many people absent from their home villages, the same period witnessed a sharp decline in the proportion of labour available for agriculture. Some authors suggest this was the cause of degradation in the traditional rainwater harvesting infrastructure (Varisco,1991).

Today agriculture occupies about 5% of the land in Yemen, though there has been some reduction in cultivated area since 1970, the loss being from rainfed arable land (Bamatraf, 1987;595). Table 4.1 indicates the decreasing agricultural proportion of GDP and the decreasing proportion of the labour force and of the population involved in agriculture. Because of the underlying population growth, however, the rural population dependent on agriculture have doubled from 5.8 million in 1970 to 11.5 million in 1990 (World Bank 1993). Despite the increasing availability of labour to work decreasing areas of land, and despite increasing mechanisation and use of fertilisers and pesticides, yields have declined or at best remained static. Growth areas in agriculture have been confined to fruit, vegetables and qat production. These comprise the main crops that use groundwater and the increase in their production has been the major factor contributing to unsustainable groundwater consumption. The huge growth in the irrigated areas (250% growth between 1970 and 1996) has been outstripped by the population growth so that the irrigated area per Yemeni is now about 17.5m by 17.5m. The Ta'iz governorate accounts for about 10% of the total cultivated land in Yemen but 16% of the population.

4.1.2 Methodology of the socio-economic surveys of rural water use, 1995 & 1996

Surveys were designed to obtain the data that would provide an understanding of water use in descriptive terms and also permit an evaluation of returns to water. Mainly due to limitations in transport availability, it was necessary to employ an essentially 'rapid rural appraisal' (RRA) method in examining water use in agriculture (Chambers,1992, Cromwell,1990;23, Pretty et al, 1989;54-62, Chambers and Carruthers,1986). This was supplemented by participatory PRA methods (ibid.), mapping of wadi areas and the use of satellite imagery described in chapter 3. The field work was conducted within the context of,

Table 4.1 Yemen National Agricultural Statistics

	Units	1970	1975	1980	1985	1990	1996
YR:$US	YR				6	8	100
% of Labour in Agriculture	%	71	66	62	59	58	58
% of Population in Agriculture	%	78	71	67	65	63	
Agricultural share of GDP	%	45			20	17.8	15
Cultivated Land Area							
Cultivated Area	M ha	1.3				0.9*	1.1
Irrigated Area	M ha	0.21					0.49
% irrigated area	%	16		17			45
Cereal	000 ha	1080		850	860	850	700
Fruit and Vegetables	000 ha	39		75	69	92	136
Qat	000 ha	8		70	75	80	91
Production							
Cereal	000 T	845				491*	731
Fruit and Vegetables	000 T	20	73	595	835	1007	1094
Qat	Million Bundles	35.2	154	352	387	501	592
Yields							
Maize	Kg/ha	2250	2140	1510	1149	1274	1240
Sorghum/Millet	Kg/ha	795	800	888	416	764	800
Potatoes	Kg/ha			12364		11830	12840
Tomatoes	Kg/ha					15528	15210

*1991

Sources: Bamatraf (1987), World Bank (1993), Statistical Yearbook (1996), World Bank (1998).

and with the financial and logistics support of, two UNDP surveys, in November/ December 1995 and September/ December 1996. More detailed accounts of the surveys and their findings are reported in Handley (1996a) and Dar El-Yemen (1997) respectively.

The 1995 Survey

Aspects of the survey discussed within this section include:

a) The overall physical, demographic*, and occupational*, aspects of five villages.
b) Land ownership and tenure*.
c) Water availability and use from surface and groundwater sources.

*Although the methodology was determined and the survey carried out by the author, the development of the methodology for the RRA part of the survey included valuable sociological inputs regarding these aspects from Cecile de Rouville, the international consultant attached to the UNDP project, and are gratefully acknowledged. The survey obtained other information than that directly relevant to agriculture, some of which is used in other sections.

The five villages were selected to give a representative agro-ecological coverage of the governorate excluding the Tihamah. Their locations and names, together with those of other nearby villages included in the survey are shown in Figure 4.1. They all comprised less than 500 people. Criteria determining the agro-ecology were selected as rainfall, soil type and irrigation method. Within that context areas which had supplied Ta'iz with water, or which are being considered for future supply to the city, were included. The villages chosen varied in rainfall between around 300 and 700mm/yr. Although the USAID satellite imagery-based soil map (1983) indicated a variety of soils, in the field the soils of the cultivated parts were quite similar, comprising immature, deep light loamy loess soils with horizons of pebbles and cobbles and occasional clay layers. Adjacent uncultivated runoff areas were rocky with little to no soil and wadi bottom areas comprised fluvially deposited sands and gravels.

Because of the distance from Ta'iz, it was necessary to stay in each of two of the villages for a week (Al ^adan and Al Khums). This permitted:

a) a greater awareness and appreciation of the village activities throughout the daily cycle, which could not be achieved by day visits (such as the pressure for well access at sunrise and sunset) and a greater degree of observer participation.

b) greater access to the villagers – many people made visits during the evenings and often talked about issues that were of more concern to them than those they had been able to talk about during the day in a group context.

The other three villages were visited on a daily basis.

Undertaking the survey during the dry winter season meant that although there was less agricultural activity than in the summer, the areas of irrigated land and rainfed land were easy to distinguish which helped observation and comprehension of the water management activities which is the main emphasis of the study.

Six main activities were conducted during the survey:

a) observation of the physical, especially hydraulic, setting of the village by walking around it
b) discussion with farmers (usually found in the market place up to 12:30, or in the fields) regarding basic aspects of village structure, place names, important people and main crop types. Village problems and water-related issues were then discussed. A venue for afternoon discussions over qat was arranged.
c) At the qat chews a checklist of questions was used covering all the aspects of the survey.
d) On the second day, at the qat chew the villagers were asked to prepare a map of the village.
e) Short impromptu excursions were arranged by the villagers to places they considered hydraulically important.
f) In the evenings individual villagers came to ask questions and clarify or correct comments they or others had made during the day.

The following points were noted regarding the methodology:

a) Although interview sampling would have been much more straight forward if the desired interviewees (farmers) could have been isolated, in Arab society opinions are often public property and they are to be developed by consensus and expressed by those considered worthy. Market place and qat chew discussions were dominated by one or two spokesmen but with perhaps 20 men listening and discussing what was being said amongst themselves and often the speaker was corrected on points. The discussions were often heated and were dominated by the visibly active males (typically between 20 and 50 years old). When the local shayx was absent the role of spokesman was taken by an influential farmer / well owner. When the shayx was present he was sometimes too old to hear or understand.

b) Another bias came with the 'technical' questions involving measurements and numbers generally. Although efforts were made to simplify them as much as possible using various RRA techniques, these questions were really only understood by those between 15 and 30 years old and sometimes only crude estimates had to suffice. On occasions it appeared that numerical answers were purposely left as vague as possible, perhaps from fear that the survey was part of a government tax assessment or plan to take their water. Sometimes fear of the shayx appeared to hold people back from answering. Because the survey was linked to the UNDP, questions could be answered in a manner more likely to attract foreign aid.

c) During the visits to hydraulic locations considered important to the villagers it was possible to visit homes on a more individual basis which permitted a refinement and, on occasions, a complete reversal of previous comments.

d) In preparing the village map the local school teacher was usually chosen as the cartographer. Other men would direct what he drew and teenage boys often had the best grasp of the details. In nearly all the villages, and without prompting, the map focussed on the wells, the routes of spate flows / streams and the alignment of fields. The shapes and sizes of features were less important.

e) The absence of a woman interviewer prohibited the interviewing of women, although it was sometimes possible to talk to older women at the well head.

1996 Survey

This survey comprised mapping the land use of the Upper Wadi Rasyan catchment in September and December 1996 to field check the extent of rainfed and irrigated agriculture noted on the satellite imagery. A brief field visit to key areas was also made in spring 1997 to check the extent of third season irrigation. Because of the high intensity of cultivation in wadi areas indicated on the satellite imagery, the wadis were surveyed in detail to determine crops grown and irrigation methods. Farmers were also interviewed regarding aspects of farm inputs and outputs to permit a rudimentary assessment of farm budgets.

4.1.3 Survey Results

Land Ownership and Tenure

This field of study does not contribute directly to the evaluation of returns to water or the description of water use practices, however it is included here because it forms relevant background regarding agricultural water users. Table 4.2 summarises the main findings regarding rent, zakaat and tenancy agreements.

The non-contiguous distribution of owned land and extreme fragmentation of land made an evaluation of land ownership and tenure very tenuous (a problem also noted by others, Mitchell and Escher,1978). Average holding sizes of 1.2ha with 4.6 parcels per holding were noted for the Ta'iz governorate (Bamatraf, 1987). NWRA (1999a) also notes that the majority of farms are under 1ha in size. Individual plots (haql, hawd or faddaan) are demarcated (tahdiid). The non-dividing up of fields upon inheritance leads to confusion of ownership but permits easier farming. Lack of land division may also be putting off the fateful day of deciding who owns what. Resolving the latter occupies most of the time of the shuyuux (plural of shayx), uses up most of the bullets that are fired in Yemen in earnest, and is further complicated by daughter's inheritances which should be half that of the sons but is often withheld by force. Since the Gulf War, migration to the cities does not result in fewer people to farm the land because rural population growth still outstrips migration. However, lack of work on the land appears to lead to a higher rate of migration. There is little incentive to measure land except for the purpose of sale. However sale is quite rare. Selling land was described as similar to the ultimate dishonour of 'exposing one's women folk'. Remittances from Saudi Arabia and the Gulf were spent on houses, vehicles, wells/pumps and businesses, but not on land purchase. Only under times of great financial stress do people sell land, as occurred in Al Jahaaza during hard times under the reign of 'imaam 'ahmad.

The average proportions of farmer-owned and sharecropped land in Ta'iz – Ibb (World Bank, 1986;Annex I) were 84.1% and 4.5% with mixed holdings accounting for 11.4%. This compares with 60.2% owner-farmers and 13.2% pure tenants in the Upper Rasyan catchment (NWRA,1999a). The average for North Yemen (Bamatraf, 1987;581) is 77.4% owned, 3.5% sharecropped, 0.3% waqf and 18.8% mixed ownership. NWRA (1999a;17) suggest a greater proportion of share cropped land and fixed-rent land is irrigated than is the case with owner-farmed land.

Table 4.2 Rent, Zakaat and Tenancy Agreements:

	Sharecrop Rent			Zakaat		Who Pays?	Length of Agreement
	Irrigated		Rainfed	Irrigated	Rainfed		
	Land Rent	Water Rent	Land Rent				
Al ^adan	1/4	1/3-1/4*	0-1/5*	3-5%	3-5%		Semi-permanent
Al Jahaaza	1/3	1/3-1/4*				tenant	
Al 'anjud							Semi-permanent
^adan As Safaa	1/3	1/3		3%		owner	>5yrs
Al Xums	1/4	1/4		2.50%	10%	owner	1-20yrs(av.5yrs)
Ar Rahayba	1/4	1/4	1/2	5%	10%	tenant	5-12 yrs
Ar Riwaas	1/4	1/4	1/2	3%*		owner	20 yrs
Al Malika	1/4	hourly		100-200YR	100-200YR	tenant	1 season
Al Malika (waqf)	1/4	hourly		10%	10%	tenant	hereditary

*see text

In the villages included in the 1995 survey very little hired labour is used, although some landowners employ help during harvest and wealthier landowners hire labour for ploughing, sowing, harvest, irrigating and tree trimming, with some employing labourers on a full time basis. Labourers may sharecrop and own small portions of land. Most farmers repair terraces themselves but skilled labour, particularly ploughmen, are hired for their skill and equipment. Payment for hire may be in crops, though it may be in cash from the few who have access to cash through the sale of water or qat.

The zakaat (tax) is supposed to be 10% for rainfed production and 5% for irrigated crops (Mitchell and Escher,1978;40) and paid to God. In reality, 3-5% is paid to the government on irrigated or non-irrigated crops via the local leadership, although this reallocation and reduction is seldom remarked upon or even noted in the literature. Cases of enforced payment of zakaat are reported (Handley,1996a;17) and the system is not free from irregularities.

Rent is paid as a proportion of the crop by the sharecropper to the landowner. It seems to make no difference whether the rent is paid in cash or crop in the case of grains, but rent for cash crop land and water rent (particularly for qat) are paid in cash. There was no indication of different rents being paid for different crops. Waqf rental payments used to be paid to the mosque or designated charity (Mitchell and Escher,1978;95) but it now appears to be paid to the state. Water rent in Al ^adan and Al Jahaaza is reduced from one third to one quarter if the land was gayl (stream) fed rather than supplied from underground sources. Share croppers sign rental agreements in the presence of two witnesses and the 'amiin (local officiary), who stamps the document. If the sharecropper stops paying then the contract is terminated. Although similar rental figures to those given in Table 4.2 are widely quoted, some frank conversations suggested that, in reality, the rainfed land sharecropper pays as little as possible. If the crop is poor he gives a token amount and if good, and depending on how tough the landowner is, he may give as much as 20%.

Sharecroppers have to obtain permission from the landowner to dig a well. The owner cannot take the well from the renter who dug it if permission was obtained. The landowner can only buy the well from the renter if the latter agrees. If the landowner wishes to sell the land and move the sharecropper off then he has to pay for the digging of the well. Similar rules apply to planting trees and repairing terraces.

Irrigation practices

Because of the seasonal rainfall variation, rainfed cultivation (daahi) is restricted to one summer season. With irrigation, two, or even three cultivation seasons are possible. Because the rainfall events are intense and of short duration, rainwater harvesting of the spate (sayl) has to be self-regulating and adequately robust. Diversion of the spate from a feeder wadi bed (saa'ila) to the fields is via a diversion structure (masqa, pl. massaaqi) (Photo 3). If the sayl is too strong there may be destruction of the massaqi and erosion (injiraaf) of the land (Photo 4) The masqa is constructed to reduce the erosive power of the sayl as well as to obtain the water, and it is reconstructed if it is destroyed. There are two types of masqa, one is the runoff routes from the mountains to the main wadi, the rights to which are ancient and are attached to the land. On a smaller scale, in the main wadi floor, the spate water derived via the masqa from the main wadi bed appeared to be the right of whoever could manage to divert the spate flow.

The other gravity-fed form of irrigation is the spring-fed stream (gayl). These may be seasonal or perennial, usually depending on the degree of exploitation upstream. In some instances, the spring source was controlled by the solid geology such as at Al 'unjud and Al ^adan where the Tawilah Sandstone outcrops with artesian flow (Photo 5). The gayl is diverted in open channels to fields in fixed rotation referred to as " 'al 'awwal bil 'awwal" or " 'al ^ala bil ^ala", that is, 'highest first'.

The valley alluvium constitutes the most important source of water for pumped irrigation. Exploitation begins with hand dug wells which are successively deepened as the resource declines until the rockhead is reached. As water levels decline further the well may be extended by up to 20m using pneumatic tools. After that those wealthy enough have to resort to drilling. Dug wells are typically 1 to 2m in diameter and are reinforced-concrete lined using corrugated iron or plywood formwork. Construction proceeds downwards, concreting about 1-2m at a time. Caving of the unsupported sides during construction may result in ground surface subsidence of up to 2-3m around the shaft. Wells are dug in winter to ensure maximum depth which is typically 5m below the summer water level. Dug wells may reach up to 70m deep. Pumping from permanent dug wells in wadi floors is usually by shaft pumps belt driven by 24 to 36 HP diesel engines. The pumps are connected to 3-inch or sometimes 4-inch steel pipe distribution networks via gate valves. More temporary arrangements may be used, especially if the groundwater level is not very deep, utilising 2-inch petrol driven suction pumps lifting water to a maximum elevation of 30m above the pump from a maximum depth of 5m below pump suction. The rising main and distribution is by 2-inch flexible hose. The wells may be abandoned and re-dug after spates.

Wells drilled by farmers are usually between 100 and 300m deep and, like the dug wells, are deepened as water levels decline. They are usually finished in 8-inch casing and are open hole below the water surface, although torch-slotted casing is sometimes used. As with the permanent dug wells, shaft driven pumps and piped distribution systems or open channels are used. NWRA (1999a) note that the preference for open channel or piped systems is largely determined by whether the topography permits the construction of channels rather than other factors. With piped systems a flexible hose is typically used at the field to direct flow more easily, particularly in larger fields.

Table 4.3 gives a summary of the different hydraulic regimes which are used for irrigation and the different regimes in which the regimes are found. Working down the table, the hydraulic regimes are cumulative, the land irrigated by a seasonal stream, for instance, will also receive water from the spate and be rainfed. The villages can be considered to be at various stages in a process of exhausting the aquifers. Large differences in wealth are attached to being able to cultivate three seasons of cash crops as opposed to only one season of subsistence crops. As the water level falls in an alluvial aquifer penetrated by shallow dug wells, the wells dry up. In this situation, the only way a farmer can maintain cultivation for two or three seasons is to drill a deeper well into the underlying rock. The costs and potential for conflict of doing this may deter him. It was observed that conflict over water access is concentrated in this situation where the water level had reached the base of the alluvium. By contrast, both when groundwater

Table 4.3: Irrigation Regime and Conflict Potential

Hydraulic Regime	Environment	State of Alluvial Aquifer	Technology	Aquifer* Exploited	Village (Cultivated Area)	Number of Seasons	Issues: Economics	Issues: Conflict	Issues: Environmental Impact (Resource Depletion)
Runoff area	Mountains				Most Dwellings	0			
Rainfed only	Mid & Lower - Broad wadis & Small Catchment Narrow Wadis	Exhausted		None	Miqbaaba	1		Minimised	Least Vulnerable (Most Affected)
				None	Al ^adan, Al Jahaaza	1			
		Almost Exhausted	Drilled Wells	Volcanics	Al Xums - mid wadi	1-2		Maximised	
				V & A	^adan As Safaa	1-2			
				V & A	Al Malika - mid wadi	1-2			
Sayl - Runon area	Upper Broad Wadis and Wadi Margins			V & A	Al Xums - Wadi Edge	1-2			
				V & A	Al Malika - Wadi Edge	1-2			
		Sufficient	Dug Wells	Alluvium	Ar Riwaas	2-3		Minimised	
Gayl - seasonal	Large Catchments with slightly depleted to un-depleted upper reaches			Alluvium	Ar Rahayba	2-3			
Gayl - permanent	Large Catchments with undepleted upper reaches and/or Geological Control	Almost Unaffected to Too Much Water		A & T	Al 'anjud	3		Minimised	Most Vulnerable (Least Affected)
				A & T?	Al Hayma before project	3			

* Aquifers:
V & A   Volcanics & Alluvium
A & T   Alluvium & Tawiila Sandstone

resources are plentiful, and when they are insufficient for all but the few farmers who were able to drill deeper wells, the potential for conflict decreases. Uphoff et al. (1990;27) expected user participation in water resources management to be most readily forthcoming in the middle range of resource availability, and Thompson thought a 'bounded egalitarian group' most likely to emerge where there is resource depletion (1988;67). However, the Yemeni experience is the opposite, with resource depletion producing the greatest conflict potential.

Whether a farm has a surplus of water relative to land or land relative to water availability has been directly correlated with farm practices regarding cropping, the extent of supplementary irrigation and feasibility to sell water (Handley, 1996b;11). By their cropping practices farmers clearly demonstrate their aim to achieve a balanced use of land and water without underutilising one or the other. A surplus of water is rarely the problem since there are almost bound to be some surrounding farmers with water deficits to sell to. A surplus of land is usually the case. This underscores the principle that greater productive efficiency of water use through improved irrigation techniques, for example, will only result in use of more land and will not in itself reduce groundwater withdrawals.

Ploughing is mostly by oxen, and the furrows (tilm) are spaced according to crop, for example cereals 40cm and potatoes 50cm, although there is considerable variation in this. Around 10 tilm make a sabba. The sabba is formed by raising the soil higher than the furrow crests so that an enclosed irrigation basin is formed. In some areas the sabba is called a tilm and comprises 4 to 6 furrows. The individual sabba is filled with water to the height of the furrows (10-15cm) and the water is then switched to the next sabba. The fields are irrigated from upstream downwards. Kuraath (everlasting onion) is grown in a separate rectangular tilm without furrowing. Although it was consistently stated that women played no role in irrigation activities, women, including axdaam (servant caste) were occasionally observed controlling the flow of water into fields.

Irrigation efficiencies of 35% are reported in an area of open channel irrigation in the At Turba district (World Bank,1986;Annex I;13). Total (well to field) irrigation efficiencies of 72% and 60% for piped and open channel systems in the study area have been estimated (Zagni, 1996). No volumetric measurements of water used in irrigation are made, all sales are by the hour and flow rates are always mentioned in terms of pipe diameters only, 2-inch, 3-inch etc.

Water Use

The land use map (Figure 4.2) for the Upper Wadi Rasyan catchment was compiled from a combination of satellite imagery interpretation as described in section 3.4.5 and field observation conducted as part of the 1996 survey. A summary of the major crops grown, the number of harvests and cropping areas in the field study area in both the major wadis and the non-wadi areas is given in Table 4.4 to 2.5ha and 0.5 km^2 accuracy respectively. The crop types are estimated from field checking and the areas of major crop types may be in error by up to +/- 10%. The calculation of areas of summer grains and qat assume observed approximate intercropping ratios of 1:2 respectively in the lowland areas and 2:1 in the highland areas.

The theoretical water use by agriculture has been calculated by the following procedure:

1. The rainfall distribution pattern (Figure. 3.2) has been applied to the cropped areas in 50mm/yr gradations.
2. Cultivation intensities were applied according to field observations of the extent of fallow, unused land, roads and tracks within the areas identified by the satellite imagery thresholding method (see section 3.4.5). An error of +/- 10% is estimated.
3. The effective rainfall on fields during the period crops are growing is calculated as: Effective Rainfall = Rainfall x Rainfall Efficiency x Seasonal Proportion of Annual Rainfall x Cultivation Area x Cultivation Intensity
4. Field Irrigation Requirement is calculated as:

   (Net Irrigation Requirement-Effective Rainfall) x Field Application Efficiency

The values used for Rainfall Efficiency, Net Irrigation Requirement and Field Application Efficiency were taken from Zagni (1996, who used CROPWAT 7, described in Smith,1992) for Wadi Warazan and Dhi Sufal, although the rainfall efficiencies may be rather high.

In calculating the pumping requirements for well irrigation a sensitivity analysis was carried out using:

> Runon-Rainfall ratios of 0 to 35% (after Eger,1986;102-105 and Zagni,1996;15). [This ratio is based on the runon relative to the rainfall falling directly on the cropped areas, not the total area]. From the observation of runon-rainfall ratios described in section 3.3, ratios of 0.1 to 0.2 are considered more likely.

Table 4.4: Agricultual Land Use

a) Areas of Intensive Land Use in Major Wadis (ha)

	Cultivated Summer[1]	Estimated Summer Crop Areas[2] (ha) Qat	Sorghum or Millet	SI Sorghum or Millet	Maize	SI Maize	Fruit	Veg
Total	2735	182.5	1152.5	322.5	182.5	810.5	47	37.5

	Cultivated Winter[1]	Estimated Winter Crop Areas[2] (ha) Qat	Maize	Sorghum or Millet	Potato	Fruit	Veg
Total	1352.5	182.5	562.5	160.5	292.5	47	107.5

	Cultivated Third Season[2]	Estimated Third Season Crop Areas[2] (ha) Qat	Maize	Sorghum or Millet	Fruit	Veg
Total	609.5	182.5	77.5	195	47	107.5

b) Excluding Major Wadis[1]
(Categories Based on Land Use Map Legend)

	Land Use Summer	Land Use Winter
	km^2	km^2
Upper Wadi Rasyan		
Uncultivated[3]	486.0	789.7
Rainfed Summer Cultivation of Poor Quality Grains	191.8	0.0
Rainfed Summer Barley	6.0	0.0
Rainfed Summer Cultivation Only	8.9	0.0
Small Scale Rainwater Harvesting	55.0	0.0
Qat growing areas irrigated by tanker	18.0	18.0
Intensive Summer Cultivation	37.5	0.0
Irrigated Winter Crops and SI Summer Grains	4.5	0.0
Highland Qat	70.9	70.9
Major Urban Areas	23.5	23.5
Total	902.1	902.1

[1]Areas determined from satellite imagery
[2]Crop area estimates based on field checking during Sept-Dec 1996 and March 1997
[3]Determined from D.O.S. Maps 1981.
SI Supplementary Irrigated

Irrigation efficiencies of 0.9 to 0.6. The average irrigation efficiency of irrigation activities in the Upper Wadi Rasyan catchment is thought to fall within this range for the following reasons:

Although average well head to field conveyance distances are quite large (287m from dug wells and 457m from boreholes, NWRA,1999a;37), on average 85% of this distance is piped (ibid.). Doorenbos and Pruitt (1977;Table 44) define conveyance efficiency in terms of supply from a main (open) canal which has no real equivalent in the Ta'iz instance. Field ditch efficiency equates more closely to the Ta'iz situation. With the given proportion of piped to unlined delivery systems (85:15) the field ditch efficiency is likely to fall between 0.9 and 0.6 (ibid. and NWRA,1999a;38), Table 4.5.

Table 4.5: The agricultural water requirements (Mm^3/yr) of the wadi areas of the Upper Wadi Rasyan catchment (areas given in Table 4.4) can be summarised as:

Major Wadis: Effective Rainfall = 6.89 Field Irrigation Requirement = 24.04			
	Pumping Requirement		
Field Ditch Efficiency: Runon : Rainfall Ratio	0.6	0.75	0.9
0	40.7	32.05	26.71
0.05	39.27	31.42	26.18
0.1	38.47	30.78	25.65
0.2	36.88	29.50	24.59
0.35	34.49	27.59	22.99

As a cross check of the amounts of water required from pumping a comparison with well abstractions can be made. The NWRA well inventory (1996) for the area indicates there are 1310 wells in the area (1073 dug and 237 drilled) which are not dry or only accessed by bucket. Applying mean measured discharges and operation periods gives a total abstraction of 36.9 Mm^3/yr. If only the wells actually operating when visited are considered the total abstraction would be 24.6 Mm^3/yr. A sensible estimate lies somewhere between these two values and gives reasonable agreement with the values in the above table.

Irrigation from stream flow is particularly important in some wadis. The irrigation requirement from the stream has been calculated on a pro-rata basis from the proportion of wadi cultivation served by the stream relative to the total cultivated wadi area (Table 4.6) using the satellite imagery to determine areas of seasonal irrigation. The irrigation requirement compares reasonably with the measured wadi flows, that is, wadi flows balance the requirement of the areas served. An irrigation efficiency for the stream of 0.6 and a runon:rainfall ratio of 20% have been assumed. The maximum annual abstraction assumes the irrigation requirement is fully met by the stream in the areas using stream water. The minimum assumes the minimum flow recorded is available. The likely water use from streams is thought to approximate the maximum since spates have not been taken into account. The excess flow at the end of the rainy season provides the outflow of Wadis Malih / Hidran and Miliha from the area, to Wadi Rasyan.

Table 4.6: Stream irrigated land in the Upper Wadi Rasyan catchment.

Stream Cultivated Area		Irrigation Requirement				Wadi Flows		Abstraction from Streams	
Summer	Winter	Summer	Winter	Summer	Winter	Minimum	End Rainy Season	Max Annual Abstraction	Min Annual Abstraction
ha		Mm^3/season		lit/sec		lit/sec		Mm^3/season	
222.5	172.5	1.85	1.44	215	168	193	393	3.31	1.71

Crop water requirements in major wadis are essentially met by groundwater abstractions and saaqiya irrigation. In the rest of the area this requirement is not met. Although runon alleviates the deficit somewhat, evidence of deficiency is seen in the low quality of sorghum and millet from the rainfed areas which incur an estimated 93% of the total deficit. Often, these crops are only adequate for animal fodder, a grain head not having formed.

In the non-wadi areas the effective rainfall is 65 Mm^3/yr leaving a field irrigation requirement of 112 Mm^3/yr. If the runon:rainfall ratio in the catchments supplying the non-wadi areas is 0.2 then runon would provide another 31.5 Mm^3/yr, totalling around 100 Mm^3/yr consumption by rainfed agriculture.

Based on the above discussion, total water use in the Upper Wadi Rasyan area is estimated as comprising:

Rainfed Agriculture 100 Mm^3/yr

Groundwater Irrigation 30 Mm^3/yr

Stream-fed Agriculture 3 Mm^3/yr

Human Use 2.5 Mm^3/yr

Livestock* 0.3 to 0.4 Mm^3/yr

(*Dar El Yemen,1997;145 and Al-Dubby and Taher,1998;8)

The estimated total is around 135 Mm^3/yr (+/- 20%).

On the basis of the number of tankers and wells observed supplying water for tanker-irrigated winter crops (NWRA well inventory, 1996) this use cannot account for more than 0.3 Mm^3/yr +/- 50%. This is equivalent to an estimated 3 percent of the total possible demand if the cultivation of only one winter crop is assumed. An amount of water not exceeding this may also be pumped from boreholes in wadi bed areas to highland qat farms.

4.1.4 Returns to Water

In examining agricultural returns to water the NWRA (1999a) data have been used. The NWRA study comprised a survey of 21 villages to examine socio-economic aspects of agriculture and irrigation in the Upper Wadi Rasyan Catchment. Crop yields quoted in the literature (Table 4.7) are somewhat contradictory although the NWRA data are the most recent, local and from the largest sample. Yields in Ta'iz approximately reflect the national average but suggest scope for the use of improved varieties.

Table 4.7: Crop yields (Tonnes/ha):

	NWRA (1999a) Draft	Statistical Yearbook (1996)	Mitchell &Escher (1978)	Bamatraf (1987)	El-Lakany (1978)
Area	Ta'iz	National	Ta'iz	National	(National) Ta'iz
SI Sorghum Grain	1.1				
RF Sorghum Grain	1.1	0.8		2.8	(0.8) 0.9
SI Maize Grain Stalks	1.3	1.2	4.4 8.8		
RF Maize Grain Stalks	1.3		3.6 8.0	2.5	(1.1) 1.0
RF Millet Grain Stalks		0.8	1.3-3.4 4.9-12.5		(1.0) 0.6
RF Wheat	1.2	1.5			
Potatoes	14.4	12.8			
Tomatoes	11.5	15.2			
Qat RF	974*				
Qat SI	1414*				

*Unit = Mandil/ha
RF Rainfed
SI Supplementary Irrigated

Farm costs and incomes from the NWRA survey combined with the water use assessment from the preceding section and for the same area (Table 4.8) permits an analysis of water use and costs. A rudimentary assessment of the costs of wells, irrigation and farm budgets was made during the 1995 and 1996 rural surveys. The latter data were within +/- 50% of the farm budget obtained by NWRA and are well within the variation noted in NWRA (1999a).

Because the NWRA sample was much larger than this survey's, the former data have been used as the basis for analysis.

Based on the labour inputs, Table 4.8 indicates the relatively small number of people needed to produce the crops. This calculation assumes continuous full employment for 270 days/year and is included to permit comparison with industrial returns to water discussed in the next section. In fact labour demand is seasonal. The minimum 'man seasons' needed to produce the crops is 6200.

Table 4.8 also indicates the large proportion of costs incurred by irrigation relative to income. This is explored further in Table 4.9. Table 4.9 assesses costs and returns for the irrigation sector alone and also the affect of variations in irrigation costs for the agricultural sector as a whole:

a) at current costs,
b) if the price of diesel for the pumps were to increase to border parity levels,
c) if border parity price diesel and capital depreciation are included.

[The method of calculation of the current cost of water in Table 4.9 is different in 'a) Running Costs' from parts b) and c). The former figure is derived from the data in Table 4.8 whilst the latter two are calculated using the assumptions given in Table 4.9. As a check of the validity of the latter method the 'current water cost' was calculated for section a) using the method for b) and c) and resulted in a cost of 95MYR ($0.73M) which agrees satisfactorily with the former method (102MYR, $0.78M).]

Summary of Economic Analysis

With only diesel charged at border parity levels, the profitability of irrigation is reduced almost to nil. [If farm costs or income were to vary by plus or minus 50%, as data error might tolerate, then irrigation would become unprofitable at current income levels.] Although current costs estimated by farmers do not include capital depreciation (and neither do World Bank estimates; 1993, Annex 2, Moench,1997;12), when these costs are included, the returns to water become negative. This conclusion is maintained even if the field averages in Table 4.8 underestimate farm income or overestimate expenditure by 50%. The argument that Yemeni farmers could grow irrigated crops at a loss becomes plausible only because much of the well digging/drilling and purchase of pumps and pipes occurred when remittances from Saudi Arabia and the Gulf were being invested in the farms prior to the Gulf War. Because of

Table 4.8 Agricultural expenditure and returns and water costs in the Upper Wadi Rasyan catchment - in Yemeni Riyals

	Cultivated Area (ha) Wadi Irrig	Non Wadi	Total Costs[3] (including family labour but excluding water)	Gross Income[3]	Net Farm Income	Net Area Income	Family Labour	Hired Labour	People Employed	Current[3] Water Costs	
Summer	ha	ha	YR/ha	YR/ha	YR/ha	YR/yr	days/ha	days/ha	'man years'	YR/ha	YR/yr
Irrigated Qat[1]	146	25	45067	337386	292319	49,986,549	22.6	40.7	40.1	40360	6,901,560
Rainfed Qat[1]		1012.5	36503	232447	195944	198,393,300	19.8	35.5	207.1		
Sorghum or Millet	922	7455	25351	49247	23896	200,176,792	19.4	12.6	992.1		
SI Sorghu or Millet	258	72	32428	50549	18121	5,979,930	23.6	17.3	49.9	20164	6,654,120
Maize	146	966	38871	65564	26693	29,682,616	27.1	20.9	197.7		
SI Maize	648.4	108	36792	63521	26729	20,217,816	23.6	17.3	114.4	25734	19,465,198
Fruit[1] (Irrigated)	37.6		40653	173000	132347	4,976,247	6.0	47.2	7.4	118790	4,466,504
Vegetables (Irrigated)	30	32	96838	133891	37053	2,297,286	86.8	87.4	40.0	159718	9,902,516
Wheat / Barley		280	144209	89918	-54291	-15,201,480	145.3	72.3	225.6		
Winter (Irrigated)											
Maize	450	180	39147	66335	27188	17,128,440	28.9	17.2	107.6	36159	22,780,170
Sorghum or Millet[4]	128.4		34504	52788	18285	2,347,752	28.9	17.2	21.9	28333	3,637,901
Potatoes	234		176695	345524	168829	39,505,986	27.6	61.7	77.4	38418	8,989,812
Vegetables	86	36	122784	164969	42185	5,146,570	99.0	70.0	76.4	51512	6,284,464
Third Season (Irrigated)											
Maize	62	108	39147	66335	27188	4,621,960	28.9	17.2	29.0	36159	6,147,030
Sorghum or Millet[4]	156	72	34504	52788	18285	4,168,905	28.9	17.2	38.9	28333	6,459,823
TOTAL						569,428,668			2225.5		101,689,098
Total Irrigated Agriculture Only						156,377,440			603		101,689,098

[1] Perennial.

[2] 6% of non-wadi qat is assumed to be irrigated: 3% by tankers and 3% by boreholes. See text.

[3] Based on NWRA (1999a). For further analysis of water costs see table 4.9.

[4] Pro-rata of summer cost and income relative to maize.

[5] Assumes 270 days worked per year and is 'man years' required to produce the crop.

SI Supplementary Irrigated

Source: Fieldwork and NWRA (1999a)

Table 4.8a Agricultural expenditure and returns and water costs in the Upper Wadi Rasyan catchment - in US $

	Cultivated Area (ha) Wadi Irrig	Non Wadi	Total Costs[3]	Gross Income[3]	Net Farm Income	Net Area Income	Family Labour	Hired Labour	People Employed	Current[3] Water Costs	
			(including family labour but excluding water)								
Summer	ha	ha	$/ha	$/ha	$/ha	$/ha	days/ha	days/ha	'man years'	[3]$/ha	$/yr
Irrigated Qat[1]	146	25	347	2595	2249	384512	22.6	40.7	40.1	310	53089
Rainfed Qat[1]		1012.5	281	1788	1507	1526102	19.8	35.5	207.1		
Sorghum or Millet	922	7455	195	379	184	1539821	19.4	12.6	992.1		
SI Sorghu or Millet	258	72	249	389	139	45999	23.6	17.3	49.9	155	51186
Maize	146	966	299	504	205	228328	27.1	20.9	197.7		
SI Maize	648.4	108	283	489	206	155522	23.6	17.3	114.4	198	149732
Fruit[1] (Irrigated)	37.6		313	1331	1018	38279	6.0	47.2	7.4	914	34358
Vegetables (Irrigated)	30	32	745	1030	285	17671	86.8	87.4	40.0	1229	76173
Wheat / Barley		280	1109	692	-418	-116934	145.3	72.3	225.6		
Winter (Irrigated)											
Maize	450	180	301	510	209	131757	28.9	17.2	107.6	278	175232
Sorghum or Millet[4]	128.4		265	406	141	18060	28.9	17.2	21.9	218	27984
Potatoes	234		1359	2658	1299	303892	27.6	61.7	77.4	296	69152
Vegetables	86	36	944	1269	325	39589	99.0	70.0	76.4	396	48342
Third Season (Irrigated)											
Maize	62	108	301	510	209	35554	28.9	17.2	29.0	278	47285
Sorghum or Millet[4]	156	72	265	406	141	32068	28.9	17.2	38.9	218	49691
TOTAL						4,380,221			2225.5		782,224
Total Irrigated Agriculture Only						1,202,903			603		782,224

[1] Perennial.

[2] 6% of non-wadi qat is assumed to be irrigated: 3% by tankers and 3% by boreholes. See text.

[3] Based on NWRA (1999a). For further analysis of water costs see table 4.9a.

[4] Pro-rata of summer cost and income relative to maize.

[5] Assumes 270 days worked per year and is 'man years' required to produce the crop.

SI Supplementary Irrigated

Exchange rate based on $1 = 130YR

Source: Fieldwork and NWRA (1999a)

Table 4.9: Cost of water to agriculture in the Upper Wadi Rasyan Catchment - Yemeni Riyals

a) Running Costs[1]	Water Used	Current Water Cost	Current Water Cost	Net Income	Returns to Water
	Mm^3/yr	MYR	YR/m^3	MYR	YR/m^3
Irrigation Only	30	102	3.39	54.69	1.82
Total Agriculture	133	102	0.76	467.74	3.52
b) Future Running Costs?		Cost with diesel at border parity & without depreciation		Net Income	Returns to Water
		MYR	YR/m^3	MYR	YR/m^3
Irrigation Only	30	151	5.03	5.38	0.18
Total Agriculture	133	151	1.14	418.43	3.15
c) Real Costs?		Cost with diesel at border parity & with depreciation		Net Income	Returns to Water
		MYR	YR/m^3	MYR	YR/m^3
Irrigation Only	30	406	13.53	-249.62	-8.32
Total Agriculture	133	406	3.05	163.43	1.23

[1] Using Farmer Estimates of Water Costs ie current diesel prices and excluding depreciation

Assumptions in calculating depreciation:

Borehole Items	[5]Depreciation Period	[5]Price	[3]Average Depth m	[3] Number of Wells
Casing & Riser -Dug	15 years	20000 YR/m	15.3	1073
Casing & Riser -Drilled	15 years	10000YR/m	150.0	237
Pump and Motor	10 years	1.5 MYR		

[3] Operating Period	5.8 hours/day	6.5 days/week
	Current	[4]Border Parity
Diesel Price	10YR/lit	18YR/lit
[5] Diesel Consumption	2.75 lit/hr	
[5] Oil Expenditure	50YR/day	

[3] NWRA Well Inventory (1995)
[4] World Bank (1998;Annex 2 pg3)
[5] Handley (1997;6)

Table 4.9a: Cost of water to agriculture in the Upper Wadi Rasyan Catchment - $ US

a) Running Costs[1]	Water Used	Current Water Cost	Current Water Cost	Net Income	Returns to Water
	Mm^3/yr	M$	$\$/m^3$	M$	$\$/m^3$
Irrigation Only	30	0.78	0.03	0.42	0.01
Total Agriculture	133	0.78	0.01	3.60	0.03
b) Future Running Costs?		Cost with diesel at border parity & without depreciation		Net Income	Returns to Water
		M$	$\$/m^3$	M$	$\$/m^3$
Irrigation Only	30	1.16	0.04	0.04	0.00
Total Agriculture	133	1.16	0.01	3.22	0.02
c) Real Costs?		Cost with diesel at border parity & with depreciation		Net Income	Returns to Water
		M$	$\$/m^3$	M$	$\$/m^3$
Irrigation Only	30	3.12	0.10	-1.92	-0.06
Total Agriculture	133	3.12	0.02	1.26	0.01

[1] Using Farmer Estimates of Water Costs ie current diesel prices and excluding depreciation

Assumptions in calculating depreciation:

Borehole Items	[5]Depreciation Period	[5]Price	[3]Average Depth m	[3] Number of Wells
Casing & Riser -Dug	15 years	154 $/m	15.3	1073
Casing & Riser -Drilled	15 years	77 $/m	150.0	237
Pump and Motor	10 years	11500$		

[3] Operating Period	5.8 hours/day	6.5 days/week

	Current	[4]Border Parity
Diesel Price	10YR/lit	18YR/lit
[5] Diesel Consumption	2.75 lit/hr	
[5] Oil Expenditure	0.39 $/day	

[3] NWRA Well Inventory (1996)

[4] World Bank (1998;Annex 2 pg3)

[5] Handley (1997;6)

the omission of capital depreciation, the current running costs in Table 4.9 relate to the economic awareness of the irrigator which are much less than his 'real costs'. The sensitivity of the depreciation period was analysed by doubling the 'lifespan' of the borehole / casing to 30 years and the pump and motor to 15 years. In this instance the irrigation returns to water indicated in the 'real costs' part of Table 4.9 would be minus 5.2 YR/m^3 (-0.04\$/m^3) and average returns to water for the whole sector would be 1.9 YR/m^3 (0.015\$/m^3).

4.1.5 Ten year shift in irrigated area

Comparison of summer and winter satellite images of the Upper Wadi Rasyan catchment from the 1985/6 and 1994/5 suggests changes in agricultural water use. Due to cloud-free image availability it was not possible to get images from the same summer months for the two dates. One was for October and the other for June. For most of the summer cropped area this is not thought to be a problem since field work suggested there is only 1% difference in cropped area between June and October. One reason for the similarity is that a second maize crop has been planted and occupies nearly the same area but in different fields. Qat occupies the same locations and sorghum has not been harvested by early October. Apart from the differences in cultivated area noted in Al Hayma (section 3.4.5) between the mid-'80's and the mid'-90's the total area of cultivation in the major wadis increased by around 16% although the area under winter cultivation has declined by 38%. Areas of reduced cultivation are downstream from Al Hayma as far as Burayhi and Wadi Malih, from lower Wadi Dabbaab to Wadi Rasyan (see Figure 3.16 for locations). These declines coincide with the areas downstream of city and factory abstractions. Declines in winter cultivation are also noted in upper Wadi Maliha, Wadi Rubay'i and upper Wadi Sawaami. A decline in winter irrigation intensity in Wadi Dabbaab, and an increase in Wadi Hidran to Wadi Rasyan, lower Wadi Miliha and lower Wadi Sawaami are also evident.

The cost of depleting the Al Hayma aquifer.

Combining the assessment of crop areas from this study with the agricultural economics data of NWRA (1999a) for Wadi Al Hayma permits an estimation of the cost of returning the aquifer to its pre-development state (less the current abstraction for the city) as discussed in section 3.6.1. The value of profitable irrigated agriculture and the labour lost if no irrigation were to take place until full recovery would amount to 1.8BYR (\$14M) which includes the labour costs of around 1000 directly related lost livelihoods (Table 4.10). These returns to water are contrasted with industrial returns in section 4.2.2 and are discussed further in sections 4.6 and 5.1.

4.2 Industrial Sector Water Use

The development of industry in Yemen has been steady and the sector is approaching the share of GDP enjoyed by agriculture (Figure 4.3). In the Yemeni context the Upper Wadi Rasyan catchment of the Ta'iz governorate has been at the forefront of industrial development with the larger companies alone accounting for an estimated 14% of the national workforce compared with a 4.4% share of the population (Ta'iz Chamber of Commerce figures CSO;1997;39,20). This assumes that the major factories of the Upper Wadi Rasyan area account for 80% of the industrial activity in the governorate.

4.2.1 Methodology

During the summer of 1995, visits were made to the larger factories in the immediate vicinity of Ta'iz. Several different sources concurred that these factories accounted for between 90 and 95% of the industrial water users that do not depend on the public supply. Some of the larger factories were revisited on occasions between 1996 and 1998 as opportunity permitted. Although coverage of industrial water users was high, the number of factories using that water is small and precludes statistical analysis of responses. Because of the size of the sample and the nature of the questions, key informant interviews were conducted with technical and managerial staff. Checklist questions were used in a discussion format to cover the following topics:

a) Number of employees
b) Attempt to assess the total amount of water used
c) Sources of water and means of abstraction and distribution
d) Costs involved in supplying water
e) Uses of water
f) Means of waste disposal
g) Problems encountered

The purpose of the questions was to obtain data that would permit an assessment of:

a) water uses and problems,
b) the financial and livelihood returns to water, and
c) awareness of and willingness to address equity and environmental issues in source and disposal areas.

Technical staff were usually very willing to give a conducted tour of the source and disposal areas as well as the main water use points in the factories. The tours permitted some contact with the inhabitants of the source and disposal areas. If not contacted during the tour, then an attempt was made to meet with them on another occasion. Apart from the observations given below, it was noted that managerial staff were less aware of the problems of the water supply and disposal systems and environments than the technical staff and that the technical staff were less aware of the equity issues involved. Technical staff were also less aware of any steps taken to remedy or contribute to problems related to those issues.

In assessing returns to water, data has been obtained from national industrial statistics and applied on a pro rata basis according to workforce. It is recognised that company income may be falsified to national bodies for tax reasons, but they might also be to a foreign researcher, such as the author. To ensure the rest of the questions were answered willingly, it was not considered information effective to pry into financial aspects.

4.2.2 Observations

Water Use

Most of the major water consuming industries of Ta'iz are involved in the processing of foodstuffs and drinks, however the soap and ghee and paint factories also use substantial amounts. As well as using water in the products, the factories use water in the manufacturing processes, particularly for cooling, for steam production and in cleaning equipment and surfaces. Water is also used for general consumption by employees.

The main water related problems noted by the companies were firstly inadequate water quality for the industrial processes involved, particularly high levels of Total Dissolved Solids and hardness leading to scale problems in the cooling systems. Problems with particular constituents, such as alkalinity, sodium, calcium and magnesium and bacterial content were mentioned. Some factories faced problems of water scarcity, particularly where their own wells did not provide water of adequate quality and they have to bring water by tanker. Queues at the supply wells have resulted in delays and loss of production, especially during dry periods. Problems of waste water disposal and conflict with surrounding rural communities over abstractions were also noted and these aspects are discussed in later sections.

National statistics (CSO,1997) indicate that the following proportions of larger industrial establishments (that is, of more than ten employees) face difficulties due to rising water costs

(18%), continuous cut off of water (13%) and lack of water from the public network (26%). Due to the public water supply problems, it is considered that the proportion of the latter category in the city of Ta'iz would be even larger than the national average. Table 4.11 summarises the water use and employment data for the major water consuming industries of Ta'iz.

Table 4.11. Industrial Water Use in Ta'iz.

Company	Water Use	Employees	Consumption m^3/day	Jobs/m^3/day
Soft Drinks	Drinks	32	175	0.2
Bottled Water	Drinking Water	37	200	0.2
Soap & Ghee	Processes	900	1000	0.9
Nadfood (Food and Drink Products)	Product and Processes	850	900	0.9
Ice	Ice	10	10	1.0
Paradise Juice (Juices)	Drinks and Processes	100	60	1.7
Shebani Food (Food Products)	Product and Processes	700	140	5.0
Genpak (Food and Packaging).	Processes	1100	220	5.0
Paint	Product and Processes	160	25	6.4
YCIC (Food Products)	Product and Processes	1850	285	6.5
Total		5739	3015	

Source: Key Informant Interviews

Proctor and Gamble, NCSPI and Bilqis Plastics and Red Sea Detergents account for around another 140m^3/day water consumption (Haskoning, 1990) and from a brief survey of stone cutters, a further 275 m^3/day of water is used in their work. These industries also depend on either their own wells or on tanker deliveries. CES (1997) estimate that around 20% of the public supply is used for small industrial and commercial companies. If the industrial component comprised half of this, that is, around 1800 m^3/day, the estimated total industrial consumption for the Upper Wadi Rasyan area would be 5230 m^3/day +/-15%. This total includes 150 m^3/day imported into the area from the Wadi Warazan catchment and 7 m^3/day exported from the area to Al Mocha. A total industrial water requirement of 150% to double the amount mentioned above has been calculated (As Sayagh;1998) however the calculation is based on standard formulae and not fieldwork.

The annual value of production and profits of the industries in the Upper Wadi Rasyan catchment, assuming the national average and estimated pro rata rate on the proportion of the national workforce, are 20,900MYR and 7,950MYR respectively. Unlike the agricultural water users described in the previous section, industrialists include the cost of providing water within their accounting in the long-term, however the allocation of funds for future investment tends not to be addressed until a 'water problem' arises. On a day to day operational basis, the only aspect of water costs that managerial and technical staffs were aware of how much their tankers had to pay at the well, or, if they received water from the public utility, how much the monthly bill was. Although more data were available to them in their accounts departments, there was no awareness of the actual costs of water in terms of costs of well, pump, pipes and tanker depreciation, staff and running costs. There was, however, a general awareness amongst most technical and managerial staff that water is a costly facet of production especially if production was lost due to the constraint of water supplies. Water conservation measures, including training of staff in water conservation and investigation of water reuse potential were being undertaken by the two larger groups of companies.

Assuming that the Upper Wadi Rasyan area accounts for 80% of the industrial activity in the governorate, the total direct employment in the industries would be 12,700. It is considered this figure is considered accurate to within +/-5%.

Comparison with Agriculture

A comparison of financial and livelihood provision returns to water between irrigated agriculture and industry provides a stark contrast:

Table 4.12: Returns to water: Irrigated Agriculture vs. Industry in the Upper Wadi Rasyan catchment.

	Water Used Mm^3/yr	Net Income MYR/yr. (M$/yr.)	Returns to Water YR/m^3 ($\$/m^3$)	Jobs Provided	Jobs/ Mm^3/yr
Irrigation	30	29.08 (0.22)	1.8 (0.014)	600	20
Industry	2	7950 (61)	4180 (32)	12700	6350

Source: fieldwork

These figures are based on current operating costs for agriculture. When depreciation on boreholes and pumping equipment is taken into account the returns to irrigation water become negative and the contrast is even more stark. The errors built into the above values through the assumptions involved in calculating them do not detract from the conclusion that industry makes far, far better use of water than irrigated agriculture in both income generation and livelihood terms. The trickle-down benefits these industries impart to the service industries would make the contrast greater again.

Industrial Waste Water Disposal

None of the factories visited measured effluent quantities, and management and technicians had no idea of the quantity of their waste water or its concentration and constituents, although the larger groups were aware that pollution is a problem. Surveys by Haskoning (1990) and Water Care Associates (1995), instigated by the Environmental Protection Council and the Hayel Sa'id group respectively, of half the factories included in this study's survey indicated that around 65% of the water supplied to the factories was returned as waste. This would suggest a total of $4400m^3$/day waste water of which at least 75% is not disposed of in the sewerage system.

Apart from an inadequate aeration treatment works at Hayel Sa'id's Nadfood site and a treatment works purported to have been completed at the same group's Soap and Ghee factory since this survey was competed, none of the factories treat their waste water. Disposal is typically to lagoons or wadis near to the factory although Nadfood and Soap and Ghee pump their 'treated' waste to more remote locations. An assessment of the environmental impact of waste water disposal in the Upper Wadi Rasyan catchment was given in section 3.7.

Equity Issues

Because the larger industrial plants are located near agricultural land, they affect the downstream rural communities. Depending on the exact locations the neighbouring rural communities are affected by both abstraction for the factories and by their waste water disposal. In some instances complaints about the smells near the discharge areas have led industrialists to pipe their waste further and further away from their factory, simply transferring the problem to another area. Some industrialists recompense farmers for loss of crops at the discharge point and offer to buy their (now polluted) land. It has been suggested that the polluting of land can be used as a tool to force people to sell it. The farmers expressed feelings of powerlessness in this situation.

Some farmers think the location of industrial discharge near their land is a convenient source of water for irrigation and appear oblivious to the dangers of degrading their soil and toxins entering the food chain. Where water is abstracted some factories try to compensate the affected rural communities by providing jobs, electricity and water, and defaulting on compensation has resulted in conflict in some instances. In other instances the provision of services by the factories has led to opportunistic behaviour by the rural communities. The equity issues raised by these situations are discussed further in section 5.6.

4.3 Rural domestic water supplies

Access to water for domestic use in Yemen provides great contrasts, particularly between urban and rural water access, and forms part of the distinction between urban and rural environments. The following table summarises the provision of water supply and sanitation in Yemen and in the Ta'iz governorate.

Table 4.13: Types of Water Supply and Sanitation in Yemen and the Ta'iz Governorate.

	National Average %	National Rural %	National Urban %	Ta'iz Average %	Ta'iz Rural %	Ta'iz Urban %
Water Supply						
Public Piped Supplies	21.1	6.4	67.5	17.0	3.8	79.5
Co-operative Project	11.9	11.9	11.6	12.1	13.2	6.6
Private Project	5.9	6.0	5.5	3.3	3.2	3.6
Well	37.7	45.8	12.7	48.6	57.2	7.9
Sanitation Provision						
Sewerage Network	10.5	1.2	39.8	11.7	1.2	61.2
Covered Pits	22.7	15.9	44.1	23.3	23.6	21.8
Uncovered Pits	18.2	21.9	6.7	25.9	29.9	7.1
Nothing	49	61.0	9.3	39.0	45.2	9.9

Source: CSO,1996b.

Nationally, the proportion of rural dwellings is 76% of the total whilst that in the Ta'iz governorate is 83%. Based on the national survey, the urban dwellers in the Ta'iz governorate are better served by piped water supply and sanitation than is common nationally, whereas rural inhabitants in the governorate have less provision of these services than the national average. [In the urban situation almost all co-operative and private water supply projects pipe water to the houses whereas in the rural environment the supply may be to a communal tank in the village or may be piped to houses.]

The rural survey described in section 4.1.2 included checklist questions regarding domestic water supplies and sanitation. The villages included in the survey demonstrated a wide variety of water supply sources and problems (Table 4.14).

Table 4.14: Rural Domestic Water Supply

Supply Method	Village	Distance to Supply	Quality EC uS/c	Frequency Reliability	Price/m3	Well/Scheme Ownership	Operated by	Date of Construction	Coverage	Supply to Others
Women	Al Xums	1-2 Km	100-160	Permanent	Free	Farmer		Early '80's	Anyone	Anyone
	Ar Riwaas	< 1Km	5100	Permanent	Free	NWSA	User	Late '60's	Anyone	Anyone
Women (failed piped system)	^adan As Safaa	0-3Km	1100	Permanent	Free	Farmer		Late '80's?	Anyone	Anyone
	Al Malika	< 1Km	1550	Runs 5hrs Waits 2hrs	Free	Farmer		Early '80's	Anyone	Anyone/ Shamiir
Piped	Al ^adan	To each house	1840	4hrs am 4hrs pm Broke down	40 YR (0.31$)	Communal Drilled by SRAD	Community Management	1985	600 houses (16 villages)	Scheme Only
	Al Jahaaza		1000	2 days once a week	20 YR (0.15$)	Private Business		1992	4000 house	Scheme Only
	Al 'anjud									
	Ar Rahayba		1200	Permanent	0 YR/mont (0.15$/mo)	EWC/shayx	Shayx's Management	1985	40 houses	Other Villages by Women

Source: Fieldwork

The villages of Al ^adan, Al Jahaaza, Al 'anjud, Ar Rahaybah and Al Malika have piped supplies (Figure 4.1 indicates locations). The schemes supplying Al ^adan and Al Jahaaza are called the Eastern and Western systems respectively. Both are supplied from wells drilled into the artesian Tawilah Sandstone in neighbouring valleys. They both comprise storage tanks located above the villages they serve which distribute via pipe to individually metered houses. Permission to drill for the Western scheme was delayed due to disputes over water rights. It delivers to 4000 households and was established by local businessmen working in Saudi Arabia. Most people respond to demand management and stop using water from the tap when their consumption for the month reaches $6m^3$, at which point a higher tariff is applied. After this point the locals resort to women and donkeys to bring their water needs. Both the Eastern and Western schemes also charge 50YR/month (0.38$/month) maintenance charge and although the Eastern scheme does not apply an increasing block tariff average, consumption remains at around $6m^3$/month per connection. The main problem facing the Eastern scheme is a lack of spare parts for the pump. This has caused the community to want to hand the scheme back to SURDU who constructed it. This scheme is one of the 92 constructed by SURDU in the Ta'iz governorate by 1986 which at that time served an estimated 220,000 people (FAO/World Bank, 1986:23).

At ^adan As Safaa, the community-managed domestic piped water supply scheme was administered by a government-appointed shayx who used the income to his own ends. A subsequent village-appointed operator also took the revenues. In Ar Rahayba GAREW drilled the well and the local council and local shayx paid half each of the distribution system. The well supplying a private piped scheme to the upper, larger part of Al Malika has dried up, although six houses are connected to another well in the village. Everyone else has to fetch water. The shayx at Ar Riwaas paid for the village to be connected to the government (NWSA) supply and others from much further afield take water from it when their wells dry up.

Where households are not connected to a piped scheme, women and children, with or without the help of donkeys, make two to three trips per day to the well. Because jerry cans are considered too expensive (150YR, 1.15$ for 20lit) and can get punctured by thorns, people often collect water in ex-corn oil containers. NWRA (1999b) estimate that on average women walk 1.7km to collect water each day and spend 2 hours walking and waiting their turn at the well.

Assessments of rural water consumption for domestic purposes consistently suggest 20l/c/d even where there is a communal piped scheme (Mullick,1987, Handley,1996b and NWRA,1999b). This would suggest a consumption of around 2.5Mm^3/yr based on the 1995 Upper Wadi Rasyan rural population. In addition to drinking water, this study estimates a further 90litres per household per day (1.5Mm^3/yr for the area) are collected for cooking and other household duties. This quantity is 70% of the NWRA estimate (ibid.). Over 80% of the NWRA survey respondents considered the amount of water available was inadequate and that they had to spend too much time collecting it (ibid.).

Although no householders interviewed in this survey boiled their water, when the EC exceeds around 1000-1500μS/cm water quality awareness causes them to change source for drinking purposes if feasible in terms of cost and transport. Most of the houses had some form of water storage facility and in some instances 90% of the village had galvanized steel tanks on the roof or adjacent to the house. Wealthier families and small businesses that depend on water (such as chicken farms) bring water by tanker. Water disposal was nearly always to a nearby open pit, minor wadi bed or covered pit.

4.4 Urban Domestic Water Supplies

A summary history of urban water supply in Ta'iz

Water supply is a crucial factor, if not the crucial factor, in the development of any settlement. Records of water supply facilities in Ta'iz go back as far as its history. Neibhur in the seventeen-sixties (Hansen,1983;272) describes large excavations to facilitate rainwater collection. Tradition has it that an aqueduct brought water from Jabal Sabir to the ancient water tank on the west side of Al Qaahira. Water channels dug into the side of the mountain are still evident lower down. A qanat runs from the old Jewish area at the head of Wadi Al Madam into the footslopes of Jabal Sabir. Some think there is also an ancient qanat running from the foot of Al Qaahira due north under Tahriir through the centre of the city to the Imam's pool at ^usayfra.

The twentieth century has seen a huge population increase in the urban area in particular (Figure 4.29) and a commensurate increase in urban water supply problems. The search for solutions goes back at least to 1917 when Cornwallis et al reported that the population of 4000 was supplied by piped water from Jabal Sabir. To this day the Muthaffar mosque continues to receive water from the foot of Al Qaahira and also from its own well.

The first major water supply network, the 'Kennedy Memorial' system was constructed during 1962-1965 and was supplied from shallow wells in the Hawbaan area (Figure 3.1). At that time the population was about 60,000. The Hawjala wellfield was connected in 1970. The next major scheme was the construction of a water supply and sewerage system between 1977 and 1982, utilising the Al Hayma wellfield. The depletion of this field sparked off an emergency drilling programme in 1987 and 1988 immediately to the north of Al Hayma, with extension of the conveyor. Further depletion of the Al Hayma field resulted in the piped water delivery frequency declining to once every 40-days and considerable water stress amongst consumers and at the offices of the public utility, NWSA. The most acute period occurred during summer 1995 and is often termed 'the crisis'.

In order to try to improve the delivery frequency, NWSA increased abstraction from the Hawjala and Hawbaan fields located immediately downstream from the city. These wells receive the sub-surface seepage from the cess pits, leaking sewers and water mains of the city together with the surface run-off during storms. The groundwater in the Hawbaan catchment is also naturally of poor quality. The abstractions from these two fields are therefore of inadequate quality, typically around 5000 μS/cm, and increases the level of pollutants in the city supply as its proportion in the supply mixture increases.

The crisis sparked off another 'emergency' drilling programme, with 18 wells being drilled inside the city in 1995. The production of these wells and the efficiency of their operation are less than might be desired. During 1996, and after 10 years of negotiations with local shayxs and farmers, six wells were drilled in Habir, further north of Al Hayma. The conveyor was extended again, and three wells were connected. They provide good quality water, but are of disappointing yield.

4.4.1 Methodology

Besides the inhabitants of Lower Al Hayma, none have felt the water shortage more than the people of the city of Ta'iz – 400,000 of them. So far, the water shortage was most closely felt during the summer of 1995 when water was available from the public utility once every 40 days. This period is often termed the 'crisis'. The shortage continues to today, although not so acutely, with availability once every 20 days (Figure 4.4). Such water stress presents a unique situation and makes it possible to consider:

a) who is affected,

b) what are their adaptive responses,

c) how this affects their attitudes and perceptions to water-stress and
d) analyse the data from the aspect of the equity.

The analysis examined wealth/income and gender and included the role of children. As part of answering points a and b above, it was also advantageous to know the basic education and employment levels of the households.

Because by its nature the shortage has a historical context, and in order to consider historical trends it was necessary to select a hydraulic event which was distinct in interviewees memories against which to contrast the present situation. The crisis period of summer 1995 served this purpose by being not too far in the past for people to remember, and an event that most of the present population had experienced.

The socially fragmented nature of Ta'iz shows much less cohesion than its rural counterpart and people communicate and interact much less regarding their commonalities. Where RRA and PRA can provide a reasonable view of aspects of rural life because of the interaction and shared views there, by contrast, individual responses seem more accessible in the urban context. However, in order to more closely approach a 'representative' urban sample many users have to be interviewed. For this reason, and because many of the questions required a numerical or 'quasi-numerical' answer, the use of a questionnaire seemed the most appropriate method of data acquisition.

The main part of the survey sought to answer the following questions:
a) How has household water use behaviour changed as water has become more available from the public system?
b) How much water do people use and how much did they use in the crisis?
c) How much time is spent on water related tasks by men women and children and how has this changed since the crisis?
d) What proportion of income is spent on water relative to other expenses and how much was spent in the crisis?
e) What is the relative importance of the following aspects of water supply: price, quality, adequate quantity, reliability, ease of access?
f) To what extent do people relate minimum water use to good health.

The issues listed above had been identified as key areas to be addressed in an assessment of urban domestic water use at the planning stage of this study and during the first two years of field work. The original intention had been to conduct a survey of around 250 questionnaires, however the UNDDSMS study (Handley,1999a) provided an opportunity to conduct a much larger survey (1250 questionnaires) covering wider issues. Those issues are reflected in the questionnaires. Discussion of the questionnaires with Peter Mawson (on contract to UNDDSMS to define the TOR for the urban domestic water use survey) and Alex McPhail (World Bank) and input from them are gratefully acknowledged. A questionnaire was developed that would address the issues listed above, disguise income related questions, present the questions in a socially acceptable order and manner and be as brief, relevant and easy to comprehend as possible (Figure 4.30). Random sampling of 1028 houses was carried out with separate male/female interviews in 222 households. The sampling permitted analyses on the basis of income (Table 4.16) and tests for significant differences between male and female responses. Copies of the Arabic and English questionnaires used in the main survey are contained in Appendix A and details of sampling and analysis are given in Appendix B.

Table 4.16. Skewed distribution of household income.

Bracket	Income	Sample (No of Households)
1	Lowest	149
2		442
3		215
4		80
5		52
6		40
7	Highest	50

Source: Fieldwork

4.4.2 Results Summary

In reading this section it should be borne in mind that the analyses are no better than the quality of the answers to the questionnaire. The relatively poor correlation coefficients obtained from the expenditure analysis described in appendix B were symptomatic of the quality of the numerical data. The tests for significance did however suggest that the following observations could be made.

Demography

There are many factors contributing to and resulting from differences in wealth and opportunity in Ta'iz. Demographically, the highest income bracket households comprise twice as many men and almost twice as many women, and fewer children than the lowest income bracket households (Figure 4.5). These trends contribute to increasing incomes and decreasing costs among the wealthier. However, from the paired gender data (analysis b in

Appendix B) women gave significantly lower estimates (at 5% level) of the number of men per household and the number of men finishing primary school. Paired data indicated that the women gave a higher estimate than the men did of the number of men with jobs.

Women gave a lower evaluation than men of the number of women in the household. The difference was only slightly significant at the 5% level, but the same variation was indicated in the paired data and was significant at the 0.1% level. Similarly the women in the paired sample gave a significantly lower estimate (at 5%) than the men did for the number of children, and for the number of children who could read and the number of children who had finished primary and secondary school. Enumerators noted that women generally took more care over answering the questions related to household members than the men. Women's responses were considered more accurate.

Expenditure

The highest income bracket ranked expenditure on qat two ranks higher than the lowest bracket, rent three ranks lower (because they mostly own their houses), health one rank lower and education one rank higher (despite having fewer children) than the lowest income bracket.

The proportion of expenditure on water as part of the items listed in Table 4.17 is around 4%. Per capita expenditure on water increases slightly with income (Figure 4.6, see section 4.5.2 regarding the proportion of income spent on water for different income brackets), and consumption may also increase slightly with income bracket.

Table 4.17: Differences in female and male ranking of expenditure by gender analysis (Methods a and b defined in Appendix B, figure gives female rank minus male rank.)

Item	Food	Rent	Education	Qat	Electricity	Water	Clothes	Health	Transport
Rank a)	+0.16	-0.23	-0.12	-1.06	+0.22	-0.27	-0.23	+0.29	-0.20
Rank b)	+0.52	+0.25	-0.30	-0.05	+0.74	+1.16	-0.11	-0.44	+0.33

Source: Fieldwork

The table suggests women think more is spent on food and electricity than the men think. Men think more is spent on qat, education and clothes than the women think. Because the purse strings are usually held by males, their view is considered more accurate.

Figures 4.7 to 4.10 indicate that there are more adult readers and more employed people in the higher income groups, although the proportion of people in the household with jobs peaks in the middle income brackets. Men have received significantly more education than women at all education levels and incomes. 10% of the households sampled had no one with a job. Most of the households without employed persons were in the lower income groups. 10% of the lowest income group households had no adult readers.

The poor may be characterised in general terms as not owning land, houses, or a variety of consumer variables that are owned by the rich. Number of rooms in the dwelling also correlated strongly with income category. Most of the villas are occupied by those from the upper income groups. The axdaam (servant) caste forms a portion of the lowest income group. All those occupying temporary housing were in the lowest income group and many of them were axdaam. They typically have no wastewater disposal facility. The lowest income group not only includes axdaam, however, and other poor families also were without any sanitation.

Water Use Patterns

Other differences between rich and poor highlighted by the survey include the presence or absence of water-related facilities (Figure 4.11). In particular the number of wash basins, the amount of water storage capacity, particularly in expensive ground tanks, and the presence of flush toilets instead of non-flush all indicated wealth. Households not connected to the public utility tend to be poorer, and those connected to a private supply, wealthier (Figure 4.12). There are six main sources of water in the city:

a) Public Utility, NWSA. (Coverage is indicated in Figure 4.13).
b) Private Piped Supplies. (Coverage is indicated in Figure 4.13).
c) Tanker Supplies. (Wells supplying them and tanker centres are indicated in Figure 4.14).
d) Free water (which can be obtained from government, private and mosque standpipes at various locations around the city).
e) Bottled water (available from grocery stores).
f) Jerry can water. This water is distributed to grocery stores where it is purchased as treated drinking water. It can be also be purchased from the companies which treat the water and their branches, however it is not referred to here as 'treated water' because it may not have been treated.

Table 4.18: Mean water prices from the different sources.

	Jerry Can	Bottled	Free	Tanker	NWSA	Private
Price YR / m^3 (\$/m^3)	2687 (20.7)	26,000 (200)	0	285 (2.2)	24 (0.18)	63 (0.48)
% Using Source	74.4	4	35.2	33.5	84*	4.5

* Best Estimate
Source: Fieldwork

Water has to be obtained from all of the non-piped sources and this takes time. The time spent is related to income, poorest income bracket families spending nearly three times longer than those in the wealthiest bracket (Figure 4.15). A higher proportion of wealthy families obtain tankers, and the collection of free water is much more significant amongst poorer families (Figure 4.12). Poor families sometimes share NWSA connections in order to reduce connection fees. However this can result in water consumption being pushed up into the next block of the tariff and, in the end, both families pay more for their water. Water collection is mostly done by children. A higher proportion of children from poorer households collect water than from the wealthier households (Figure 4.16). Women think more time is spent collecting water and that more children and women are involved than the men think.

Table 4.19: Percentage of men, women and children responsible for collecting water. (according to men and women).

Responsibility for Collecting Water	Men	Women	Children
According to Men	48	3	40
According to Women	37	7	52

Source: Fieldwork

Although the number of women collecting water is much less than the number of men, the women's views are considered more realistic. All other water related tasks are almost entirely done by women, apart from watering gardens, which is evenly shared between men and women. Lower income households are more likely to keep livestock than wealthier ones and hence spend time watering them. In contrast, more wealthier families have gardens than poorer families, and have to spend time irrigating them. There is a significantly higher consumption of NWSA water for watering gardens amongst the rich.

Although around 75% of all income brackets use jerry can water for drinking, the rich also use it for cooking.

less willing to pay for a regular daily supply of water than men are, and are also less interested than men in a private supply. More essential water uses, such as drinking and cooking, become less important to users in higher income groups and more important to lower income households and vice versa.

Consumer Attitudes and Household Social Adaptive Capacity to Water Stress

The current water shortage is considered to affect convenience primarily, followed by cleanliness and health, and still fewer people think it has no effect on them. A similar sequence was indicated when respondents were asked what the effect on them would be of a future increase or decrease in supply. A greater proportion of wealthier people than lower income households consider there is no impact on them from the current water shortage (Figure 4.23). A greater proportion of wealthier people than lower income households also think there would be no effect on them in the future if more or less water were available. It is inferred that the wealthy are more cushioned from the water stress than poorer households.

60% of respondents considered they would change their water use practices if there were a change in water availability. Fewer wealthy than poor thought they would change their practices if water supplies were reduced. More men than women think less water would be used in household activities if less water were available. However, a higher proportion of women, who do the tasks, think the water use would be the same. Men seem less aware than women, perhaps, of the difficulty of reducing water consumption in these tasks below the current, suppressed demand level.

A greater proportion of NWSA supplied households than private or non-supplied would reduce consumption if less water were available. More privately supplied households than NWSA supplied households thought they would use the same amount of water if the supply decreased. Thus, the NWSA-supplied households appear to have a greater awareness of the consequences of reduced supply, confirming they experienced the impact of the NWSA water crisis (measured in terms of decreasing supply frequency) much more.

The effect of water shortage or abundance on health and cleanliness were considered less important than the effect on convenience. The impact of current or future water shortages or increases in supply on health, cleanliness and convenience was considered less significant by the rich than the poor (Figure 4.23). 90% of the poorest category of those interviewed thought lack of water was detrimental to health. This proportion declined to 70% of the wealthiest category. The current water shortage was blamed by some for their health problems.

Consumers are well aware of the increase in reliability, quality and amount spent on NWSA water since the crisis, and access to water in general has been perceived as easier since the crisis. Trends of less water being used, more time spent collecting water and less time spent in water-related activities during the crisis relative to now were noted more by women than men. Lower income households were more aware of using less water during the crisis compared with water consumption now than were higher income households. A greater proportion of NWSA supplied households than non-NWSA households responded to the crisis by:

a) changing their water use practices,

b) getting more water and using less during the crisis, and

c) now using more water than they did during the crisis.

These observations suggest that the NWSA-supplied households felt the impact of the crisis more than the non-NWSA-supplied households.

The water crisis of summer 1995 highlighted some of the problems and issues of water supply in consumers' awareness. Although the proportion of people utilising jerry can and tanker water supplies was the same as now, the amount of water obtained from them was significantly greater (Figure 4.24). More people were accessing free water, and were also accessing more of it, during the crisis. When the public utility supply failed to provide, many more people received a quantity of water in the flat rate part of the tariff structure. As consumption falls below 10m^3/month (the maximum within the flat rate tariff), people end up spending more per m^3. Thus for 11m^3/month the consumer paid around 270YR, 2.1$ (water and sewerage) that is, 24.5YR(0.19$)/m^3. If the supply rate falls below 5m^3/month the cost per m^3 exceeds this. For instance 3m^3/month at the flat rate of 120YR(0.92$) minimum charge is equivalent to 40YR(0.31$)/m^3. Thus, more is paid per m^3 when the water cannot be delivered! Consumption of NWSA water was more strongly related to income during the crisis, with higher income groups consuming more than lower income groups, than is currently evident. Estimated consumption of NWSA water was reduced by around a third during the crisis relative to the time of the survey.

A lower bound estimate of consumption of NWSA water during the crisis should be based on NWSA records of water sold. The mean monthly NWSA water sales for 1995 was 196000m^3 with an average delivery frequency of 21.5days giving 138350m^3 delivery on each occasion.

A 40 to 45 day delivery interval suggests approximately half this consumption. Assuming 20% is supplied for non-domestic use (CES et al, 1997), and 75% or 90% NWSA coverage, the household consumption from NWSA would have been 2.14 m^3/month or 1.78m^3/month respectively, equivalent to 7.8 or 6.5 lit/capita/day.

4.4.3 Conclusions

There are large differences in wealth and opportunity between rich and poor in Ta'iz. Many of these differences are reflected in water use patterns and in attitudes and perceptions regarding water. Tanker, private piped, bottled and to some extent, public utility water sources are all accessed more by wealthier households and free water by poorer ones. However, the overall low level of supply, close to the WHO recommended minimum, has suppressed the demand for water. Although the wealthy have a much greater capacity for storing and using water, this capacity is not fully realised, and any future increase in supply is likely to be used disproportionately by this sector. Poorer households prefer water, from whatever source, primarily on the basis of price, and will spend much more time fetching it. Wealthy people are more interested in quality.

Most of the water provided by the public utility to the city supply operates on a system of recirculating polluted water. Water is pumped from the Hawjala wellfield to the city where, after use, it seeps from the cess pits and leaky sewers back to the well field. Low quality supply from the public utility has led to the sharp increase in the number of drinking water treatment companies. With 75% of the population drinking treated water, a dual supply system is effectively operating. Although people would prefer a high quality piped water supply, they are not willing to pay much more for it. In the absence of large amounts of high quality groundwater being discovered in the area, dependence on a dual supply is likely to continue for some time. People had to obtain more water from alternative sources during the 1995 crisis of the public utility supply. These sources (apart from free water) are more expensive. Because of the expense and the loss of convenience, people changed their water-related activities considerably.

Consumers are acutely aware of differences in time and money spent on the various water related activities and water sources as availability changes. They are also well aware of variations in water quality and to some extent of health implications of declining water availability and quality. The private sector has shown its ability to adapt and evolve to the need for improved quality drinking water and to provide in times of shortage.

4.5 Water Markets

As indicated in the previous sections, water is widely bought and sold in the Ta'iz area, that is, water markets exist. It is the purpose of this section to examine their size and how they function. Three fundamental types of water market are identified:

Table 4.22: Types of Water Market in Ta'iz.

Market Type	Specific Markets
Rural - Rural	Irrigation (Described in agriculture section)
Rural - Urban	Public Piped, Tankers, Private Piped, Free Water
Urban - Urban	Jerry Can, Bottled

Because of the distribution of water resources nearly all of the water used in the city is sourced from rural areas, however jerry can and bottled water could be considered separately since this is 'produced' and sold in the urban setting.

4.5.1 Methodologies and Descriptions

Private Piped Supplies

Each of the operators of the six private schemes operating in the city were interviewed. Each is essentially operated by one man and in total they supply not more than 230m^3/day piped water to small, specific parts of Ta'iz (Figure 4.13). This estimate is considered accurate to +/- 20% and is based on tank sizes for the borehole schemes, and header reservoir sizes in the case of the spring-based schemes. Table 4.23 records some of the key data obtained from the private piped water suppliers.

Four of the schemes are located on the slopes of Jabal Sabir where they tap spring sources. The declining yields of the spring-sourced schemes is considered to be due to the increased use of water upstream in the villages of Jabal Sabir for domestic purposes or qat irrigation. An increase in qat irrigation on the Northern slopes of Jabal Sabir during the period 1986-1995 has been confirmed by satellite image studies (Leung,1999). Although of good overall quality, the spring water is rich in fluoride, and accounts for the characteristic brown 'Ta'iz teeth'. Apart from in Saalah, households connected to the other schemes also receive NWSA water and are dependent on it for their non-potable supply. Yields from the schemes barely cover the potable water requirements.

Private Piped Water Supplies

Name of private piped scheme		Saalah	Al Haadi	Al Hindi[2]	Al Magraba	Ash Shallaal[3]	Al Abyad
Number of connections		210	120[1]	12	70	20	30
Frequency of supply days/mo		30	15	30	4		30
hrs/day		0.5	0.5	24	0.5		12
source		spring	spring	borehole	spring	spring	borehole
Total Vol Water supplied daily (est. m3/d)		30	18	5	2.5	0	13
lit/capita/day		15	10	50	2.6	0	50
Also connected to NWSA?		No	Yes	Yes	Yes	Yes	Yes
Supply Sufficient or Supplemented by:		Dabba	Dabba	Sufficient	Some Dabba	Dabba	Sufficient
Cost of Connection[4]		Physical Only	No new connections	na	No new connections	No new connections	Physical Only
Previous arrangement if no new connections			Was only for physical	na	Was only for physical	Was only for physical	
Charging Method: Meters?		Flat Rate	No one pays	na	Flat Rate	Was Fixed	Flat Rate (meters dont work)
Billing Frequency		Monthly		na	Monthly	Monthly	Monthly
Customer Categories		Rich / Poor[5]		na	Rich / Poor[5]	Was Rich / Poor[5]	Estimates consumption
Tariff Structure		50-150YR/mo		na	50-150YR/mo	Was 50-150YR/m	500-1000YR/mo
		Pay for Repairs			Pay for Repairs	Pay for Repairs	Customer does not pay for repairs
Method of revenue collection		Receipt		na	Receipt		
Non-payment action		Disconnect after 1 month	Allowed to fall into disrepair	na	No action	na	Disconnect after 1 month
Cost of production YR/m3		30	13	16	63	na	5
Revenue recovered YR/m3		23	0	0	93		100
Profit YR/m3		-7	-13	-16	30		95
Consumer view of service:	Quality	Good	Good	Say its good	Good	Good	Bad
	Price	OK	OK	na	OK	OK	Bad
	Quantity	Insufficient	Insufficient	Sufficient	Insufficient	Finished!	Sufficient
Drink Bottled Water Instead?		No	No	No	No	No	Yes
Management / Ownership		Co-operative Non-profit	1 man Non-profit	1 man na	1 man Non-profit	1 man Non-profit	1 man For Profit

1 520 connections in mid-80's
2 Dried up in 1997
3 Family connected only
For dollar equivalent divide by 130

4 In all cases the consumer only paid for the pipes required from his house to the nearest main.
5 The revenue collector determines what should be paid according to ability to pay.
na not applicable

Table 4.23 Taiz Private Supplier Survey - Piped Connections

Because of the limited supply, the spring water is used only for drinking, except for the Saalah scheme where there is no alternative non-potable NWSA supply. No new connections are being added to the spring-based schemes. The limited supply causes consumers even to supplement their drinking water needs with jerry can (dabba) water.

In all the schemes the customer arranges and pays for the physical connection between his house and the main, and no connection fee is charged. In each of the spring-based schemes, except Al Haadi, the customers are assessed by the operator for their ability to pay and are charged accordingly. A similar system operates when repairs are needed. In calculating the cost of production of the spring-based schemes, the reservoir and distribution systems have been valued at 1MYR and 1MYR per Km of mains, discounted over 30 and 20 years respectively. All three schemes only allow for the operating costs including a small allowance for the operator and have no funds allocated for capital works replacement. The Saalah scheme is the largest, and operates as an essentially non-profit co-operative.

The Al Haadi scheme theoretically belongs to the 'awqaaf (religious endowment ministry) but no one pays for their water. Appropriation of water by force by some of the wealthiest sections of the Ta'iz community combined with a declining resource, has discouraged the person responsible for its upkeep and the system has fallen into disrepair, the number of connections declining from 520 to 120. All four spring-based schemes are running at a loss and, in the absence of maintenance, are steadily deteriorating. Of the two schemes based on well supplies in the city centre, one only serves the houses of the immediate family and the other sells water to about 50 houses at a profit.

In summary, the private piped schemes are in decline due to failing water resources and unsustainable institutional arrangements and form a negligible contribution to the water supply of Ta'iz.

Private Wells

Apart from the springs supplying the private piped supply schemes described in the preceding section, all water consumed in the city is derived from wells, most of which are located outside the city. Eighteen of the main wells that account for supplying at least 95% of the tankers were visited, and operators were interviewed regarding water sales. The main findings are summarised in Table 4.24 and the well locations are indicated in Figure 4.14.

Well Data	Well Name	Sa^iid Mahyuub	Ahmad Sirhan Haamid	Ahmad Hassan	Mohammad ^abdu	Ali Qaaid Mohammed	Al Hindi	Al Udayni	Ar Rayaan (Mosque)	Al Abyad (Mosque)
Well Location		Hawbaan	Hawbaan	Hawbaa	Hawbaan	Hawbaan	26-Sep	Ad Dabu^a	Tahriir	Tahriir
Involved in Irrigation?		y	y	y	y	y	n	n	n	n
Well Depth (m)		50	52	50	52	50	200	120	100	150
Discharge (litre/sec)		3	3	4.9	5.1	2.6	2	2.9	2.4	4.5
hrs/day		17-18[1]	17-18[1]	12[1]	11[1]	12[1]	10	12	12	11
Number of Tankers / day	Small[3]	50	50-40	50-60	30-40	10-15	15-20	20-25	15-20	20-30
	Large[4]	2-3	0	1	0	0	0	0	0	1-2
Water sold to tankers (m^3/d)		153	117	151	91	33	46	59	46	77
Tanker payment at well	Small[3]	50	50	50	50	50	130	120-130	130	120-130
	Large[4]	150	150	150						
Consumer Perception of Quality		Poor	Poor	Poor	Poor	Poor	Acceptable	Acceptable	Marginal	Marginal
Gross well income (YR/day)		2875	2250	2900	1750	625	2275	2820	2275	3300
Gross well income (YR/m^3)		19	19	19	19	19	50	48	50	43
Profit less running costs (YR/d)		2520	1979	2686	1626	538	1963	2543	2015	3066
Profit less running costs (YR/m^3)		16	17	18	18	17	43	43	44	40
Profit less depreciation and running costs(YR/d)		-154	-148	-247	-212	-165	-1045	-735	-665	-907
Profit less depreciation and running costs(YR/m^3)		-1	-1	-2	-2	-5	-23	-13	-15	-12
* Profit less depreciation and running costs(YR/d)		-99.8	-91.3	-192.2	-155.1	-110.5	-612.7	-475.3	-448.8	-583.1
* Profit less depreciation and running costs(YR/m^3)		-0.7	-0.8	-1.3	-1.7	-3.4	-13.5	-8.1	-9.9	-7.6

[1] Includes irrigation time

[2] Also supplies public standpipe

[3] Varies from 2000 to 2700 lit, typically 2400 lit
There are also some medium sized around 4000 lit

[4] Varies from 8000 to 12000, typically around 10000 lit

* Net profits with depreciation period doubled to 30 years for wells and 20 years for equipment

For US dollar equivalent divide by 130

Table 4.24 Private Wells Supplying Tankers. Taiz.

Well Data	Well Name	Al Yaafa^i (Mosque)	Hizaad (Mosque)	Al Qirshi (Mosque)	At Taajir	Kaamil	Al Hamaadi	Mohammad Naaji	Daa'il Naaj Sultaan	Usaywaraan Daa'il Zaa'id	Total
Well Location		Najd Alla Akbar	Ar Rahman Masbah	Tahriir	Dabbab	Dabbaab	Dabaab	Dabbaab	Al Hawjala	^usayfra A3-198	
Involved in Irrigation?		n	n	n	y	y	y	y	y	y	
Well Depth (m)		90	150	150	90	30	90	30	54	50	
Discharge (litre/sec)		1.9	2.6	1.9	12.5	4.2	10.7	3.8	3.3	3.8	75.1
hrs/day		10	12[2]	11[2]	14[1]	12[1]	14-15[1]	12[1]	11[1]	12[1]	
Number of Tankers / day	Small[3]	15-20	10-11	7-10	20	10	15	12-15	3	8-15	
	Large[4]	0	0		10	2-3	10-12	0			
Water sold to tankers (m^3/d)		46	29	26	130	46	130	39	8	39	1262
Tanker payment at well	Small[3]	125-130	120	130	40	40	40	40	50	80	
	Large[4]				110	120	120				
Consumer Perception of Quality		cceptabl	Acceptable	Acceptable	Good	Good	Good	Good	Poor	Poor	
Gross well income (YR/day)		2275	1320	1300	2100	800	2070	600	150	1500	33185
Gross well income (YR/m^3)		50	46	50	16	18	16	15	19	38	
Profit less running costs (YR/d)		1946	1169	1112	2028	725	1986	529	134	1359	29922
Profit less running costs (YR/m^3)		43	41	43	16	16	15	14	17	35	
Profit less depreciation and running costs(YR/d)		-553	-990	-953	-226	-114	-227	-111	-131	-85	-7669
Profit less depreciation and running costs(YR/m^3)		-12	-35	-37	-2	-3	-2	-3	-17	-2	
* Profit less depreciation and running costs(YR/d)		-358.7	-666.1	-629.2	-127.8	-81.2	-128.7	-78.7	-72.0	-30.8	-4942
* Profit less depreciation and running costs(YR/m^3)		-7.9	-23.3	-24.2	-1.0	-1.8	-1.0	-2.0	-9.2	-0.8	

[1] Includes irrigation time
[2] Also supplies public standpipe
[3] Varies from 2000 to 2700 lit, typically 2400 lit
There are also some medium sized around 4000 lit
[4] Varies from 8000 to 12000, typically around 10000 l
* Net profits with depreciation period doubled to 30 y

For US dollar equivalent divide by 130

Table 4.24 Private Wells Supplying Tankers. Taiz.

The well discharge was determined from the time required to fill a tanker. It is suspected that well operators may exaggerate the number of hours per day the wells are operating, and, for the wells outside the city, the operation time given in Table 4.24 includes the time the well is used for irrigation. For a variety of reasons the wells are not operated every day of every month. The well operator's estimate of running time is given without taking into account over-(or under-) estimates. Obtaining a reliable figure regarding the number of tankers supplied per day from well operator responses to survey questionnaires is also hazardous. Fear that the survey is for taxation purposes might lower the estimate, or a desire to be considered the owner of the most important and reliable well to prospective customers might raise the estimate. For these reasons the number of tankers per day collecting water from the well is only considered accurate to +/- 25%. Wells which do not have a storage tank of significant size in which to hold the water pumped from the well when tankers are not being filled are particularly limited in their delivery capacity. Wells are also limited in delivery capacity, even if they do have a storage tank, if they lack more than one delivery hose. The Ta'iz wells have neither storage tank nor more than one delivery hose. A well yielding the typical 5 lit/sec cannot turn round more than 50 tankers of $3m^3$ capacity in a 10 hour working day with no lunch or qat breaks.

There is no seasonal variation in price, although some wells increased the price slightly during the water shortage of summer 1995. The only wells yielding good quality water are in Wadi Ad Dabbaab and there is a slight recognition of this in the price paid by the customer. The income generated by sales to the tankers is indicated in Table 4.24.

In calculating the diesel and oil costs, it has been assumed that the motors use 200YR(1.5$) of diesel and 100YR(0.77$) of oil in a 12 hour day (well operator estimates, summer 1997 prices). This amount has been applied on a pro-rata basis according to the operating period calculated necessary to fill the tankers. Maintenance costs have been estimated at 20% of the depreciation. None of the private well operators do sufficient business to warrant employing others so no deduction for salaries has been made in calculating running costs. Although these assumptions are based on discussions with well owners, they should be considered rather approximate.

Table 4.24 indicates the difference between pre-depreciation profits versus the real loss all the wells are incurring when depreciation is taken into account. This difference is particularly marked for the drilled wells (those greater than 90m) where the construction costs are significantly greater than for dug wells. The dug wells are located outside the city and are also involved in agriculture (and, in some instances, block manufacture). To them, the income from the tankers represents immediate cash as opposed to the seasonal income from the farm. Many of the private wells were constructed with remittances from Saudi during the pre-Gulf War boom, a factor which could contribute to depreciation not being 'felt' or accounted for by the operators.

Water quality is poor in most of the wells except those in Wadi Ad Dabbaab and there is no regular monitoring of the resource in terms of water levels and abstractions. The ability of the wells to maintain a service was severely tested during the water crisis, with some wells running dry. However they provide a vital supply line both for low quality water when the public utility fails and, more importantly, providing the main source of 75% of the population's good quality drinking water.

Water Tankers

Water may be obtained from vendors who usually own small tankers of approximately two to two and a half cubic metres. There are a few larger ones of four to five cubic metres. The tankers fill up at wells mostly outside the city and congregate at the six centres indicated on Figure 4.14. Each centre is organised into a rota by an elected, overseer who is paid by the driver. During August 1997, a survey of water tankers was carried out. Five tankers at each of the depots (a sample of 30% of the total number of tanker operators) were interviewed regarding:

a) the wells they obtain water from,
b) how much they pay for the water,
c) where they deliver to,
d) how many trips they make,
e) how much they sell for,
f) what their running costs are,
g) what new equipment costs, how long it lasts, and what maintenance is needed.

In most instances, each driver owns his own tanker and there are no indications of cartels in operation. The tankers deliver to the area surrounding their centres and are not usually asked to deliver further afield due to increasing cost with delivery distance. One exception is tankers which fill up with high quality water from Wadi Dabbaab, which may be asked to deliver to any part of the city. Results of the survey are presented in Table 4.25.

Tankered Water Supplies	Centre:	Bir Baasha	Usayfra	San'a	Muruur	Madina	Bir Hindi	Total
Number of tankers operating from pick-up point		25	8	30	12	20	8	103
Size of tanker (m3)		2.1	2.4	2.275	2.1	2.4	2.1	
Distance to source (Km)		5	3	2	1	0.5	0	
Number of trips / day		5.3	5	5.9	5	5.1	4.2	
Total number of tankers/day	(tankers/day)	133	40	177	60	102	34	545
Total m3 delivered /day	(m3/day)	278	96	403	126	245	71	1218
Cost to tanker at source	(YR/tanker)	40	80	50	90	120	120	
	(YR/m3)	19	42	22	43	50	57	
Cost to customer at pick up point	(YR/tanker)	550	600	610	540	600	570	
	(YR/m3)	262	250	268	257	250	270	
Cost of transportation: well to pick up point	(YR/tanker)	510	520	560	450	480	450	
	(YR/m3)	243	217	246	214	200	214	
	(YR/m3/Km)	49	72	123	214	400	No Distance	
Cost to customer at 2Km delivery point	(YR/tanker)	910	810	870	760	880	880	
Cost of transportation after 2Km delivery	(YR/m3/Km)	124	146	205	223	304	380	
Running Costs per tanker (Petrol + Oil)	(YR/mo)	21200	17520	22400	21600	16800	22000	
Income per tanker after deducting running costs	(YR/mo)	88510	76230	99730	62400	78060	54230	
Income per tanker after deducting maintenance and capital costs (YR/mo)		75030	62750	86250	48920	64580	40750	
Total expenditure on tankers by customers	(YR/day)	72875	24000	107970	32400	61200	19152	317597
Total income by tankers excluding maintenance and capital costs	(YR/mo)	2212750	609840	2991900	748800	1561200	433840	8558330
Total income by tankers including maintenance and capital costs	(YR/mo)	1875750	502000	2587500	587040	1291600	326000	7169890

(Data are average of five tankers per centre)

For US dollar equivalent divide by 130

Table 4.25 Tankered Water Supplies. Taiz

Table 4.25 gives averages for the five tanker operators interviewed at each depot. In calculating depreciation drivers estimate the new price of the basic truck, tank, pump and hose at 1.1MYR(8500$), 50,000YR(385$), 60,000YR(462$) and 15,000YR(115$) respectively. These prices have been discounted over ten, five, five and three years respectively. Running costs were obtained from the drivers for petrol and oil and averaged 4500YR(35$)/week and 2400YR(18.5$)/month respectively. No labour costs are incurred. Maintenance has been estimated at 20% of the purchase price spent over the depreciation period. After deduction of running costs, maintenance and depreciation, a very adequate income is provided if the demand for tanker water remains high (at five, or more, trips per day). When demand is high, tanker driver income is considerably more than the average income (as determined from the expenditure survey). However, when the NWSA supply improves, there is a prompt decline in work for tankers. To offset this risk, the tanker drivers can remove the tank and pump and become general hauliers instead.

The tankers are providing between 30% (for the lowest income group) and 55% (for the highest income groups) of the city with water. A major issue with the tankers is the water quality. Apart from incorrectly informing the customer regarding where they get the water from, tankers have been observed emptying cess pits and dumping it in the nearest wadi. Whether they are cleaned out before delivering the next load of 'clean' water is not known. Although they are supposed to be cleaned out regularly drivers often bribe the 'baladiyya' inspectors not to bother them. There is, therefore, a need for legislation, spot checks, and for enforcement of quality standards.

Despite some shortcomings in the tanker service, they form a very effective safety valve to cover times of shortage. They rapidly adapt to changes in demand and maintain a round-the-clock service. They are also much more efficient at delivering water than the public utility, with little to no losses, and are more consumer aware.

They do not, however, cater for the poor, and, in fact, they typically prove more expensive for poorer clients. One reason for this is because there are proportionately more poor living in multi-storey apartments, and if there are more floors to lift the water up, tanker drivers charge more. A second reason is that many of the poor are located at the edges of the city. The outskirts are the main areas receiving new arrivals from the countryside and where land and rents are cheaper. These are the same areas which are not covered by the public utility and therefore need the tanker supply, but they are also further from the tanker depots and are often not served by asphalted roads, so, again, tanker drivers charge more to deliver to these areas.

Drinking Water Treatment Companies

All eighteen drinking water treatment companies were visited during the summer of 1997 and their operators interviewed regarding water supplies, processing, distribution and sales. Their responses to the interviews are presented in Table 4.26. Water is collected from good quality wells, either in Wadi Dabbaab or from Dhi Sufaal (near Al Qaa'ida) in owned or rented, dedicated tankers. The tanker brings water to the plant where it is processed first through a sand filter, then a fine cotton filter to reduce particulate matter and lastly through one or more Du-pont reverse osmosis (RO) cylinders to reduce salinity. For micro-organisms chlorine is claimed to be used. Although a chlorine bottle was often noticed at the plants, they were not generally connected because any hint of chlorine in the taste reduces sales. Some plants also add chemicals to the water in an attempt to precipitate salts and control pH. The key to processing the water is the RO equipment which is brought (or smuggled) from Saudi. The RO plant has some wastage, and ideally should be cleaned at periodic intervals to maintain efficiency. However this is seldom carried out, and rather than the manufacturers design wastage of 15%, the actual is around 50%.

A wide range of product quality can be found. Some operators manage to reduce the salinity whilst others actually manage to increase it. In fact the sources are of reasonably good quality and were no treatment, except filtration, carried out, would produce an acceptable product for the public palate.

Water distribution is either direct from the plant via 5, 10 or 20 lit plastic jerry cans carried by pick-ups to the shops. Alternatively, many of the processors have branches and distribute to them by tanker (either the same tanker that brought the water, for low production plants, or another, usually smaller tanker, if the water-fetching tanker is busy). The jerry cans may be owned by the drinking water treatment plant, the shops or the customer. Processing plants also sell a small amount of water direct to the public who live in the immediate vicinity. The branches contain a storage tank and a few taps for the public to fill from in a small room fronting onto a road. There are also various unofficial branches which receive water from one or more drinking water treatment companies. The water is sold for 15YR(0.115$) per 10 lit jerry can and 7.5YR(0.058$) per 5 lit to the shops and branches who in turn sell it for 20YR(0.15$) and 10YR(0.077$) respectively to the public. Jerry can water prices are relatively fixed throughout the city, though more is charged per litre for smaller quantities

Company	Kawther	Makka	Al Janatayn	Al Axawayn	Al Haram Makka	Al ^ayn	Zamzam	At Tahliyya	Al Fardaws	An Niil	Al Gadiir	Al Wujaana	Al Wahda	Al Hanaa'	As Salsabiil	An Na^iim	Tayba	Al Ward	Total	Mean
Location	Jamaal St	Baab Muusa	Al 'ujaynaat	Siina	Bir Baasha	Al Mujalliya	Bir Baasha	Farazat San'a	Farazat San'a	Kalaaba	Al Huraysh	Al 'ujaynaat	Al Hurays	Al Huraysh	Usayfra	Al Huraysh	Usayfra	Al 'ujaynaat		
Operational Since	89	96	96	96	96	95	93	94	94	93	96	90	96	95	90	90	95	96		94
Tankered Deliveries / day	4	2	3	3	2	3	6	2	2	4	2	3	2	1	2	2	4	5	29	
Tanker Owned?	y	y	n	n	y	n	y	y	y	y	n	n	n	n	y	n	y	n	9y,9n	
Source of Water	Ad Dabbaab	Ad Dabbaa	Ad Dabbaab	Ad Dabbaab	Ad Dabbaab	Ad Dabbaa	Ad Dabbaab	Al Qaa'ida	Al Qaa'ida	Al Qaa'ida	Ad Dabbaa	Ad Dabbaab	Al Qaa'ida	Ad Dabbaa	Ad Dabbaab	Ad Dabbaab	Ad Dabbaa	Ad Dabbaab		
Water Treatment c=cotton filter, s=sand filter, ro=reverse osmosis	c,s,ro	c,s,ro	c,s,ro	c,s,ro	c,s,ro	c,s,ro	c,s,ro	c,s,ro	c,s,ro	c,s,ro	c,s,ro	c,s,ro	c,s,ro	c,s,ro	c,s,ro	c,s,ro	c,s,ro	c,s,ro		
Use of Chlorine?	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y		
Distribution Method (Tanker / Pick-up)	tanker	pick-up	tanker	tanker	tanker	pick-up	pick-up	tanker	tanker pick-up	pick-up	tanker	tanker	tanker	tanker	pick-up	tanker	tanker	tanker		
Pick-up owned/rented?	o	o	o	o	o	r	o	o	o	r	r	o	r	o	o	o	o	o	14o,4r	
Water input lit/day	16000	8000	8000	16000	8000	8400	9000	16000	6000	16000	8000	8000	6000	5000	6000	4000	16000	16000	180400	
Sales of 10 lit dabba /day (No.)	50	40	30	40	60	300	50	40	20	40	30	150	50	30	50	20	60	70		
Sales of 5 lit dabba /day (No.)	50	25	35	25	20	120	50	20	15	30	25	50	20	35	25	10	50	45		
liters sold per day by dabba?	750	525	475	525	700	3600	750	500	275	550	425	1750	600	475	625	250	850	925	14550	
Number of Branches	6	3	2	6	2	0	3	6	1	3	5	0	5	4	2	0	5	3	56	3.11
Lit/day via tanker to branches	8000	4000	4500	8000	3000	0	2500	8000	2000	7000	3500	3000	3000	2700	3000	1500	8000	7000	78700	
Total litres sold/day	8750	4525	4975	8525	3700	3600	3250	8500	2275	7550	3925	4750	3600	3175	3625	1750	8850	7925	93250	
Calculated Water Loss (%)	45%	43%	38%	47%	54%	57%	64%	47%	62%	53%	51%	41%	40%	37%	40%	56%	45%	50%		48%
Stated Water Loss (%)	70%	65%	80%	50%	70%	60%	>50%	70%	70%	80%	70%	50%	70%	50%	60%	70%	80%	80%		67%
Proportion of extra sales in summer relative to winter.(%)	70%	70%	60%	70%	70%			70%	60%	70%	70%	70%	60%	60%	50%	70%	70%	70%		66%
Distribution Area	Whole City	Whole City	Whole City	Whole City	Whole City	Town Centre	Bir Baasha	Whole City	Whole City	Whole City	Whole City	whole city Al Barh	Whole City	Al Ashbat	Whole City	Al Ashbat Al Kamp	Whole City	Whole City		
Charge YR per 10lit and 5lit	15, 7.5	15, 7.5	15, 7.5	15, 7.5	15, 7.5			15, 7.5	15, 7.5	15, 7.5	20,10	15,7	20,10	20,10	15,7	15, 7.5	15, 7.5	20,10		
Total Sales Value (YR/day)	9125	4788	5213	8788	4050	5400	3625	8750	2413	7825	4138	5625	3900	3413	3938	1875	9275	8388	100525	
YR/m3 water sold	1043	1058	1048	1031	1095	1500	1115	1029	1060	1036	1054	1184	1083	1075	1086	1071	1048	1058		1093
Profit after deducting running costs (YR/day)	6825	2288	1913	5488	2283	1733	192	6250	-88	4692	1771	2325	1533	1979	1438	108	6975	5821	53525	
Profit after deducting capital and running costs (YR/day)	2973	-1129	-282	2654	-522	-461	-2947	5509	-2865	1247	-424	131	-22	424	-1340	-2058	3123	2376		
Net profit (YR/m3)	340	-250	-57	311	-141	-128	-907	648	-1259	165	-108	27	-6	133	-370	-1176	353	300		

For US dollar equivalent divide by 130

Table 4.26 Water Treatment Companies. Taiz.

and if the water is cooled. The price has been monitored from summer 1995 to spring 1998. After steadily increasing, the price levelled out in summer 1996 (at 25YR(0.19$)/10 lit) falling for the first time in autumn 1996 with the seasonal decline in demand and it has not risen since. This may suggest that the market is now saturated as a result of the very rapid increase in the number of suppliers between 1994 and today (Figure 4.27). Some drinking water treatment companies have recently started to sell bottled water.

Consumption of jerry can water indicated by the household survey is eight times greater than the stated production of the drinking water treatment companies. There could be an 'underestimate' of production by the companies for tax or other reasons. Drinking water may be also sold by vendors (shops or company branches) which is, in fact, untreated. This latter alternative is thought to take place rather often. The discrepancy may also result from households overestimating the quantities consumed, though this is thought less likely. Some water companies may have been overlooked in the survey, although efforts were made to include all the processing plants. The data given in Table 4.26 are based on stated sales and do not include the higher consumption of 'jerry can' water indicated by the household survey. The amount of water stated as sold to the drinking water treatment companies by the wells included in the well survey should be less than that claimed to be bought by the companies since some water is also brought from the Dhi Sufal area which was not included in the well survey. The fact that the amounts are approximately the same suggests that the water processing companies have underestimated their water sales and purchases.

Companies were not readily forthcoming with information regarding equipment costs. In calculating the costs of the drinking water treatment companies, plant has been depreciated over ten years and vehicles over 15. Operating costs were estimated on the basis of a monthly rate of 20,000YR(154$) for building rental, 10,000YR(77$) for RO tube maintenance, petrol and oil at 22,000YR(169$) per vehicle, electricity at 3,000YR(23$) per month and salaries at 8,000YR(62$) per tanker per delivery per day. Other equipment maintenance was based on 20% of the depreciation rate. Only one rented building has been assumed for each processing plant. Often the branches are rented under a separate agreement by the branch manager who effectively operates as a financially separate business. If the water sales figures are to be believed, most of the drinking water treatment companies would operate at a slight loss if depreciation, calculated by the method used above, is taken into consideration. However, this loss is offset in some instances where the main building is owned rather than rented, by owning only one vehicle to collect and deliver water and by not maintaining the RO tubes. The latter is a false economy, resulting in the loss of up to 35% of their potential income.

Company profitability appears to be rather variable, and depends on careful management and good technical know-how. Four companies have ceased to operate in the past two years probably through being unprofitable because of inefficient operation.

The market for jerry can water in Ta'iz is huge, with 75% of the city buying jerry cans, mostly daily. The water processing companies exist because the water from the public utility is perceived as inadequate for drinking.

Although there are generally few complaints regarding jerry can water quality, the fact that water sales stated by the companies are only one eighth of the quantity claimed to be purchased by the public suggests that much of the water bought has never been near a processing plant. Branches can be tempted to fill people's jerry can from the public supply, especially when they have not received a delivery from the processing plant.

Because of the potential for incompetence and cheating the public, monitoring and some command and control measures are needed. There is also a need for technical help in optimising the equipment operation. As with the tankers, there is no provision for the poor, and jerry can water is the largest part of the monthly water bill. Although the price has remained steady, because of the dependence of so many on the source, and, in the absence of significant finds of good quality water in the area, the consumer needs some kind of protection from profiteering. On the whole, the need for a potable water supply in Ta'iz has been met reliably and relatively cheaply by the water processing companies. Although the price of the drinking water is very cheap by global standards, it is still unaffordable to 25% of the population.

The Public Water Supply Utility - NWSA

The supply of water to the urban population by the public utility NWSA differs from the other providers discussed above. Where this supply is different and where it is similar are worth noting. Regarding similarities, water is sourced from rural areas and the public utility competes with the other suppliers in a market for water in terms of price, water quality and reliability / ease of access. This competition is perhaps not immediately apparent in what is usually considered a monopoly. The monopoly, however, applies only to the piped nature of the NWSA supply (the private piped suppliers are almost insignificant in terms of their contribution to providing for the water needs of the city). Other differences between non-piped suppliers and NWSA relate to their ownership (private as opposed to public), and, if the water shortage is not too acute, the quantity of water they bring (that is, less than NWSA).

Coverage & Amount Provided

The estimation of per capita water consumption from NWSA supplies is difficult to assess for two main reasons. Firstly, the mean number of people per family in the census of Dec 1994 was 6.5, whilst the number per NWSA connection in this survey was 9.7. Secondly, the volume of water supplied from the water authority was 7123m^3/day as estimated by NWSA versus 16878m^3/day as estimated from household monthly water bills determined by the domestic water use survey. NWSA estimated 75% coverage in 1995 and 61% in 1998. These estimates are based on a simple model of one family ('usra) per connection and 6.5 persons per 'usra (1994 census figures and definitions). This assumes that a family is equivalent to a connection, that all houses are occupied and all connections legal. The random survey of 1028 households estimated 90% coverage and included illegal connections (2.5% actually admitted to this) and shared connections (another 4% admitted to this). The survey found an average of 9.7 persons per meter and excluded empty dwellings. An issue of whether the growth of the population of the city has been matched by a proportionate increase in the number of houses or whether there really more people per household is also raised by the conflicting persons per household statistics. All these factors lead to an underestimation of coverage by the NWSA method. Public utility underestimation of supply has been suspected from other surveys, such as San'a (Dar Al Handasah, 1997).

Similarly, the difference between the NWSA estimates of sewerage coverage (48%) and those of the urban domestic water use survey (68%) may result from a combination of illegal connections and also respondents assuming they were connected to NWSA sewers when in fact they are not. As well as cess pit sewerage, it is possible that there are some small private sewer networks, that is, a few houses connected to a common cess pit, or to the wadi, where there is no NWSA coverage.

Table 4.27: Effect of assumptions on per capita consumption. 1997 figures of 382000 population and 35808 connections.

	Scenarios			
People / Connection	9.7	6.5	9.7	6.5
% of total pop with connection	91%	61%	91%	61%
Water supplied (m^3/day)	5700*	5700*	16878	16878
Lit/capita/day m^3/capita/yr**	16.4 5	24.5 8	48.6 16	72.5 35

* according to NWSA. Assumes 20% is sold to institutions and commercial enterprises (CES, 1997). ** WHO minimum 10m^3/capita/yr.

Regarding the quantity of water supplied by NWSA, the figure of 16878m^3/day is based on household bills. However there is a possibility that NWSA is over-charging, as indicated by the average charge of 24YR/m^3, equivalent to an impossible 15m^3/month delivery. Together with an average storage capacity of around 3m^3 indicated by the survey, the argument leans towards the lower quantity of water delivered and is likely to have been below the WHO guideline for some time (Figure 4.18).

As well as the problem of insufficient water supplies from NWSA, there is a problem of water quality. Although both aspects deteriorated during the 1995 water crisis and have improved somewhat since (Figure 4.4) the quality in terms of Electrical Conductivity remains below the European Economic Community maximum of 1500 µS/cm.

Free Water

There are two main sources of free water in the city of Ta'iz. One is to collect rainwater. This is income related with a higher proportion of poorer households collecting rainwater (Handley,1999a). A second source of free water is obtained by queuing for water at the mosques, public standpipes and outside the houses of a few wealthy households that make water accessible to the public. The time involved in collecting free water (Figure 4.15) suggests that the poor spend time to save money and the rich vice versa. The trade-off between time for money indicates that 'free' water is actually a market and the water carries an opportunity cost at least. For this reason it is suggested that free water should not become easy or quick to obtain, otherwise those in less need of it will use it. The quality of free water can be very variable and because it is free, be the least amenable to minimum quality standards and its users, the poor, are hence the most vulnerable.

4.5.2 Water Market Overview

Table 4.28: Quantities of water (m^3/day) consumed by the city from non-NWSA sources.

	Supplier Estimates	Consumer Estimates
Jerry can purchase by households	93	790
Water tankered to water processing companies	180	
Water sales to tankers by wells	1262	
Tanker sales to houses	1218	
Water purchase from tankers		2318
Free water consumption	(1548)	1548
Total	2859 m^3/day	4656 m^3/day
Per capita based on population of 382,000 at the time of the survey.	7.5 lit/cap/day 2.5 m^3/cap/yr	12.2 lit/cap/day 4.5 m^3/cap/yr

Besides the estimates of consumption of NWSA-supplied water given in Table 4.27, Table 4.28 estimates the consumption of non-NWSA water.

The per capita water consumption lies somewhere between the supplier and consumer estimates and, because it is not possible for NWSA to provide the amounts indicated by consumer billing, the actual consumption is considered to be nearer the supplier estimate (16-24 lit/capita/day). This quantity is very low and when added to the provision from other sources only approaches the WHO recommended minimum (28 l/c/d). This quantity is not considered unlikely and similar estimates have been deduced for other Yemeni towns (for instance Amran and Yarim, Handley,1997a and Davies 1997 pers com.). Despite the discrepancies in the estimates, the importance of non-NWSA water sources are apparent (Figure 4.24). Alternative water supplies to NWSA comprise up to 37% by volume of all domestic water use.

The failure of NWSA to provide water of better quality in terms of salinity than the European Economic Community recommended maximum has led to the city depending almost entirely on a separate supply for drinking water. This need has been met by a rapidly growing jerry can drinking water market. Although the volumetric quantity of 'jerry can', bottled and private piped water is not great, it does comprise over 85% of the drinking water. Around 20% of the non-potable water used is tankered water, which is the direct alternative to NWSA water. The proportion of tankered water increases notably above this level when NWSA production declines. Those who do not have the option to access alternative sources tend to be the urban poor.

Based on consumer estimates of household expenditure the average cost of water is calculated at just over 4% of household income. Although the poor pay a much higher proportion than the wealthy (Figure 4.25) 89% of the population are thought to pay more of their income on water than the World Bank recommended maximum of 2% (quoted in Allan,in prep;5.22).

The mean costs of water production from the different suppliers (inclusive of depreciation) and the sale prices are summarised in Table 4.29 and Figure 4.31.

Table 4.29: Cost and sale price of water for various water sources YR/m^3 (\$/m^3).

	Wells to Agriculture	NWSA Supply	Private Piped	Wells to Tankers	Tankers to Public	Jerry Can Water**	Bottled Water
Cost Price	33 to 35* (0.25-0.27)	48 (0.37)	43 (0.33)	33 to 35* (0.25-0.27)	65 (0.5)	1,017 (7.8)	?
Sale Price	15 (0.12)	24 (0.18)	32 (0.25)	31 (0.24)	285 (2.2)	2,687 (21)	26,000 (200)

*Higher cost for shorter depreciation period of well and equipment.
**Based consumer estimates of purchases, not drinking water treatment company estimates of sales.

Based on summer 1998 data, and the national tariff applicable at that time, the price elasticity of demand for NWSA water in Ta'iz is –6 (Figure 4.26). The national tariff was 25.5YR(0.20\$)/m^3 water and sewerage charge for 0-10m^3/month water consumption, 42.5YR(0.33\$)/m^3 for 11-20m^3/month, 68YR(0.52\$)/m^3 for 21-30m^3/month and 85YR(0.65\$)/m^3 for more than 30m^3/month. The average monthly charge was 24YR(0.18\$)/m^3 (Table 4.29).

Although private piped supplies and NWSA simply run at a loss, the drinking water treatment companies have mostly been established since the Gulf War brought a virtual end to the remittances (Figure 4.27). The other private water suppliers make an immediate profit that they live off and chew off, but it would need another remittances boom for significant replacement of plant and equipment or reinvestment.

The production, sale price and water quality from each source are contrasted in Table 4.30 and production and price in Figure 4.28.

Table 4.30: Quantity, Quality and Sale Price of Water.

	Quantity	Quality	Price	Price
	m^3/day	µS/cm	YR/m^3	\$/m^3
Wells to Agriculture	8200	1000	15	0.12
NWSA	5700	1750	24	0.18
Wells to Tankers	1250	3500	31	0.24
Private Piped	230	800	32	0.25
Tankers	1250	3500	285	2.20
Jerry Can Water	200	600	2687	21.00
Bottled Water	2	400	26000	200.00

The relationship between quantity supplied and water price for most sources lie on an approximately linear trend (on log-log scale). Notable exceptions are the private piped supplies, which now provide very small amounts of water and the sales by wells to tankers that do not cover their costs. Table 4.30 suggests the quality of water sold by the tankers to the public does not warrant the price charged. The loss of economies of scale by this method does not permit significant price reductions for tankered water and the lack of availability of wells providing good quality water from all but Wadi Ad Dabaab sources precludes an improvement.

4.6 Summary and Observations

Agricultural Water Use

Rainfed agriculture topped up by spates in wadi areas and small areas of stream-fed agriculture was the traditional form of cultivation until the mid 1970's. Since then the technological impact of boreholes and pumps financed by remittances from Saudi Arabia and the Gulf has led to the depletion of groundwater resources and hence also spates and stream flows.

Despite the growth in groundwater development, the same period has seen a decline in the agricultural proportion of GDP and a population increase even in both urban and rural areas. The result has been a sharp decline in per capita water availability.

Land holdings are small and fragmented which forms a major cause of disputes. Relative to their urban counterparts the rural population is poorer. Rural wealth differentials are accentuated by water allocation which determines both the number of cropping seasons and the type of crops that can be grown. The wealthiest are those who control the headwaters of streams and groundwater flows and water resource development moves progressively back to this point. In the few locations where surface flows still occur many have been polluted by urban and industrial development.

Areas of volcanic rocks are not very productive and alluvial tracts dominate the agricultural economy. The conflict over declining groundwater levels is concentrated in wadi areas at the base of the alluvium / top of the volcanics. As the groundwater level declines below this point only the few farmers with deep enough drilled wells can obtain water and maintain two or three cash crops per year at this inequitable final stage in the tragedy of the groundwater commons (Table 4.3). The direct cost of ultimate groundwater depletion has been evaluated for Al Hayma.

Since there is more cultivatable land available than water resources, improvements in production efficiency are only likely to result in more use of land rather than conservation of water. Although the irrigation methods are inefficient the main loss is in (cheap) diesel as water is recirculated to the aquifer. Efforts to reduce irrigation inefficiency are more related to the potential that the topography gives for the installation of piped distribution systems than to any other factor.

Although two restricted areas have seen a decline in agricultural production over the past ten years due to abstractions of groundwater for industrial use, declines have also been noted in non-industrial areas. A decline in rainfall over the period is possible but statistically unprovable.

Rainfed agriculture accounts for around 75% of the agricultural water use in the study area. Because of its distribution, this water cannot be used for any other purpose. The water derived from stream flows accounts for less than 10% of the water use and is difficult to appropriate for any other purpose since much is polluted and the remainder falls within strict allocative rules. The only water which could be reallocated to other sectors is the groundwater which comprises around 30Mm^3/yr in the Upper Wadi Rasyan catchment or 22% of the total agricultural water use. Even this modest amount includes a portion of overexploitation. Hence, right at the outset of this discussion, a severe limit is set on the potential for water reallocation.

Considering that economic and livelihood returns to water in agriculture are meagre and, if depreciation on boreholes and pumping equipment is considered, returns are definitely negative, one might ask if remittances were really a good thing? Despite these realities the Yemeni's heart remains in his soil.

Industrial Water Use

Although Yemen is a relatively unindustrialised country, the manufacturing contribution to the GDP is increasing and, compared with the rest of the country, the Upper Wadi Rasyan catchment is more industrialised. Water quality is a problem for some industrial processes and managers are aware of the problems of water shortages for production and are making some efforts to reuse and conserve water. Industrial returns to water are in marked contrast to those of agriculture both in the provision of livelihoods and in economic terms. However this is not without cost. The growth in industrial pollution is essentially unchecked and attitudes towards it are rather ambivalent. Although there is an awareness of pollution problems there is very little action to rectify them and some may even use them as a means of land acquisition. Certainly specific manufacturers allow pollution to become an externality.

Domestic Water Supplies

A greater proportion of people in the Ta'iz governorate live in a rural setting than the national average and those people are worse served by water and sanitation than the rest of the country. In contrast the urban population is served better than the national norm. In most rural areas water is fetched by women and/or donkey and consumption is very low at around 20 lcd. In some areas where there are adequate water resources and people live close together enough to make a piped network economically feasible the private sector can and does provide adequate water. A major problem facing piped schemes whether private or public is the supply of spare parts. Another problem in 'community-run' schemes is the potential for corruption, much depending on the quality of the local shayx.

In the city of Ta'iz, there are very distinctive differences between the poor and the wealthy. The differences not only are seen in the more obvious forms of jobs and income, possessions, housing and level of education, but also in the water-related activities. Hydraulic differences are accentuated in the high water stress situation exhibited in Ta'iz. The wealthy have more water using facilities (Figure 4.11) and the poor, especially children of poorer families, spend more time collecting water (Figures 4.15 and 4.16). The rich can better afford tankered water and the poor are more dependent on queuing for free water from standpipes (Figure 4.12). The wealthy were much more cushioned from the affects of water shortage (Figure 4.23) and could afford the luxury to place water quality higher on their priorities than poorer people (Figure 4.22).

The quality of piped and tankered water is below WHO drinking water guidelines for over 95% of the households. The quantity provided by the public supplier is below those standards (Figure 4.18) and the total from all sources consumed by the 'average individual' is at or around that limit. Water stress felt through severe shortage and declining quality results in more time spent collecting water (Figure 4.17). Although less time is spent using it, that time is concentrated in bursts of hydraulic activity particularly in washing clothes on the rare occasions that water comes out of the tap (Box 2). With water from the public utility being relatively cheap, the price for that source did not figure as important to consumers as water quality (Figure 4.19). Although the city's inhabitants are conditioned to adapt to water shortage those with a single 'monopoly' supplier, such as the public utility, are more vulnerable to water stress. The differentials described in this section provide the hallmarks of the Ta'iz urban hydraulic society.

Water Markets

Private piped supplies are a very small (1%) and declining portion of water supplies in Ta'iz. They are a monument to upstream resource capture, lack of monitoring, lack of regulation, commercially unreal administration, and community failure in allocating equitably.

The failure of the public utility to provide enough water or water of adequate quality for drinking has spawned private sector initiatives. Wells are the source of the private sector and run at a loss, particularly those within the city which are effectively subsidised by mosques. Water tankers provide an inequitable, expensive, alternative source of poor quality water to the public utility. The loss of economies of scale in the tanker delivery method is the 'flip side' of being a good job provider. Irregularities in the quality of water provided by tankers beg enforced regulation of standards.

The drinking water treatment companies have proliferated as the quality of water provided by the public utility has declined. Although a reasonable price is charged, the proportion of income spent by most of the population on water is well above the World Bank recommended level of 2% of household GDP, and for the poor is above the maximum of 5% (Figure 4.25). Most of household expenditure on water is for drinking water.

NWSA supply water for 10% of the time, at 18-30 day intervals. Although a block tariff is used by the NWSA the wealthy probably gain access to greater quantities of this government-subsidised source of water. Inconsistencies in the evaluation of public utility water provision make this observation uncertain, however, it may be stated that the NWSA water supply is inadequate in terms of quality, quantity and reliability, as well as being inequitable, inefficient, and financially unviable (see also section 5.4.2).

It must be asked whether the opportunity cost of queuing in the free water market is equitable and whether 'free' water should be exempt from water quality standards simply because it is free. Despite the failings of the private sector in maintaining quality standards and providing for the poor, the private suppliers have proved themselves adaptable to water stress and have provided water when the public utility has failed – but at a price.

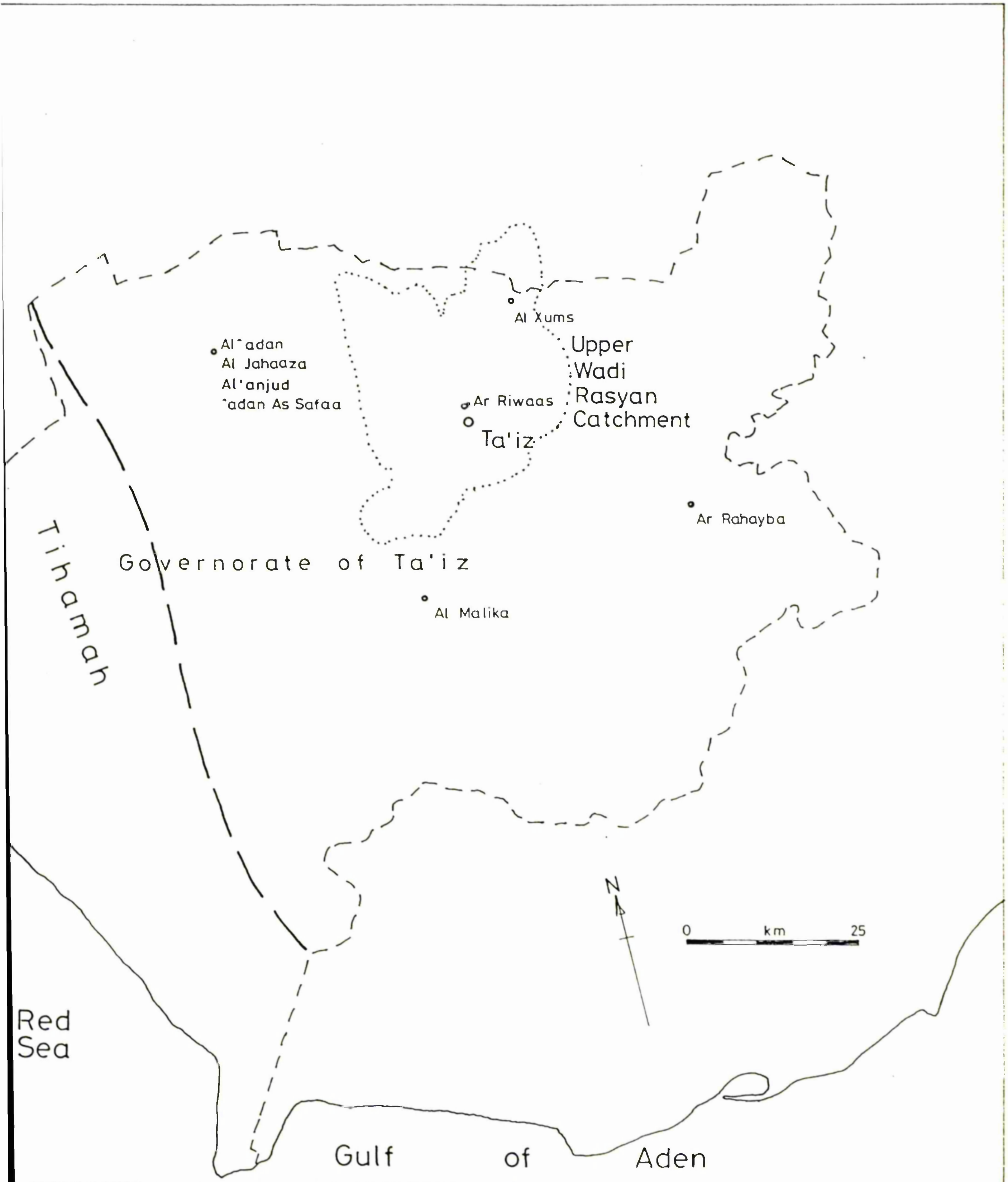


Figure 4.1 Locations of villages included in 1995 survey

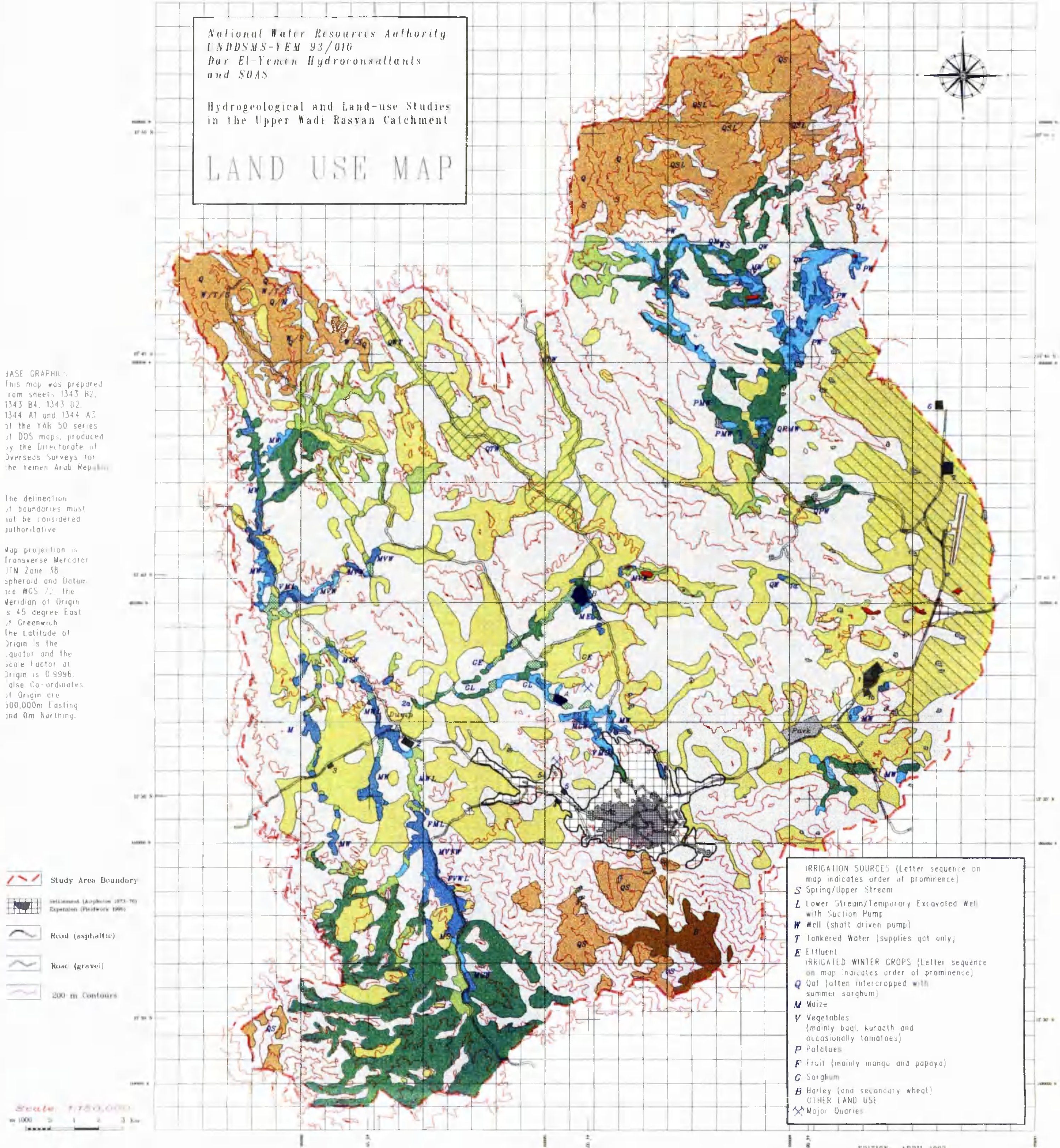


Figure 4.2: Land Use Map

Uncultivated Land (Essentially Unterraced Runoff Areas)

Rainfed Summer Cultivation of Generally Poor Quality Sorghum/Millet

Rainfed Summer Cultivation Only. Better Quality Sorghum/Millet

Intensive Summer Cultivation. Essentially Sorghum/Millet

Irrigated Winter crops and Supplementary Irrigated Summer Sorghum/Millet

Intensively Irrigated Winter Crops and supplementary Irrigated Summer Sorghum/Millet & Maize

Summer Rainfed Barley (secondary wheat)

Large Terraces, Field Sized Rainwater Harvesting

Highland Qat. One or no winter irrigation, intercropped with sorghum/millet in summer

Major Crop Qat with Almost Only Tankered Winter Water Supply

Grass and Palm Trees

Dried-out Wetland

City Dump

Main Park

Major Factory 6 , Major Factory Waste Water Disposal 1a

Open Water (A: Amira Dam; B: Hurayhi Sewerage Lagoons)

MAJOR FACTORIES

1- Hayel Saeid Houbar
2- Hayel Saeid Hidran
3- Sheibani Taiz
4- Sheibani Paints
5- Soft Drinks
6- Proctor and Gamble
7- Gas Plant

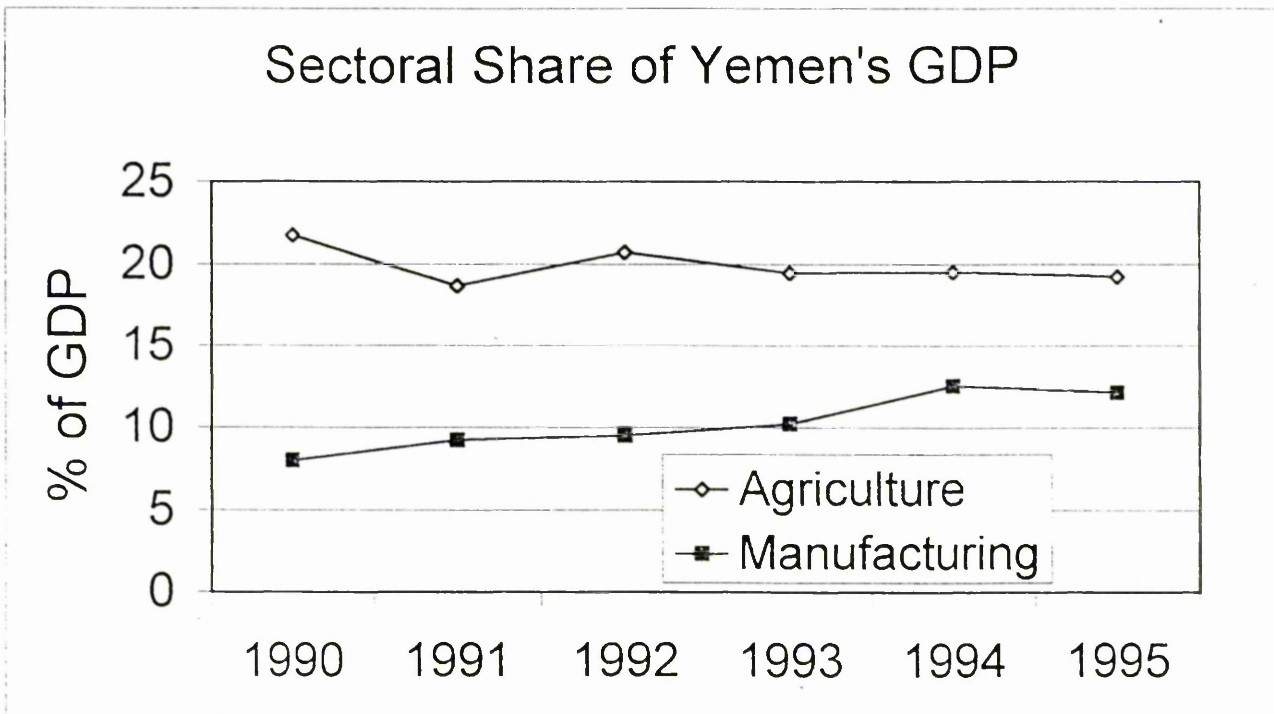
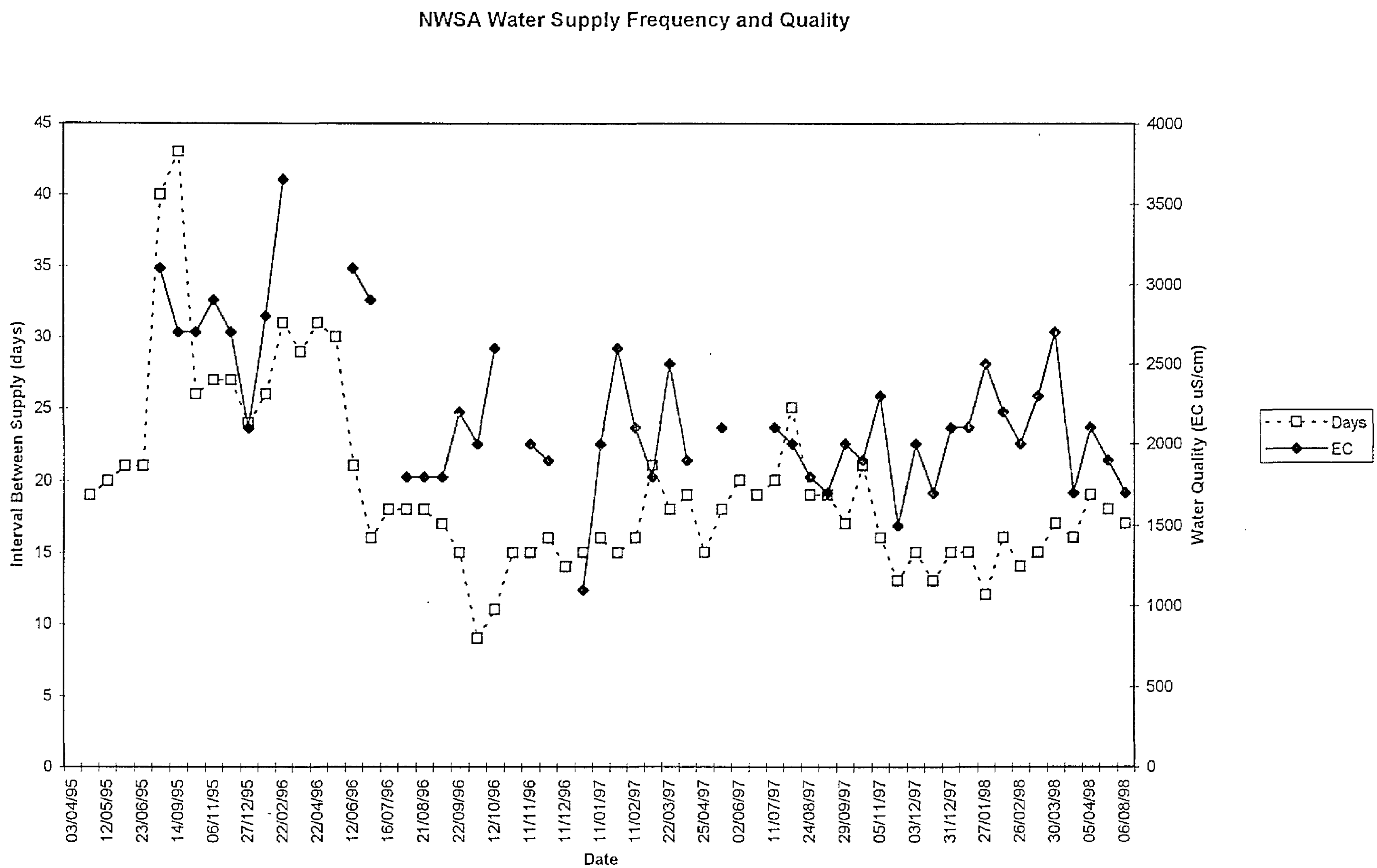
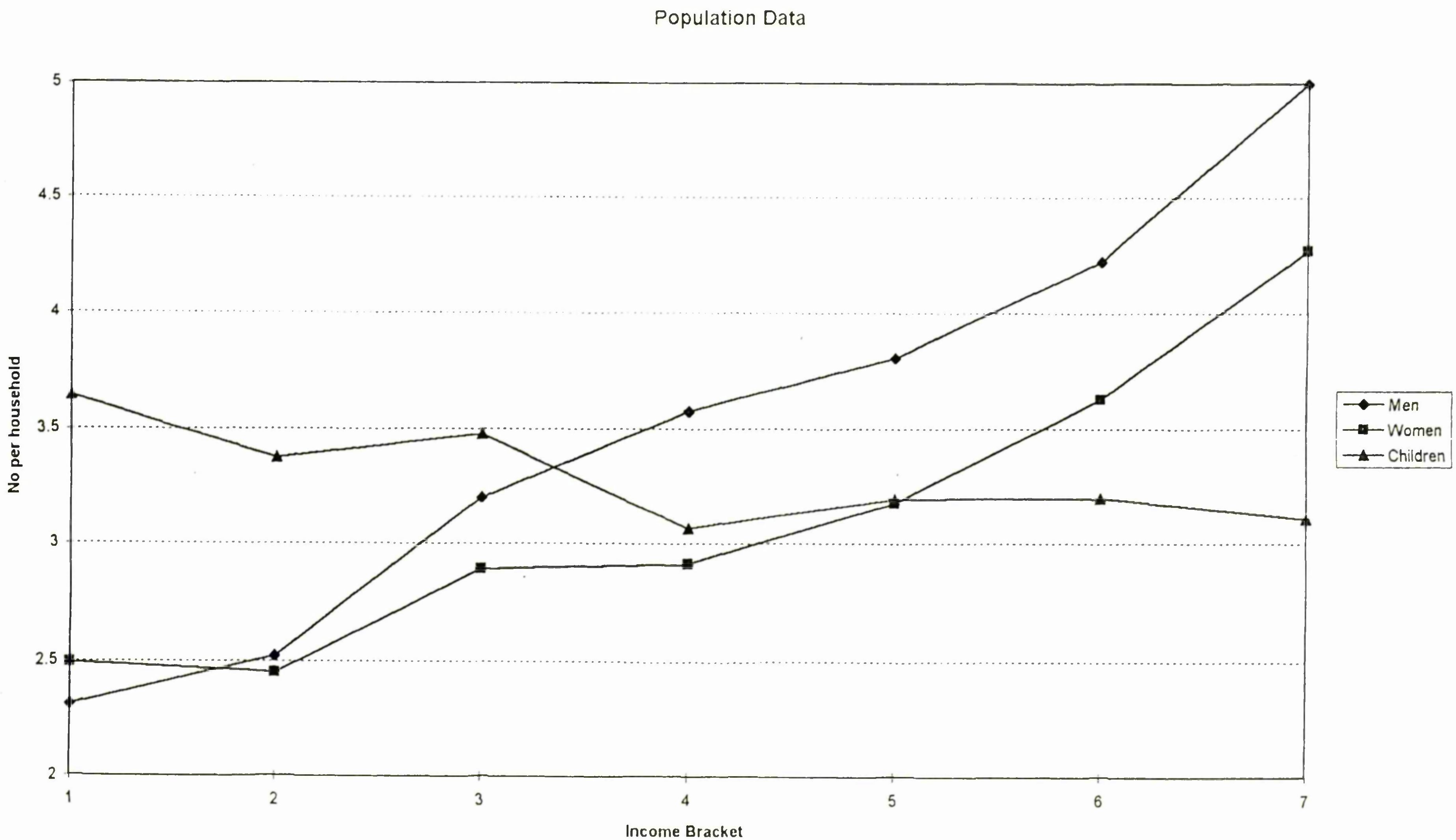


Figure 4.3 Sectoral Share of Yemen's GDP. *Source: Statistical Yearbook, 1995.*



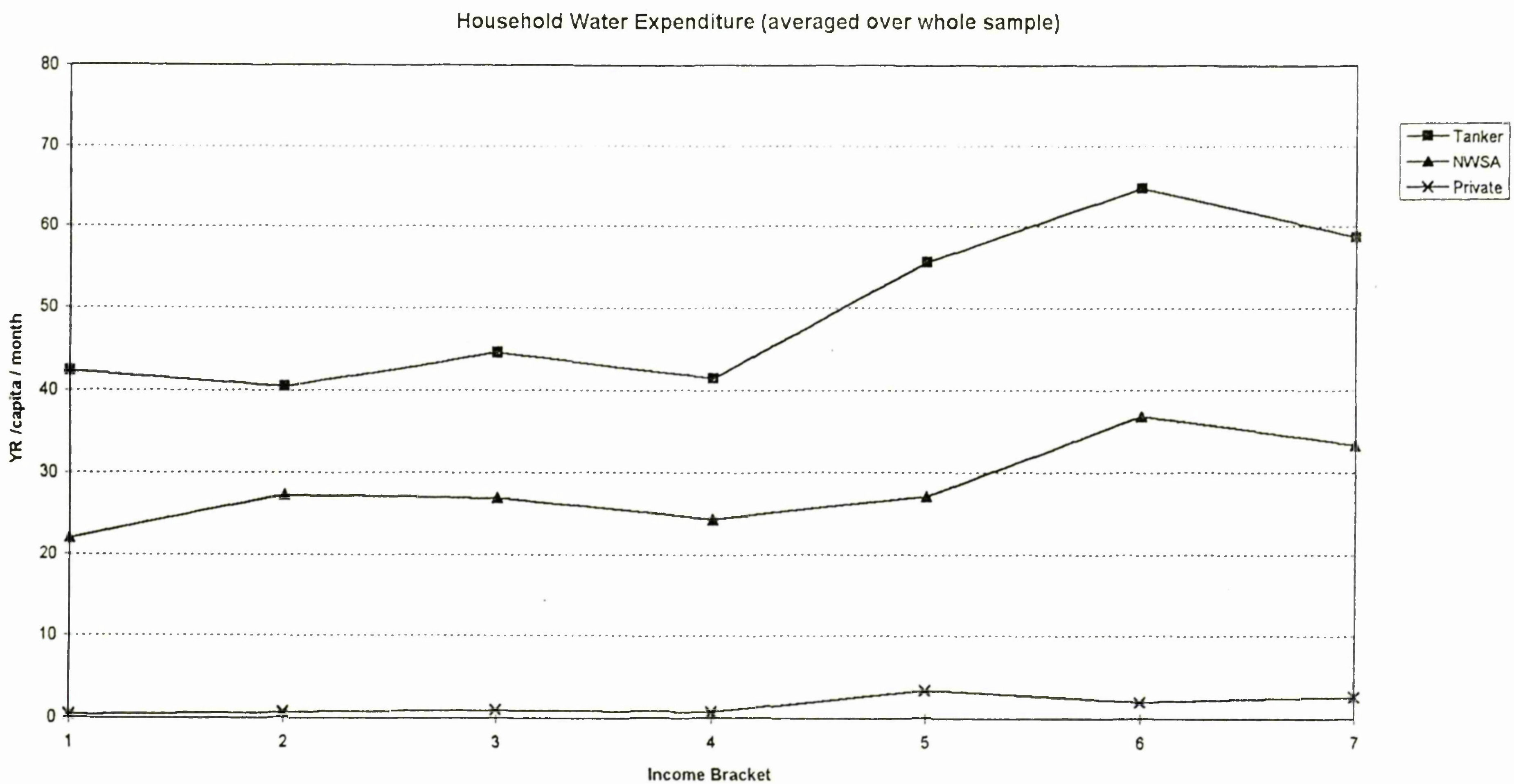
NWSA Water Supply Frequency and Quality
Interval Between Supply (days)
Water Quality (EC uS/cm)
Date
Days
EC
45
40
35
30
25
20
15
10
5
0
4000
3500
3000
2500
2000
1500
1000
500
0
03/04/95
12/05/95
23/06/95
14/09/95
06/11/95
27/12/95
22/02/96
22/04/96
12/06/96
16/07/96
21/08/96
22/09/96
12/10/96
11/11/96
11/12/96
11/01/97
11/02/97
22/03/97
25/04/97
02/06/97
11/07/97
24/08/97
29/09/97
05/11/97
03/12/97
31/12/97
27/01/98
26/02/98
30/03/98
05/04/98
06/08/98

Figure 4.4



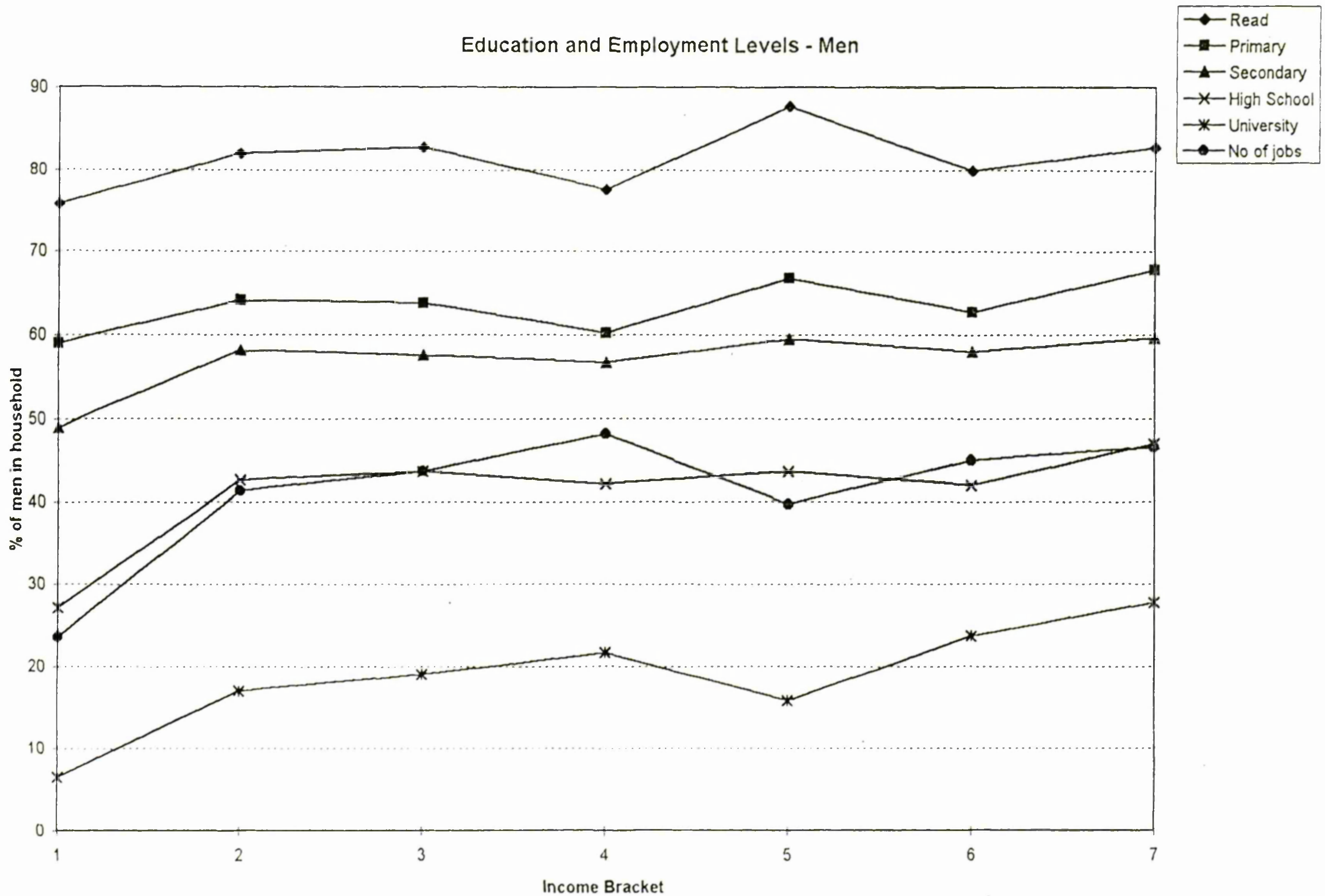
Population Data
5
4.5
4
3.5
3
2.5
2
No per household
1
2
3
4
5
6
7
Income Bracket
Men
Women
Children

Figure 4.5



Household Water Expenditure (averaged over whole sample)
YR /capita / month
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
Income Bracket
Tanker
NWSA
Private

Figure 4.6



Education and Employment Levels - Men
% of men in household
Income Bracket
Read
Primary
Secondary
High School
University
No of jobs

Figure 4.7

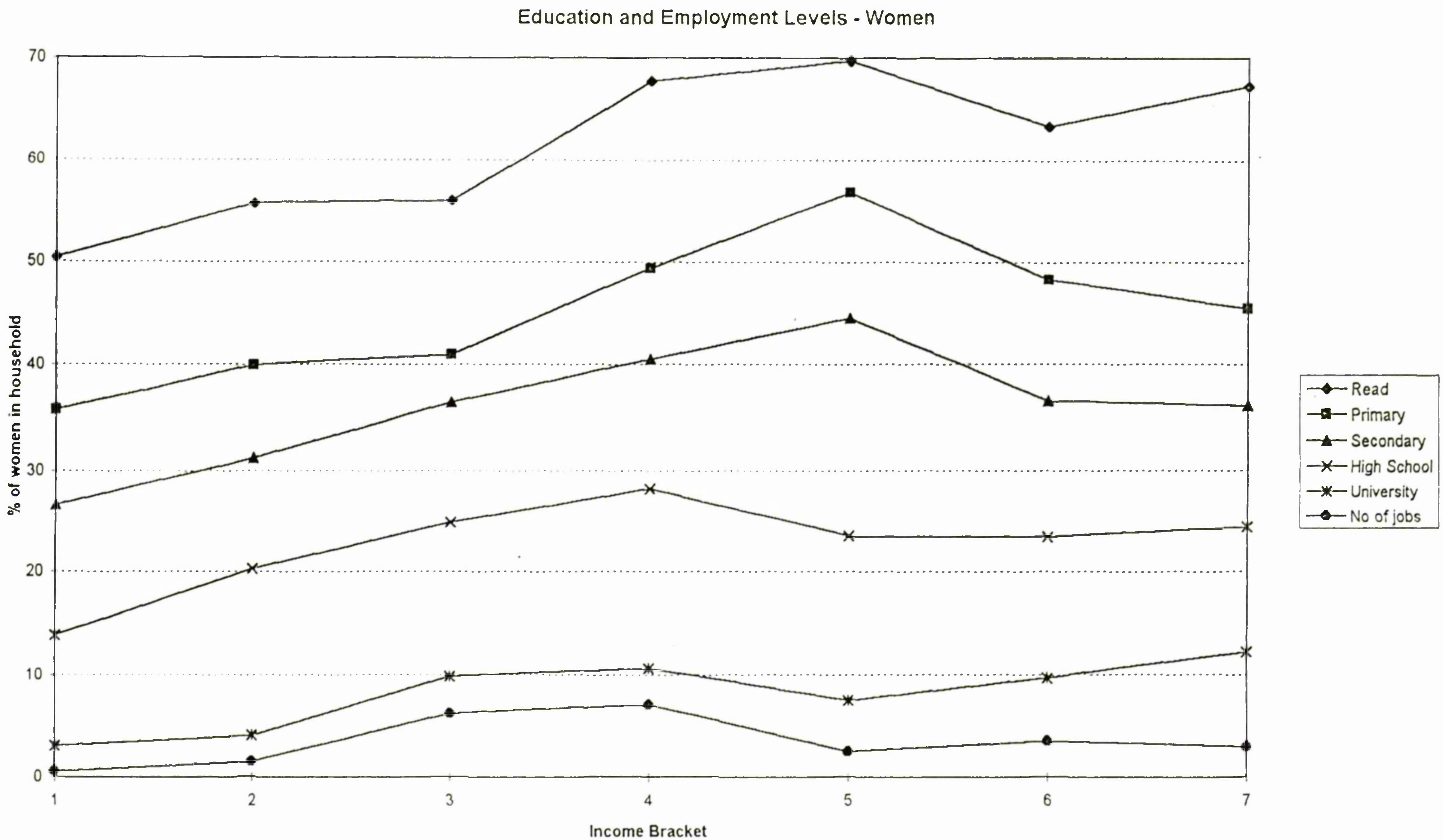

Education and Employment Levels - Women
70
60
50
40
30
20
10
0
% of women in household
1
2
3
4
5
6
7
Income Bracket
Read
Primary
Secondary
High School
University
No of jobs

Figure 4.8

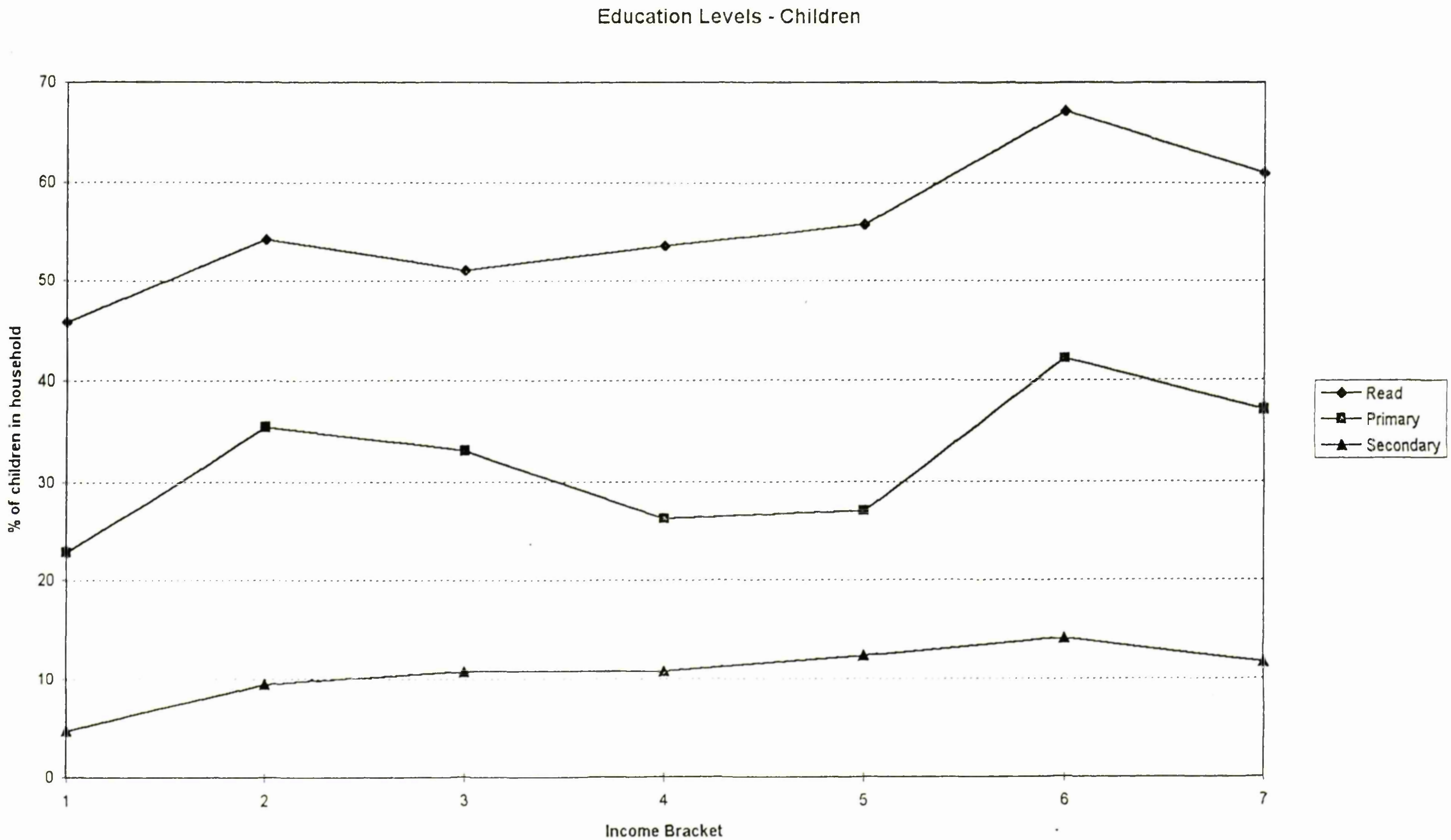

Education Levels - Children
% of children in household
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
Income Bracket
Read
Primary
Secondary

Figure 4.9

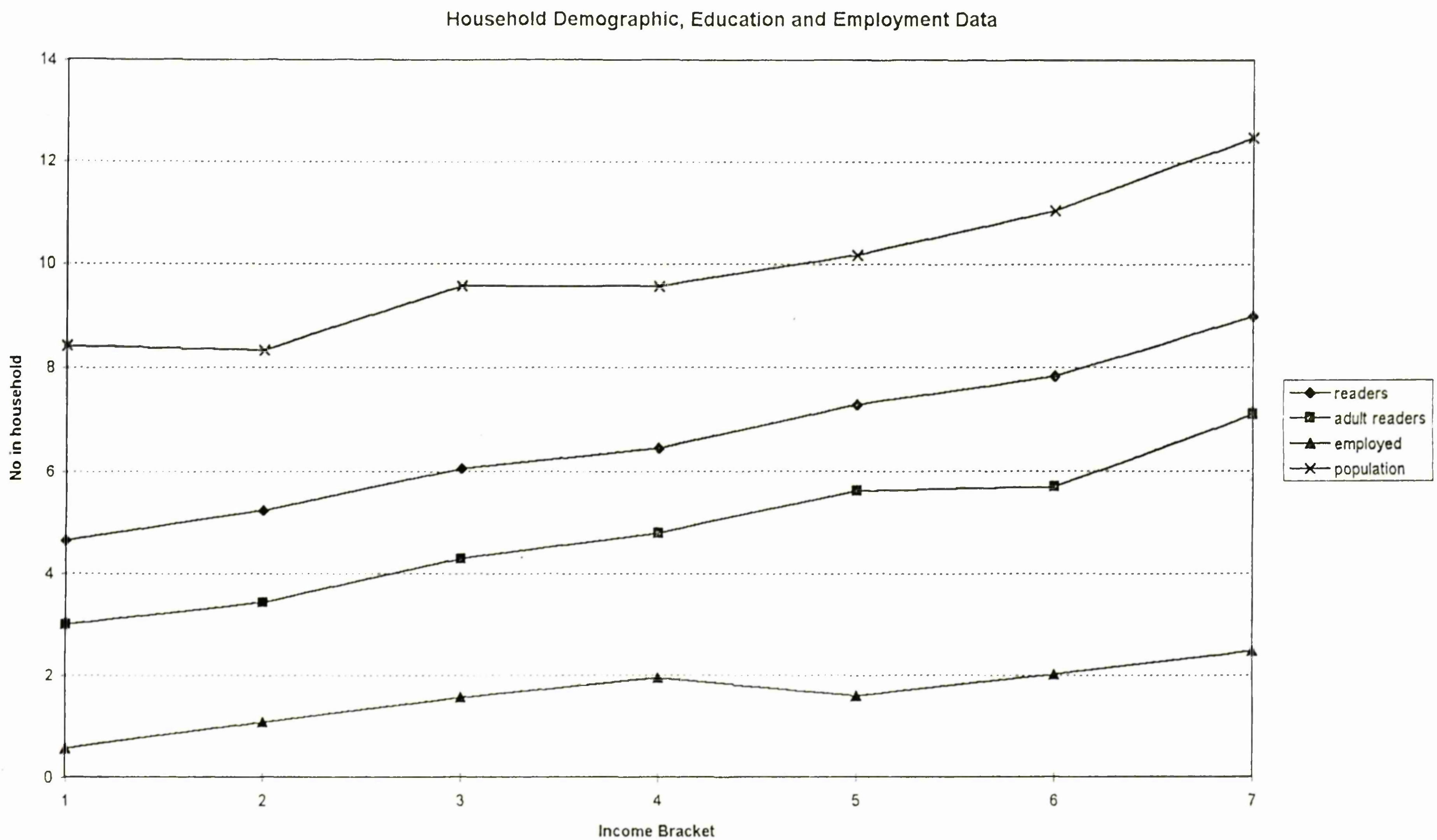

Household Demographic, Education and Employment Data
No in household
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
Income Bracket
readers
adult readers
employed
population

Figure 4.10

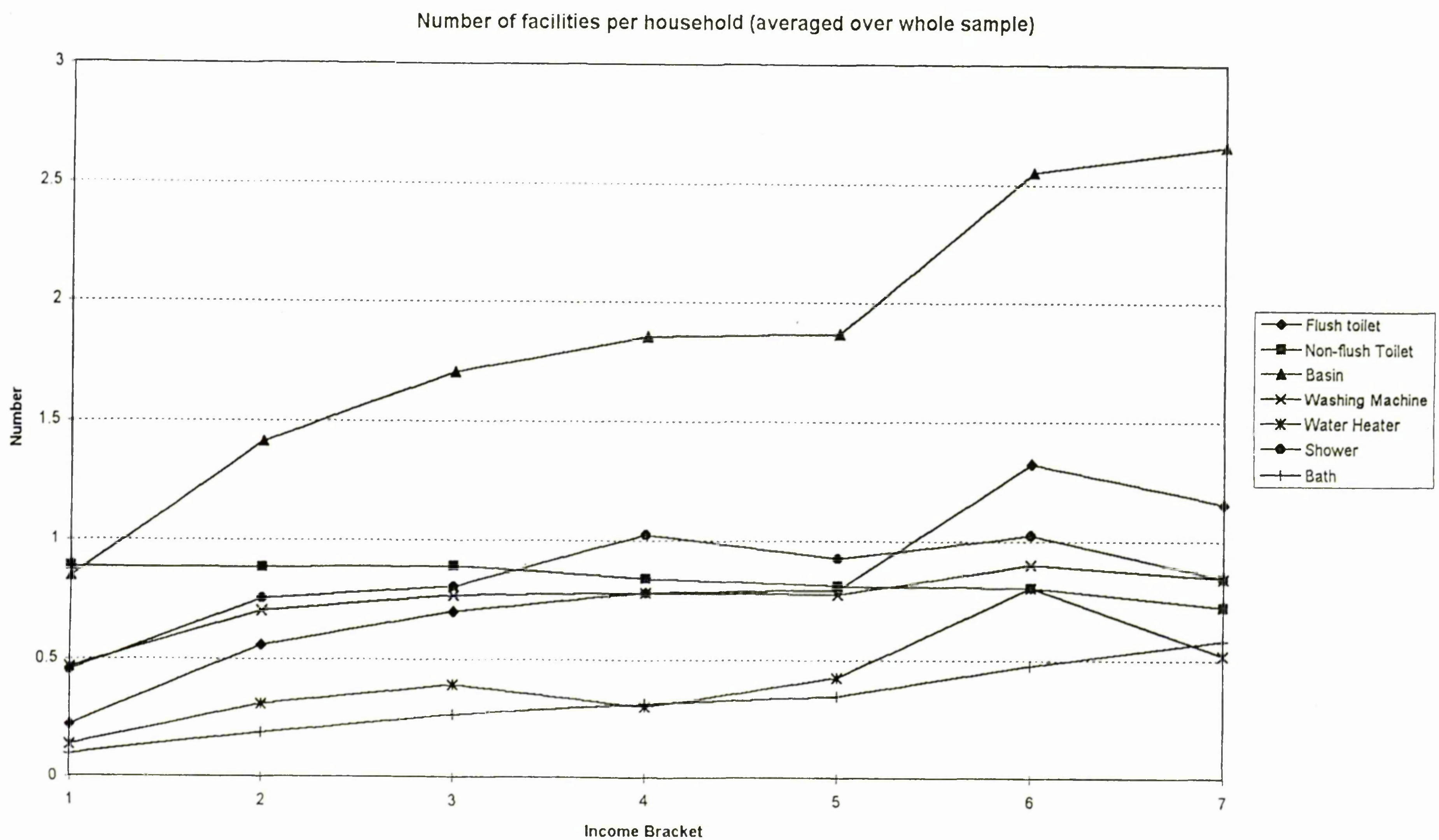

Number of facilities per household (averaged over whole sample)
Number
3
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
7
Income Bracket
Flush toilet
Non-flush Toilet
Basin
Washing Machine
Water Heater
Shower
Bath

Figure 4.11

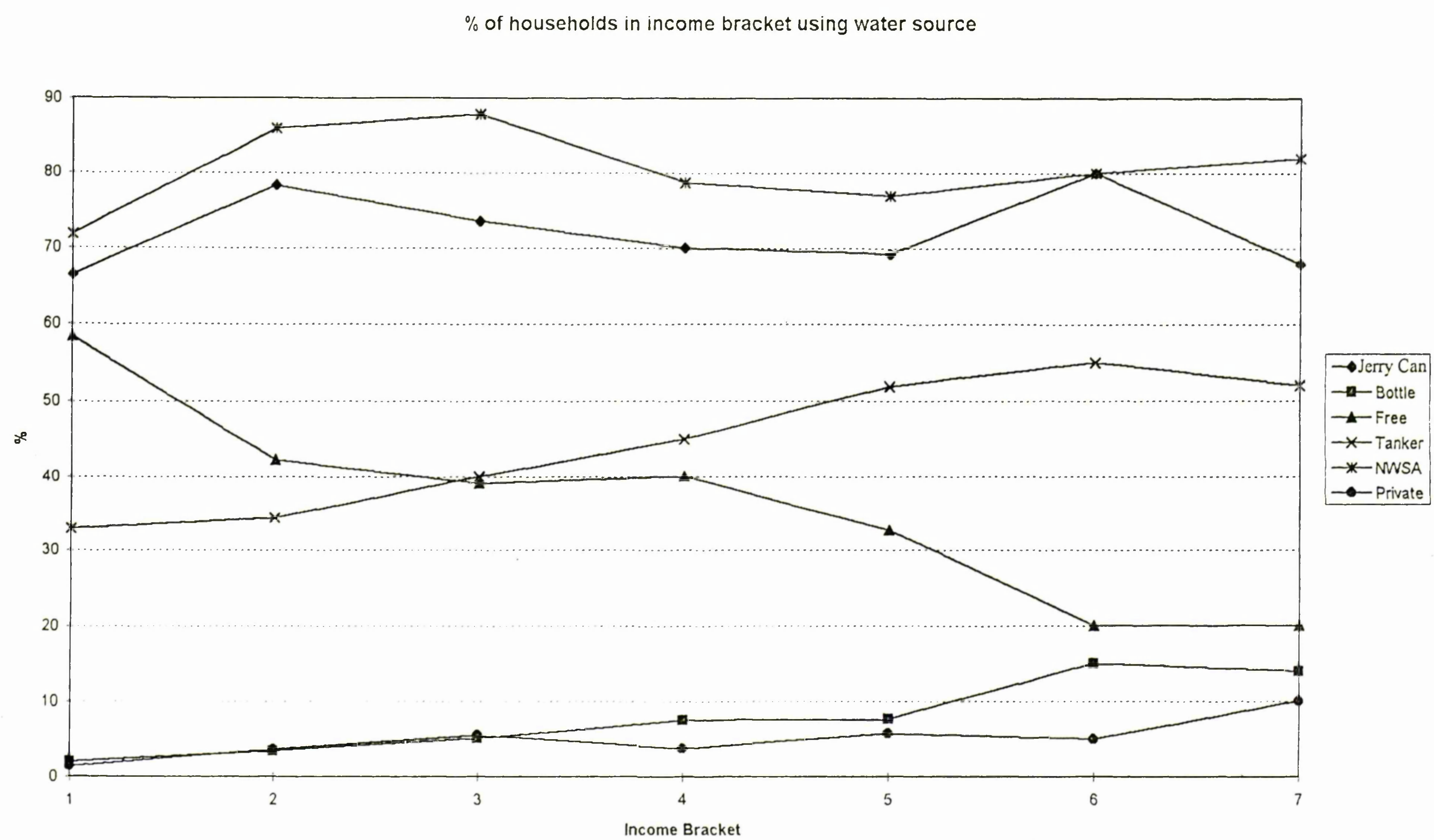

% of households in income bracket using water source
90
80
70
60
50
40
30
20
10
0
%
1
2
3
4
5
6
7
Income Bracket
Jerry Can
Bottle
Free
Tanker
NWSA
Private

Figure 4.12

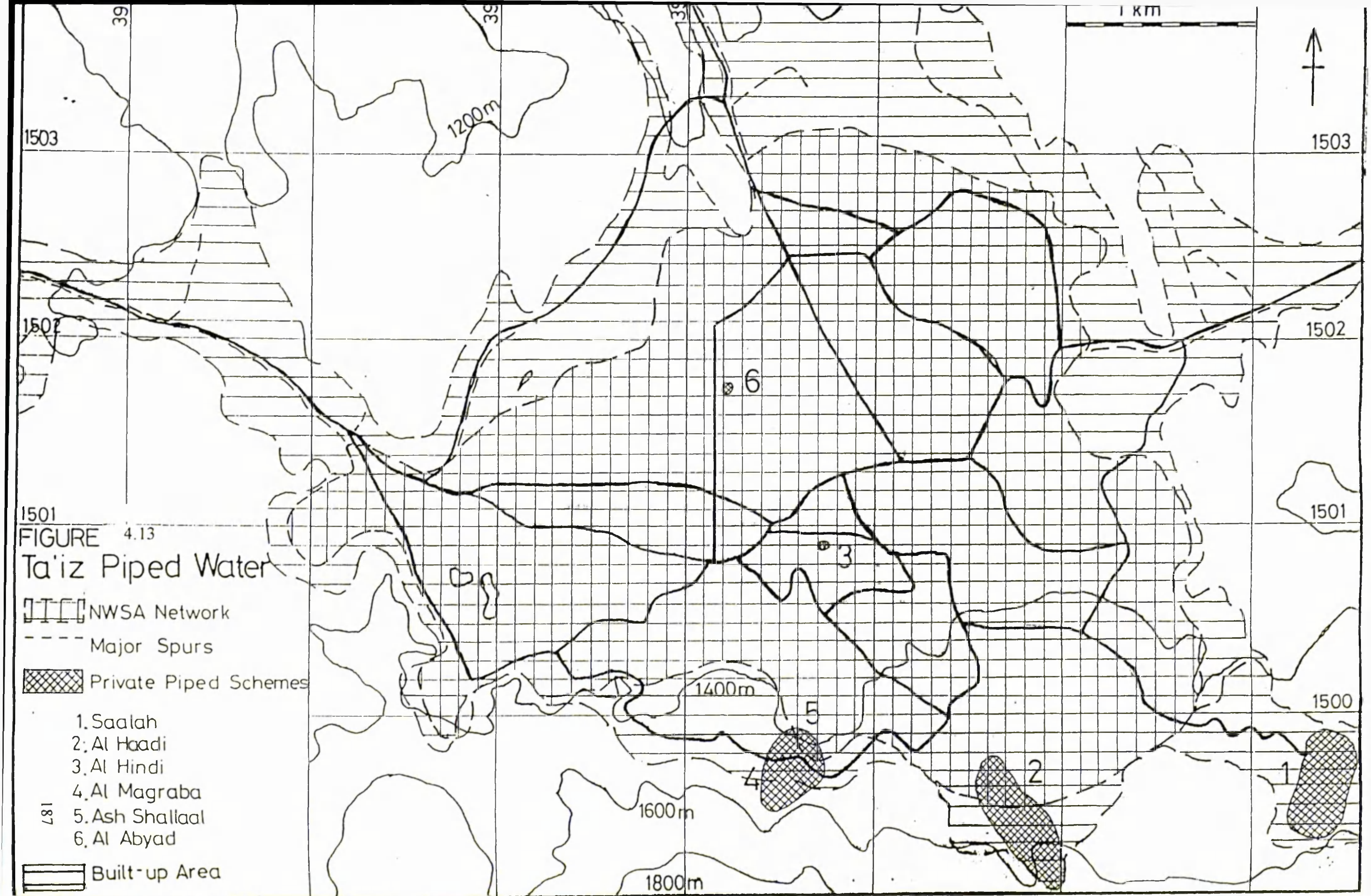


FIGURE 4.13
Ta'iz Piped Water

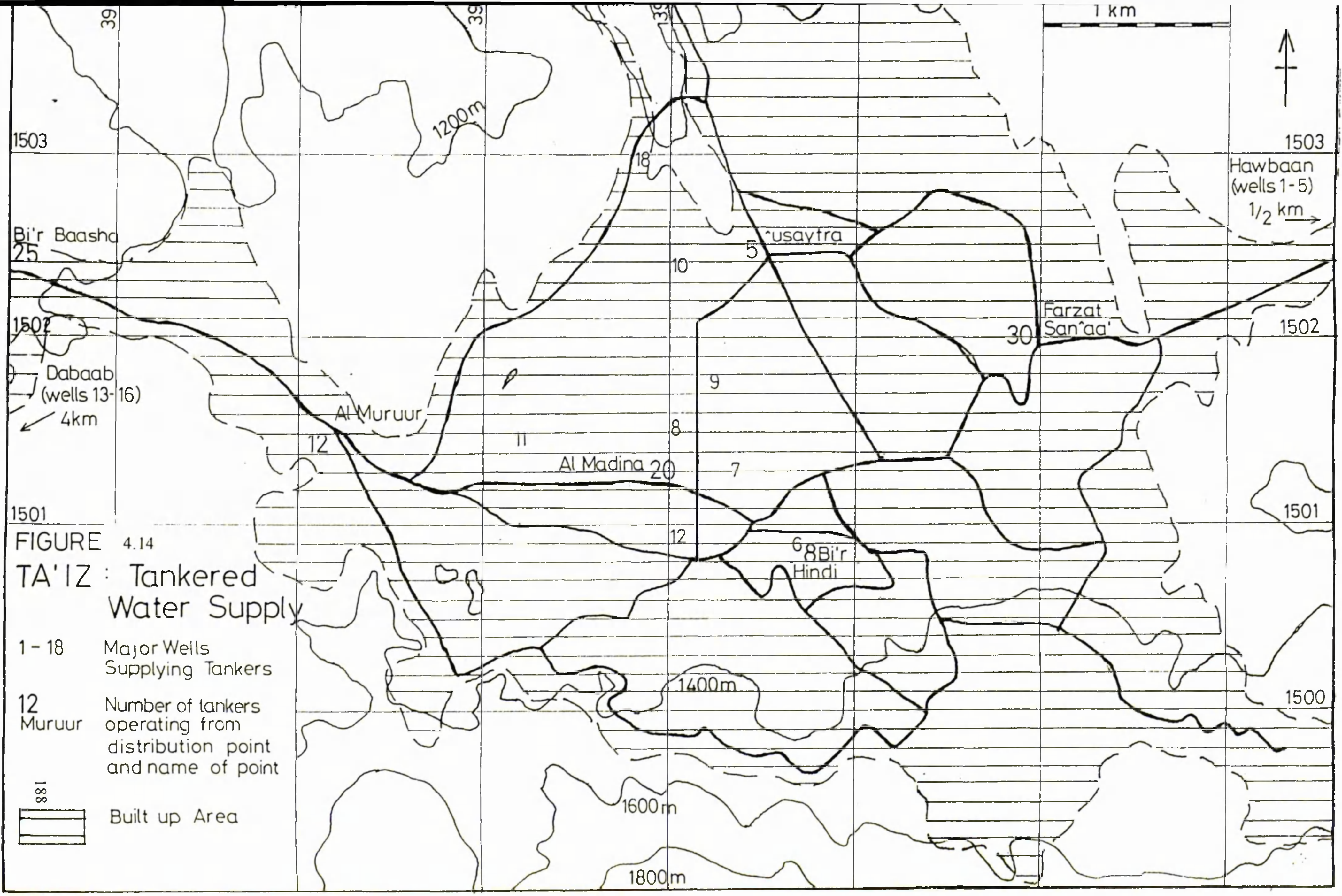


FIGURE 4.14
TA'IZ : Tankered Water Supply

Total time spent fetching water per household

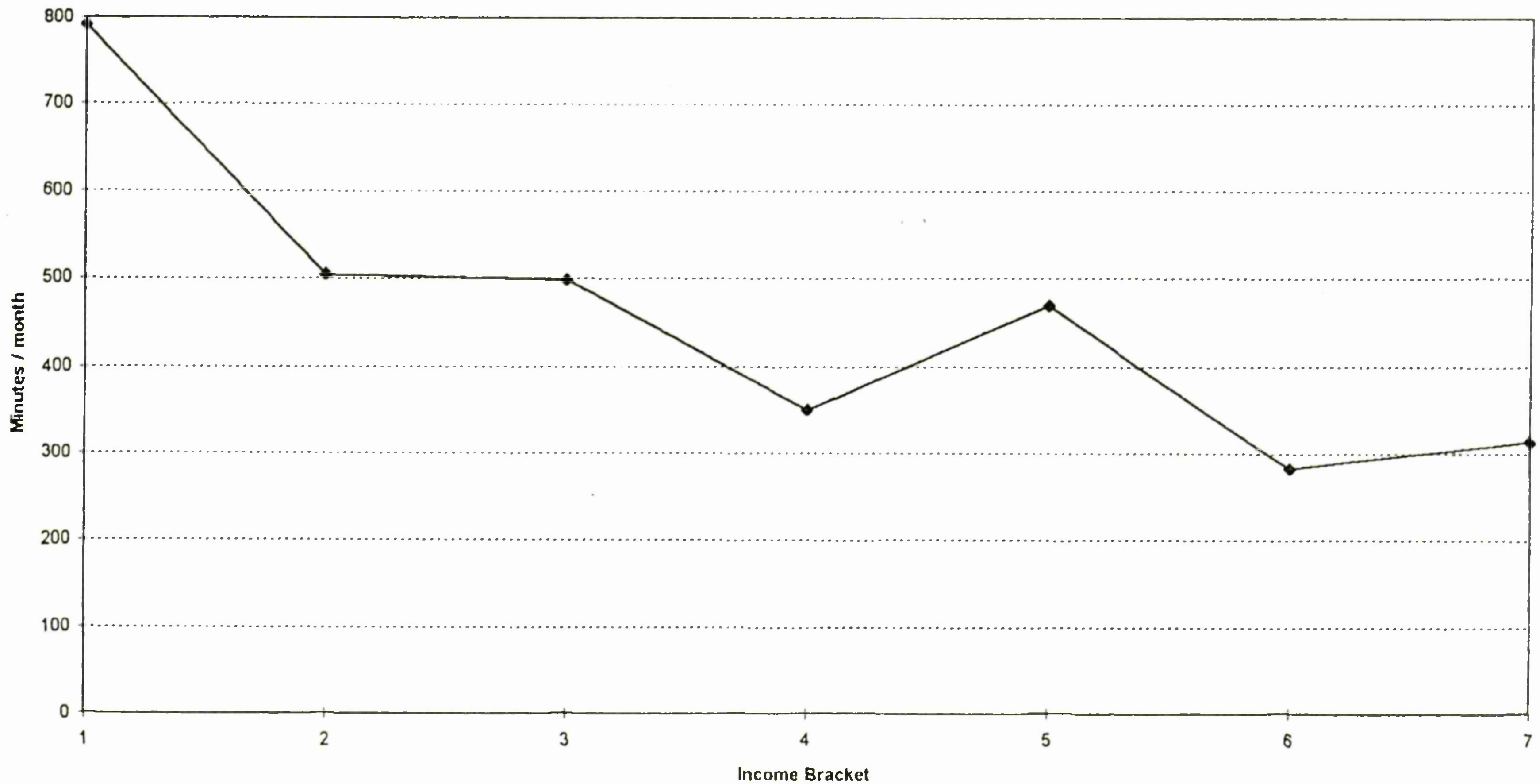


Figure 4.15

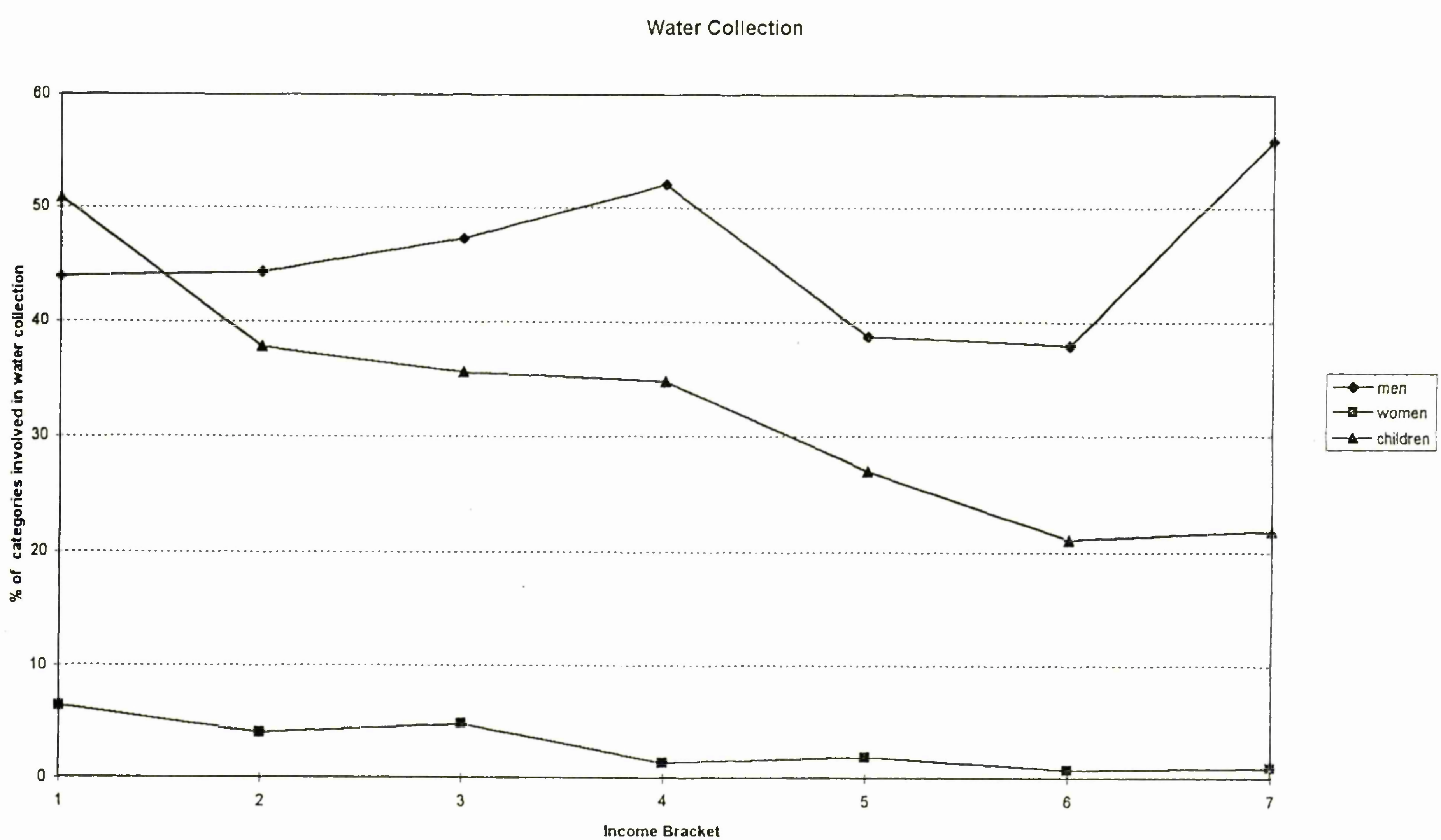

Water Collection
60
50
40
30
20
10
0
% of categories involved in water collection
1
2
3
4
5
6
7
Income Bracket
men
women
children

Figure 4.16

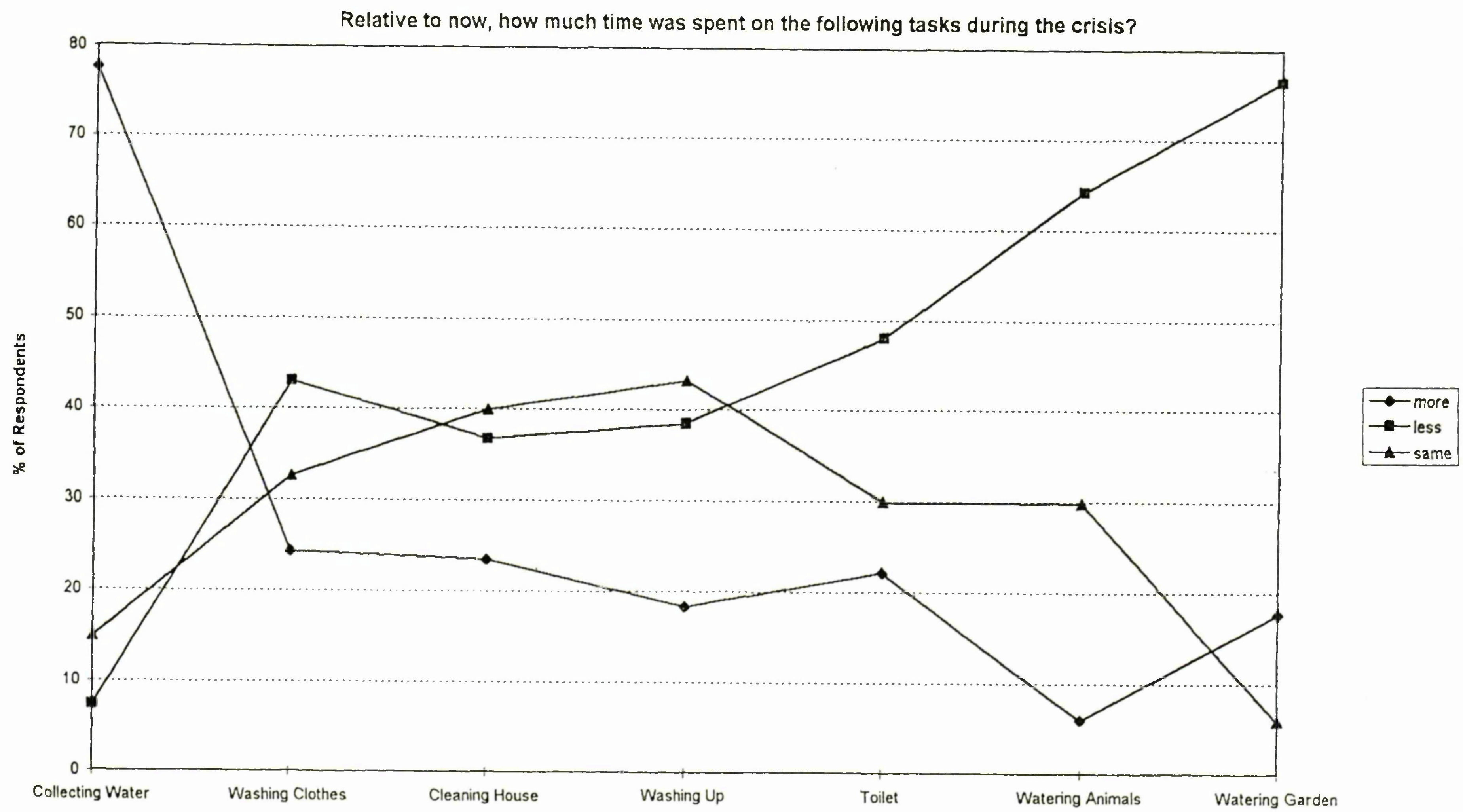

Relative to now, how much time was spent on the following tasks during the crisis?
% of Respondents
0
10
20
30
40
50
60
70
80
Collecting Water
Washing Clothes
Cleaning House
Washing Up
Toilet
Watering Animals
Watering Garden
more
less
same

Figure 4.17

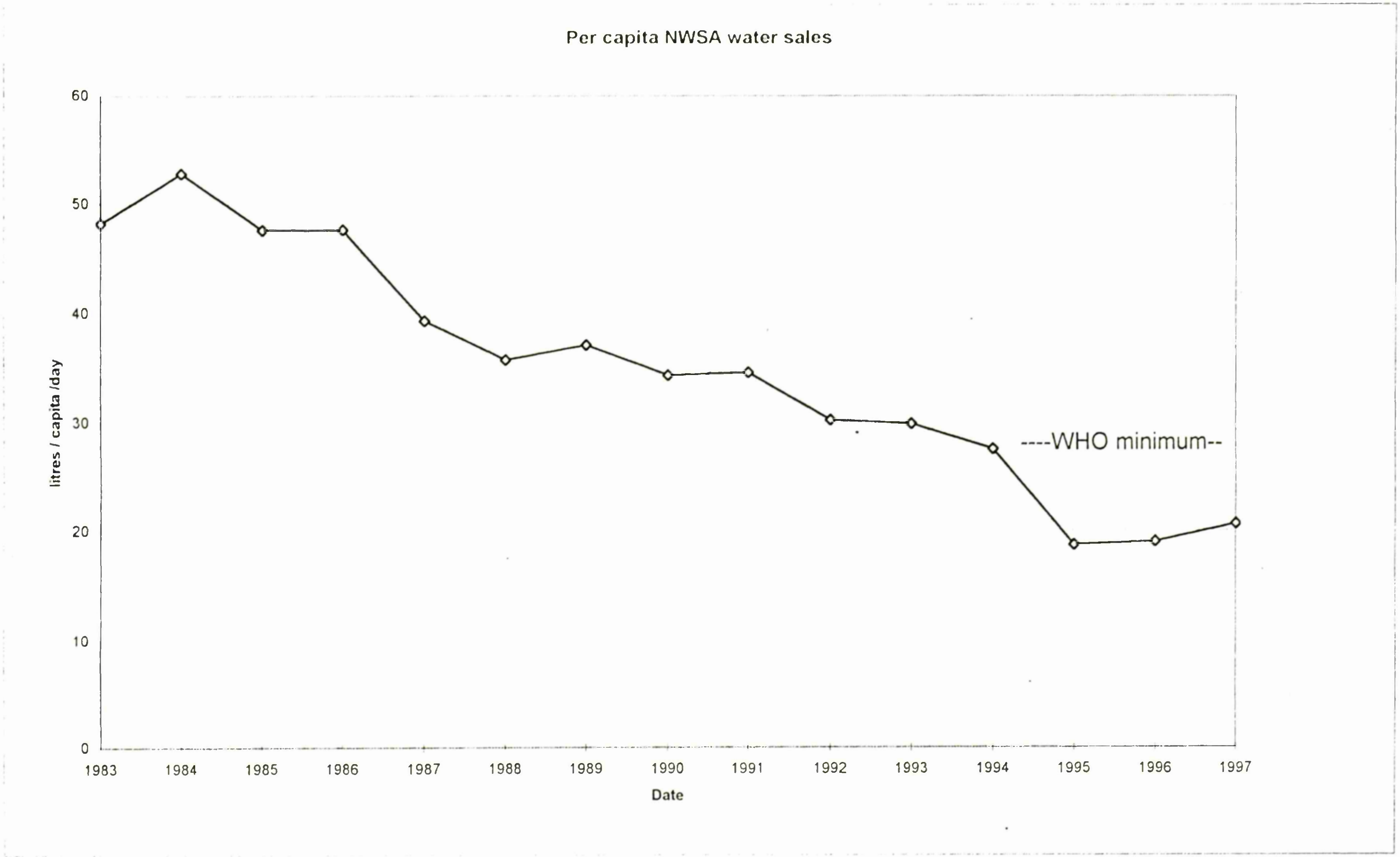
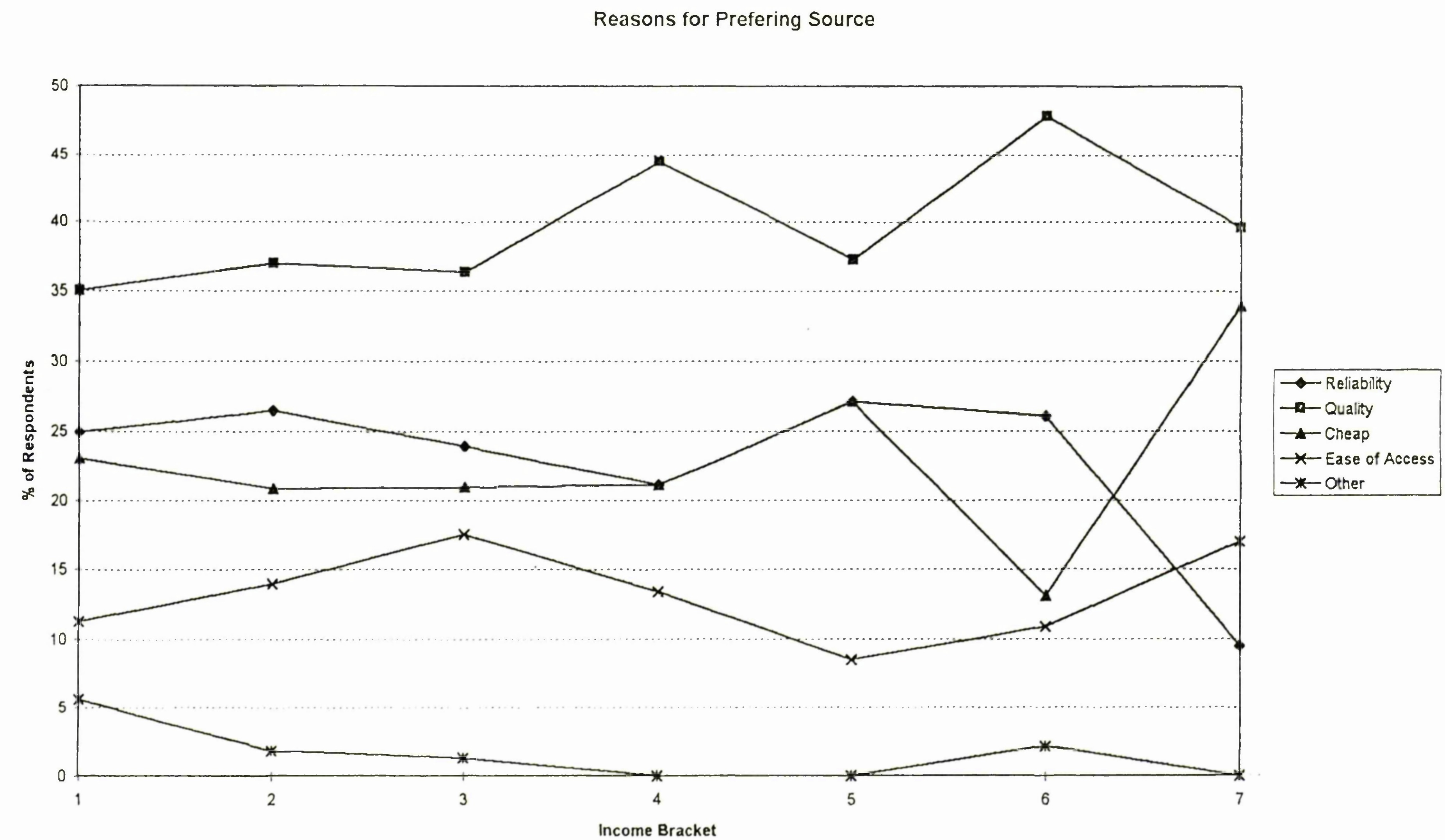

Per capita NWSA water sales
60
50
40
30
20
10
0
litres / capita /day
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
Date
----WHO minimum--

Figure 4.18



Reasons for Prefering Source
50
45
40
35
30
25
20
15
10
5
0
% of Respondents
1
2
3
4
5
6
7
Income Bracket
Reliability
Quality
Cheap
Ease of Access
Other

Figure 4.19

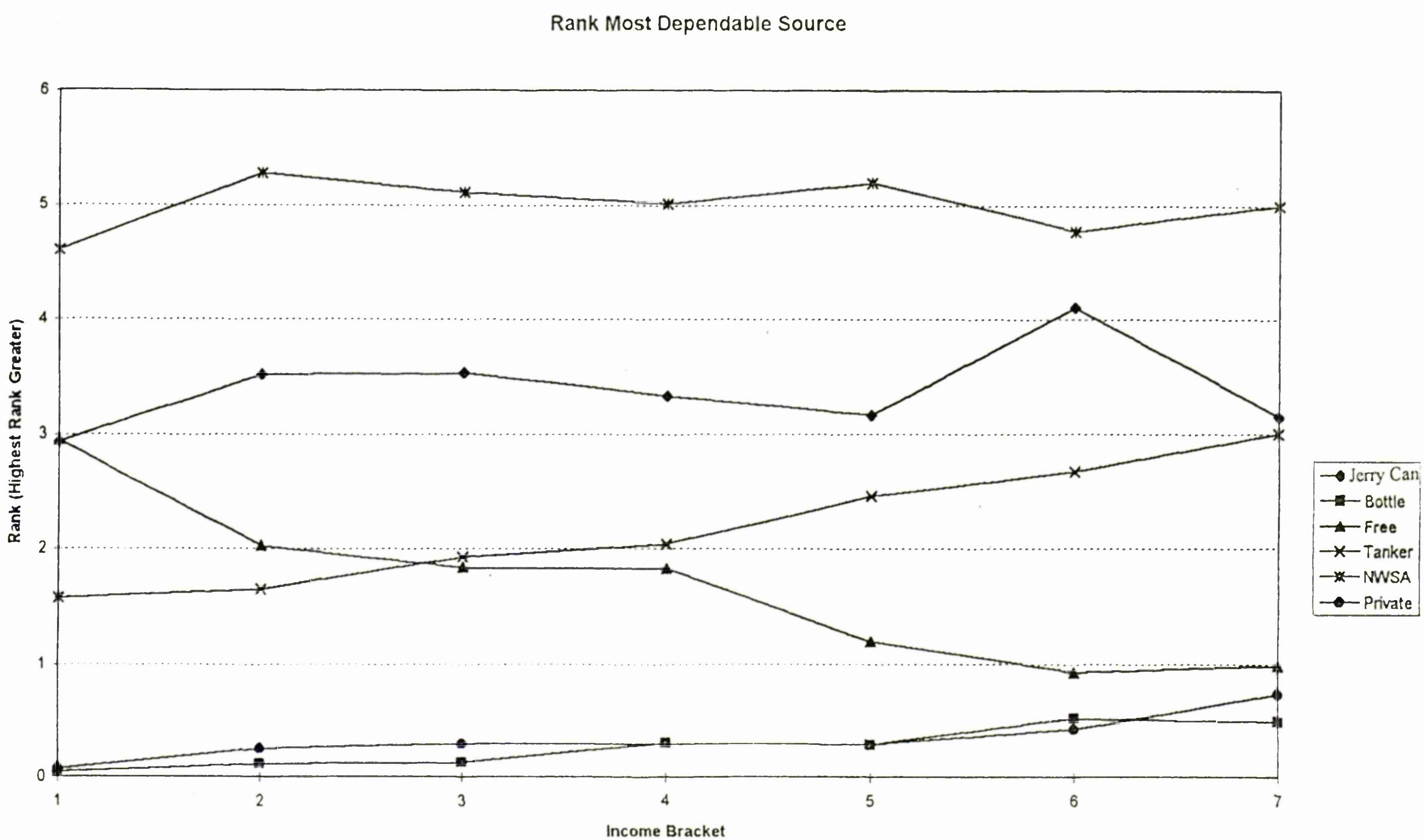
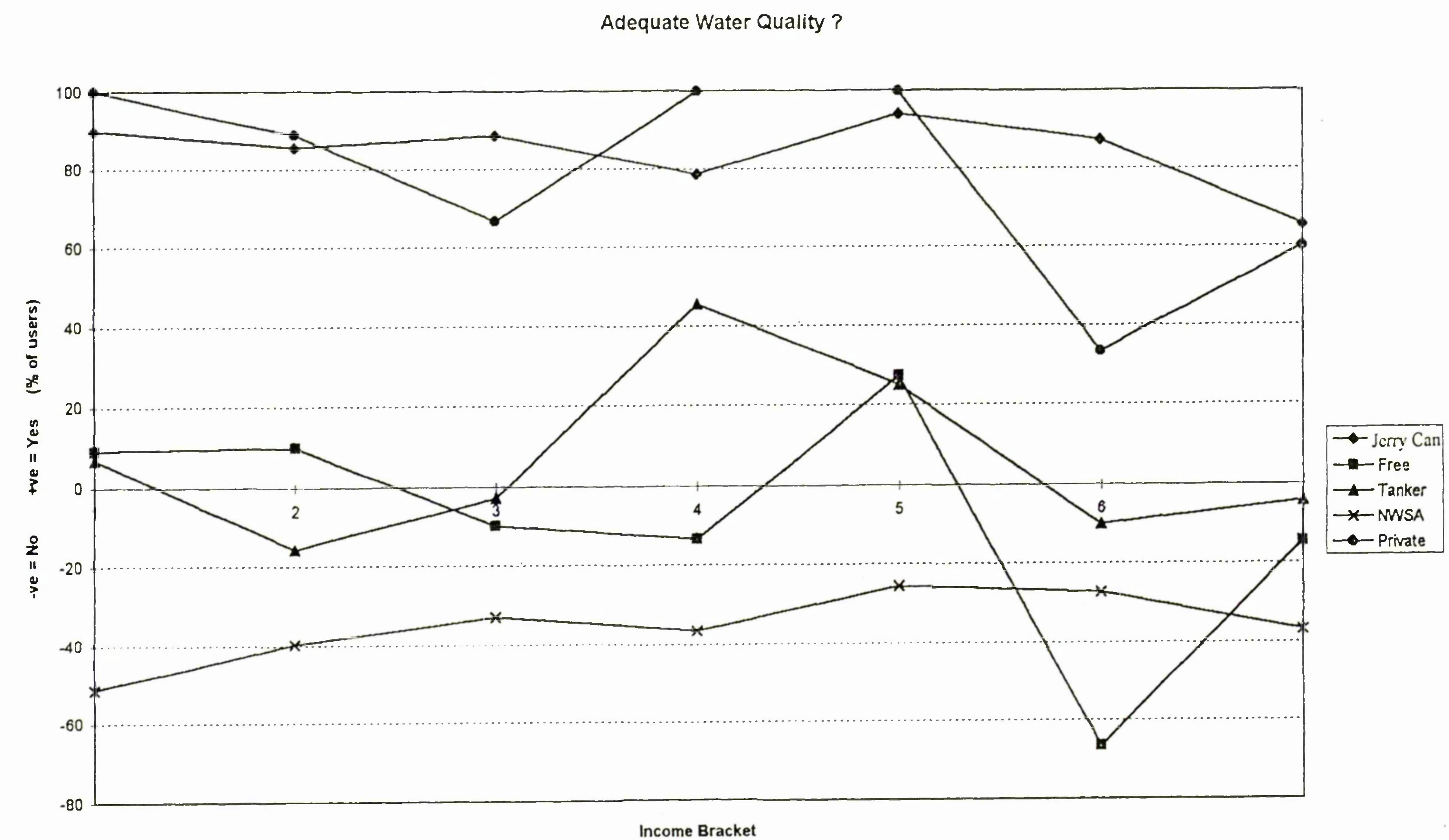

Rank Most Dependable Source
Rank (Highest Rank Greater)
0
1
2
3
4
5
6
1
2
3
4
5
6
7
Income Bracket
Jerry Can
Bottle
Free
Tanker
NWSA
Private

Figure 4.20



Adequate Water Quality ?
100
80
60
40
20
0
-20
-40
-60
-80
-ve = No   +ve = Yes   (% of users)
2
3
4
5
6
Income Bracket
Jerry Can
Free
Tanker
NWSA
Private

Figure 4.21

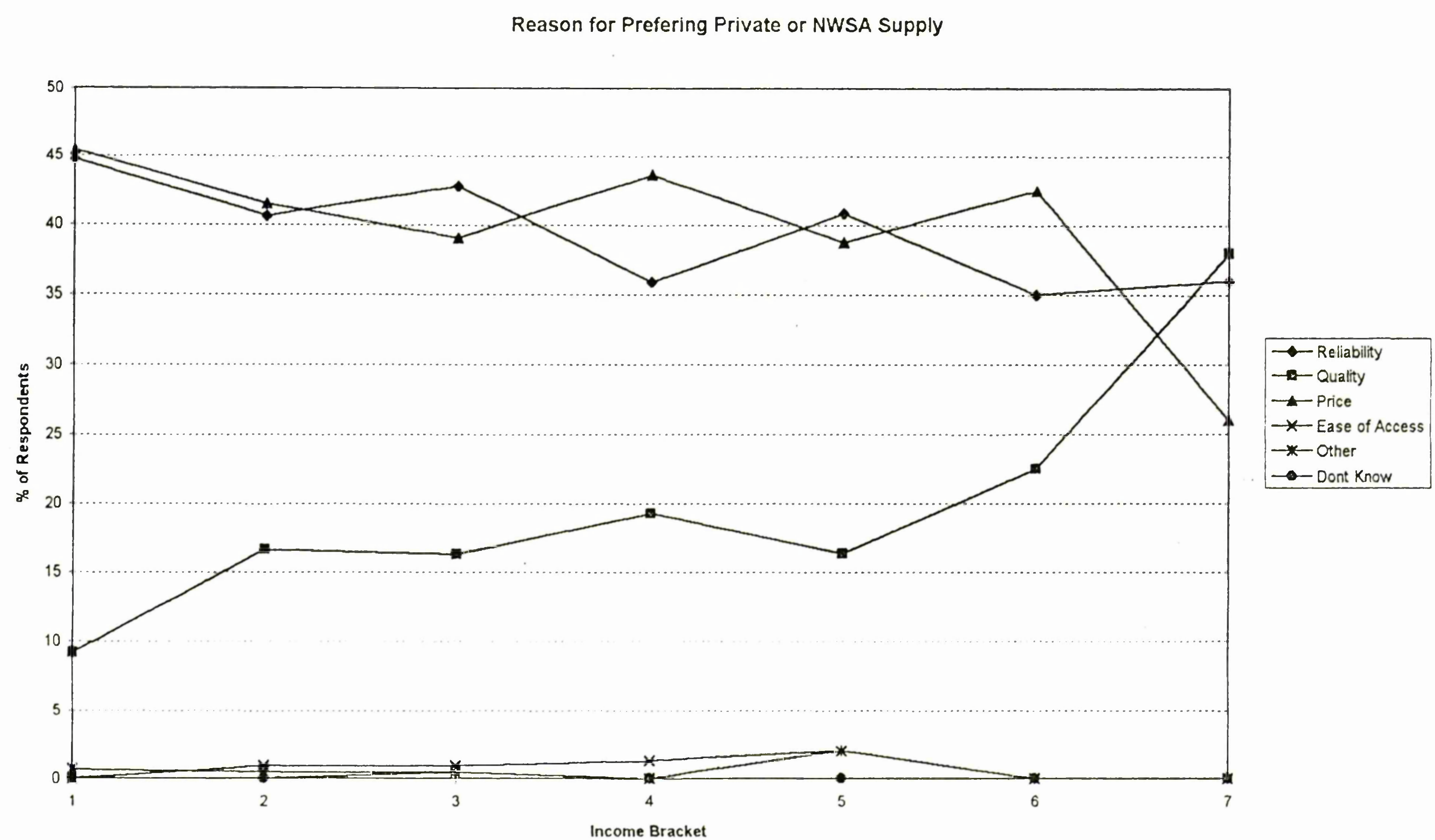
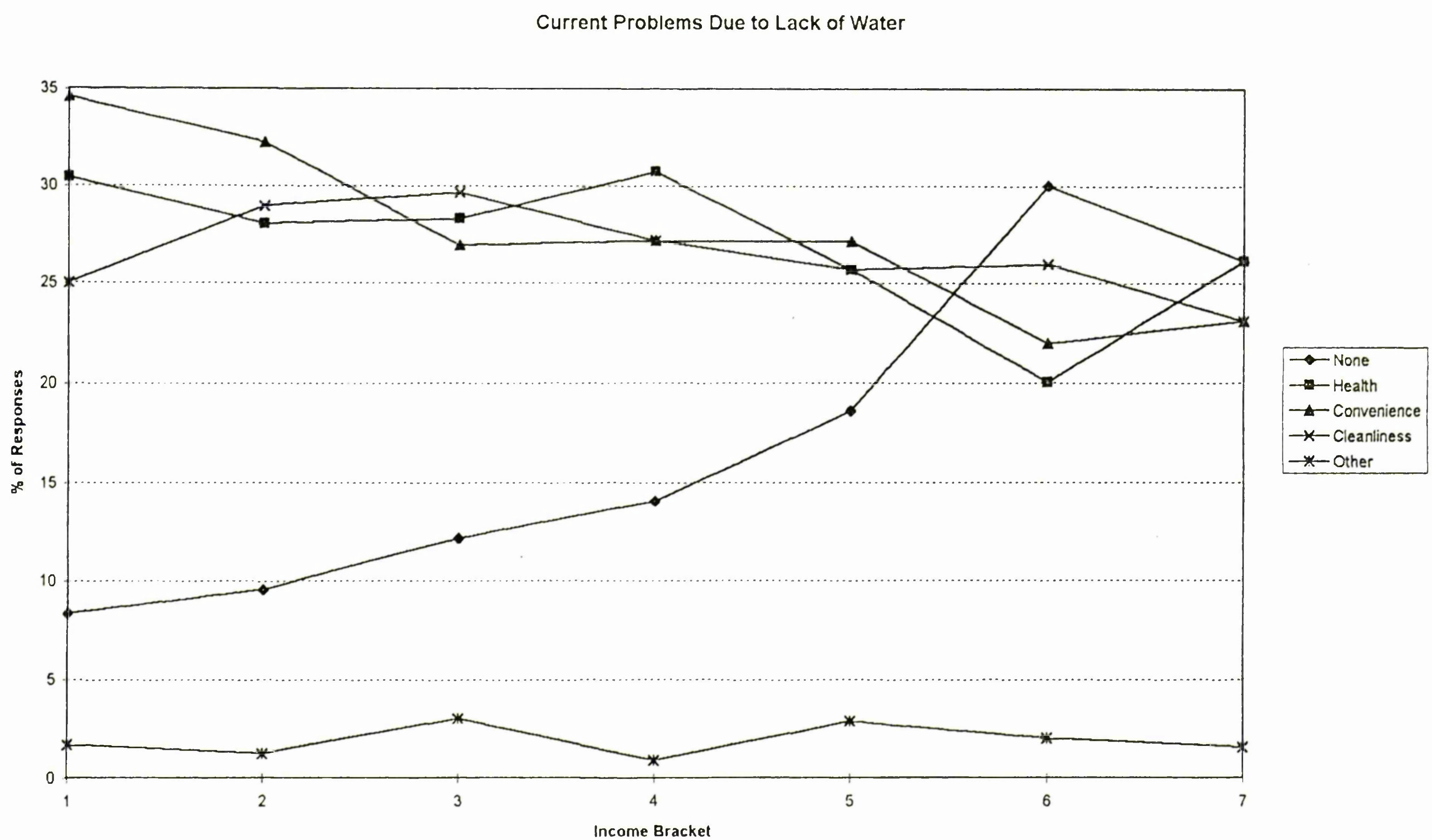

Reason for Prefering Private or NWSA Supply
50
45
40
35
30
25
20
15
10
5
0
% of Respondents
1
2
3
4
5
6
7
Income Bracket
Reliability
Quality
Price
Ease of Access
Other
Dont Know

Figure 4.22



Current Problems Due to Lack of Water
35
30
25
20
15
10
5
0
% of Responses
1
2
3
4
5
6
7
Income Bracket
None
Health
Convenience
Cleanliness
Other

Figure 4.23

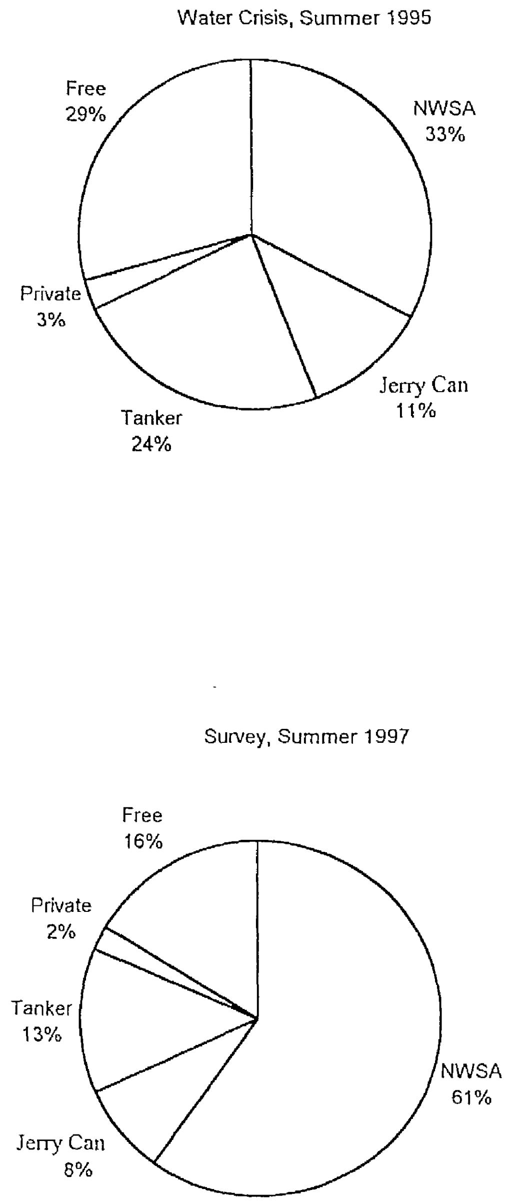


Fig. 4.24 Proportion of water supplied to households from different sources during the water crisis and during the survey (by quantity).

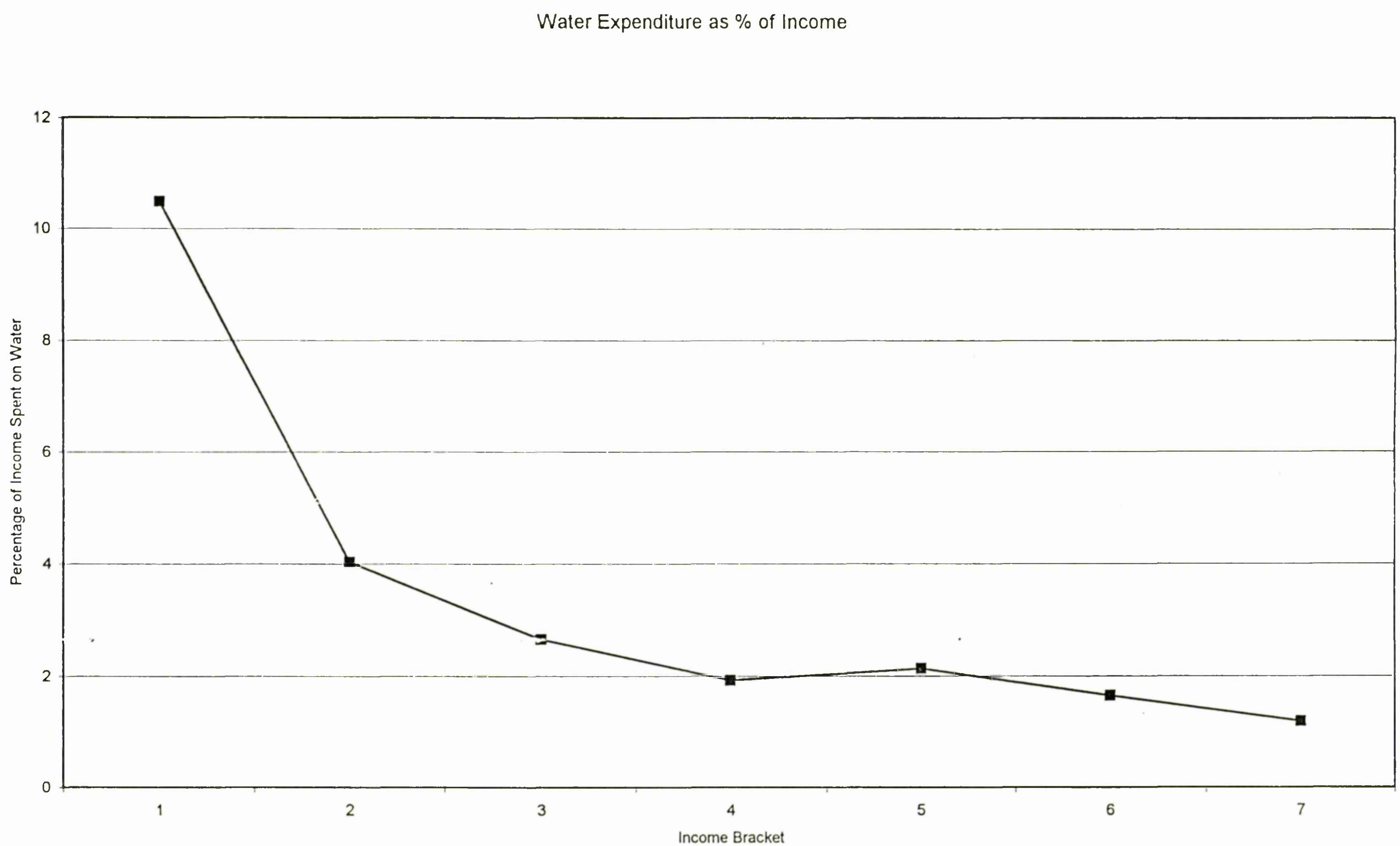


Figure 4.25: Household expenditure on water as a percentage of income.

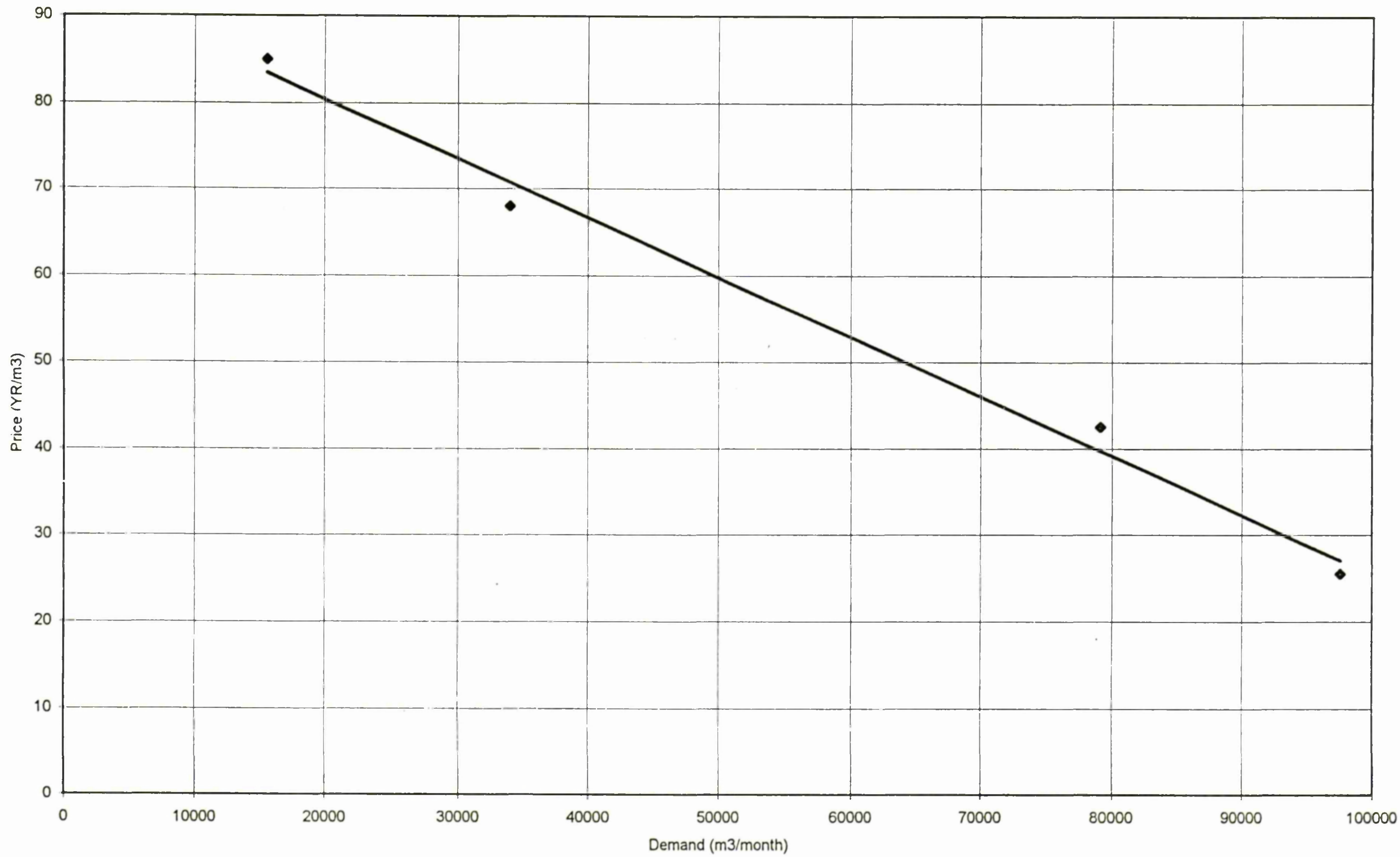


Figure 4.26: Price Elasticity of Demand for NWSA water.

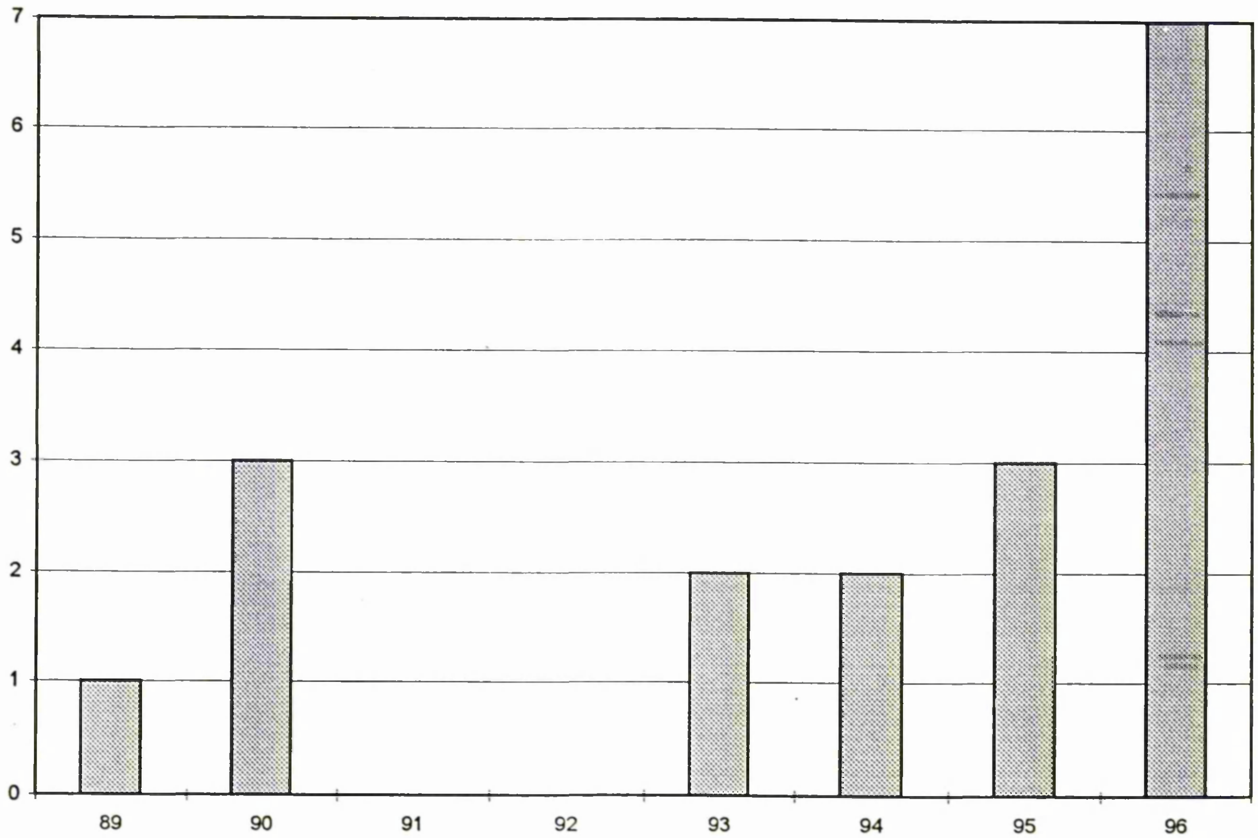


Figure 4.27: Ta'iz Drinking Water Treatment Companies Established Annually.

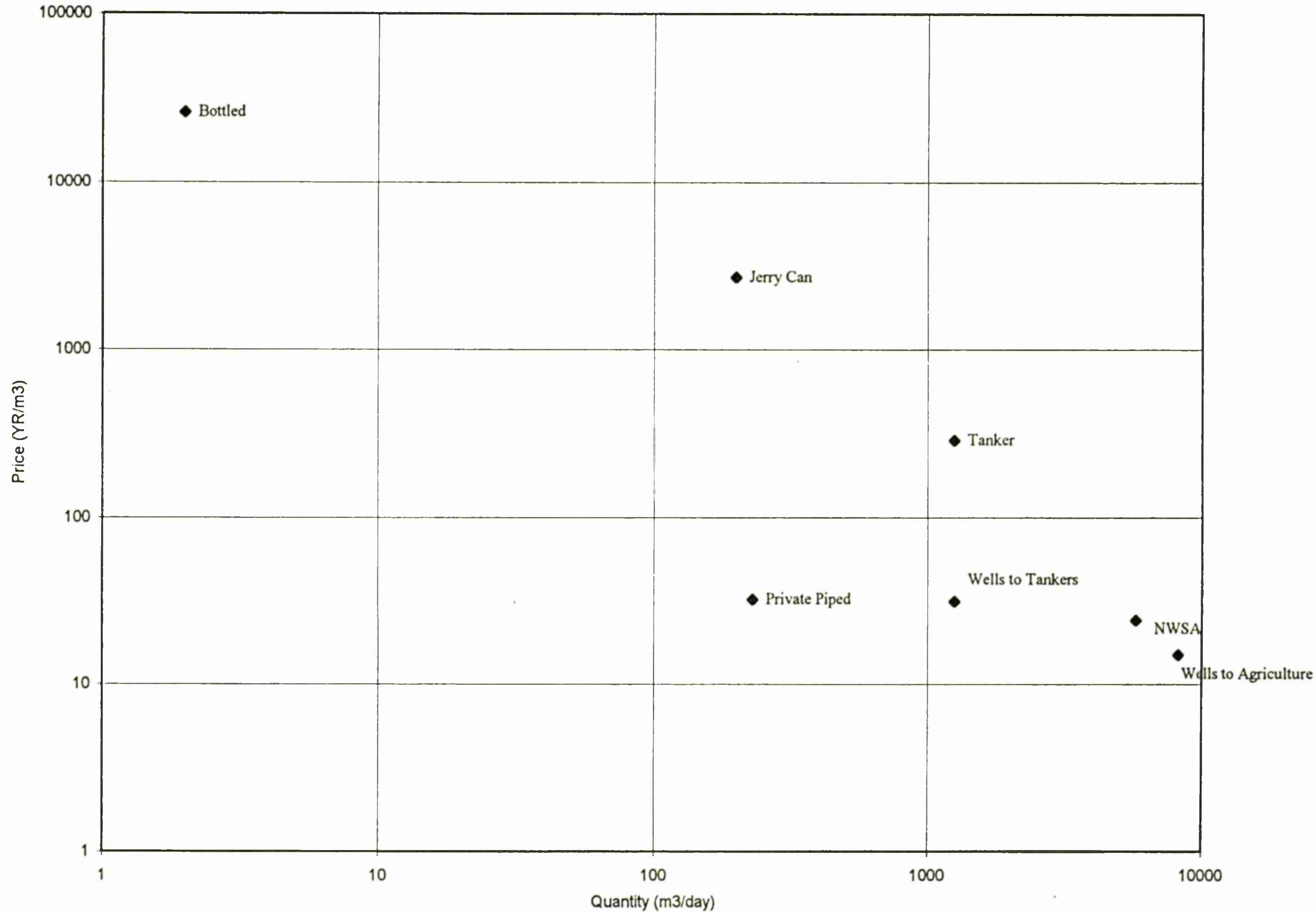


Figure 4.28: Sale Price vs Estimates of Quantities of Water Sold in Upper Wadi Rasyan Water Markets

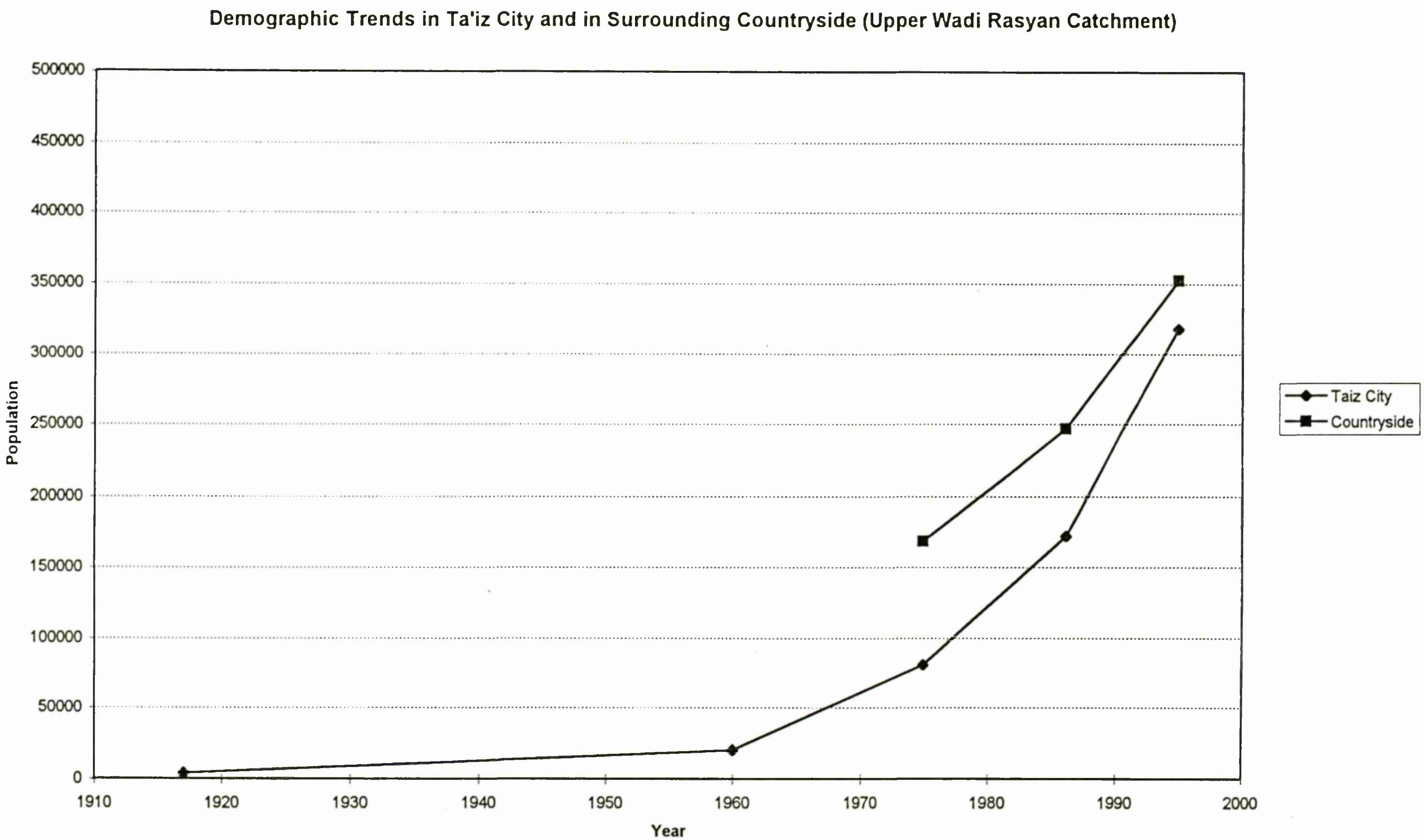
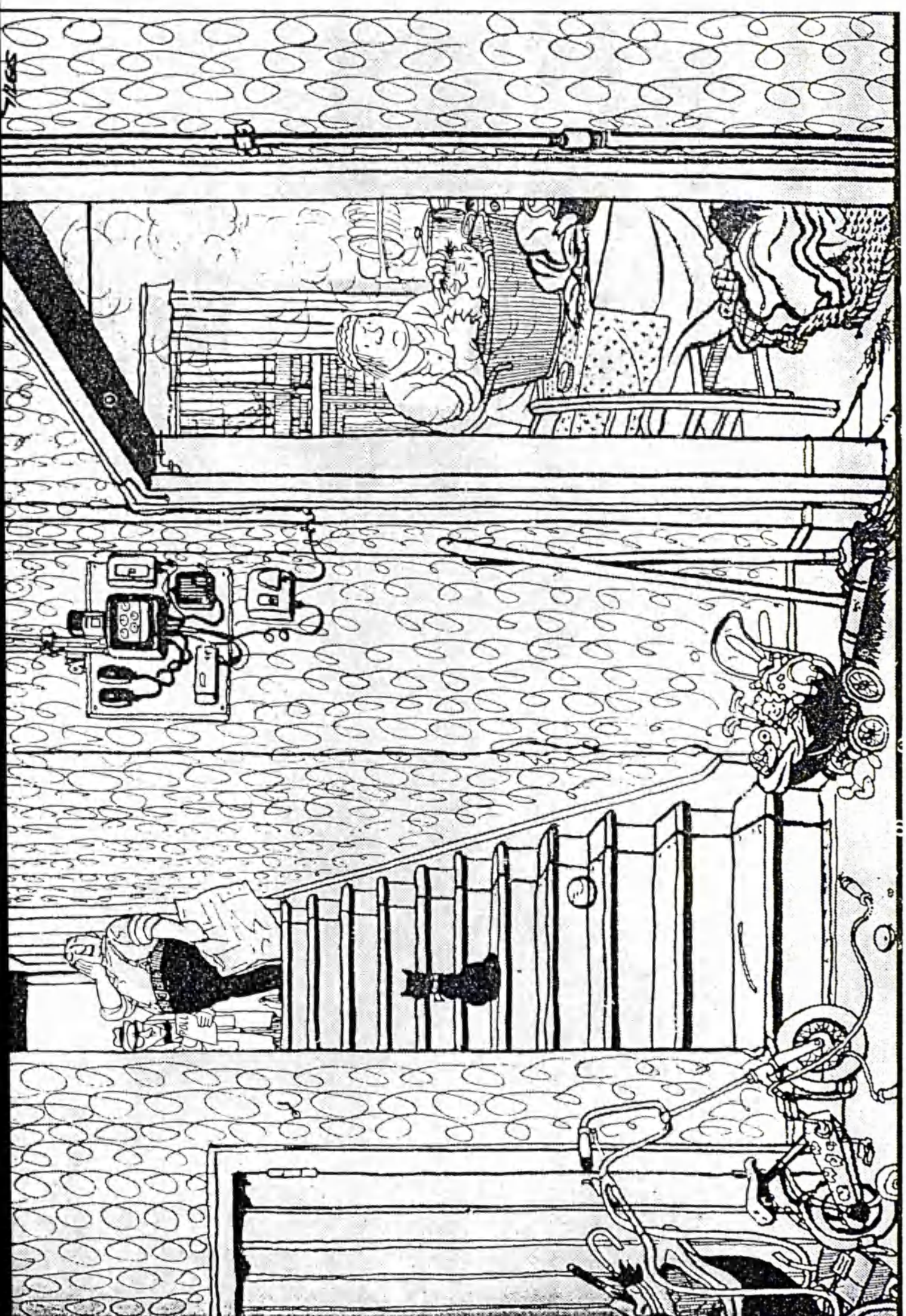

Demographic Trends in Ta'iz City and in Surrounding Countryside (Upper Wadi Rasyan Catchment)
Population
500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Year
Taiz City
Countryside

Figure 4.29



"Mother! Gentleman from the Polls wants your opinion on Fox Hunting."

Sunday Express, November 26th, 1972

Figure 4.30: The Relevance of Domestic Water Use Questionnaires

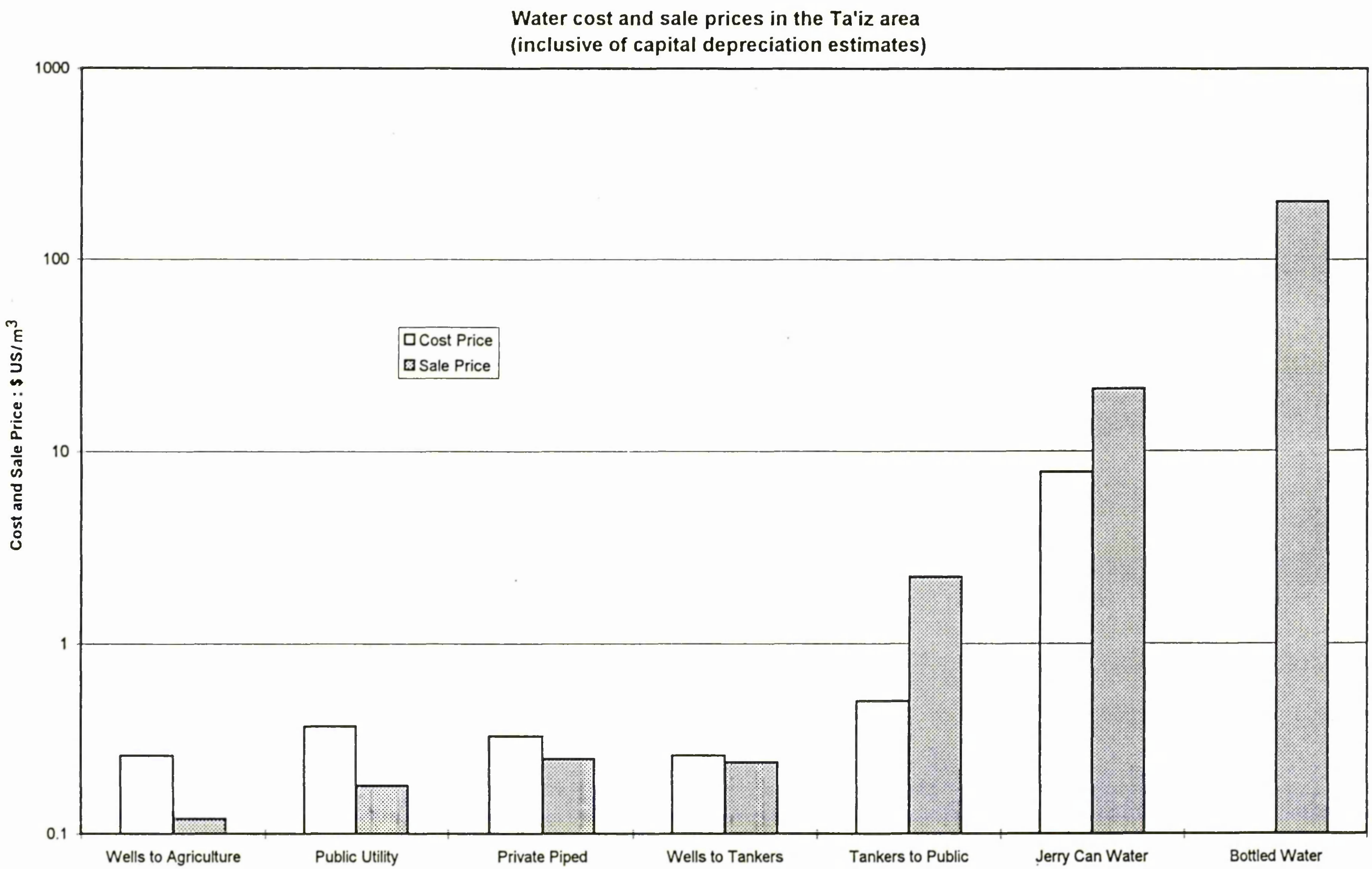

Water cost and sale prices in the Ta'iz area
(inclusive of capital depreciation estimates)
Cost and Sale Price : $ US/m3
1000
100
10
1
0.1
Cost Price
Sale Price
Wells to Agriculture
Public Utility
Private Piped
Wells to Tankers
Tankers to Public
Jerry Can Water
Bottled Water

Figure 4.31

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Papers
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for Copyright
reasons

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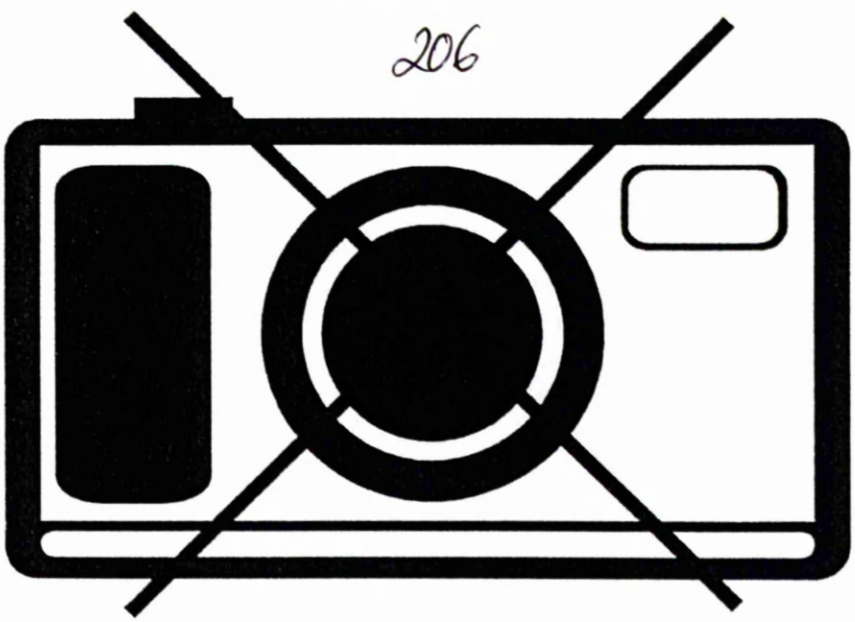


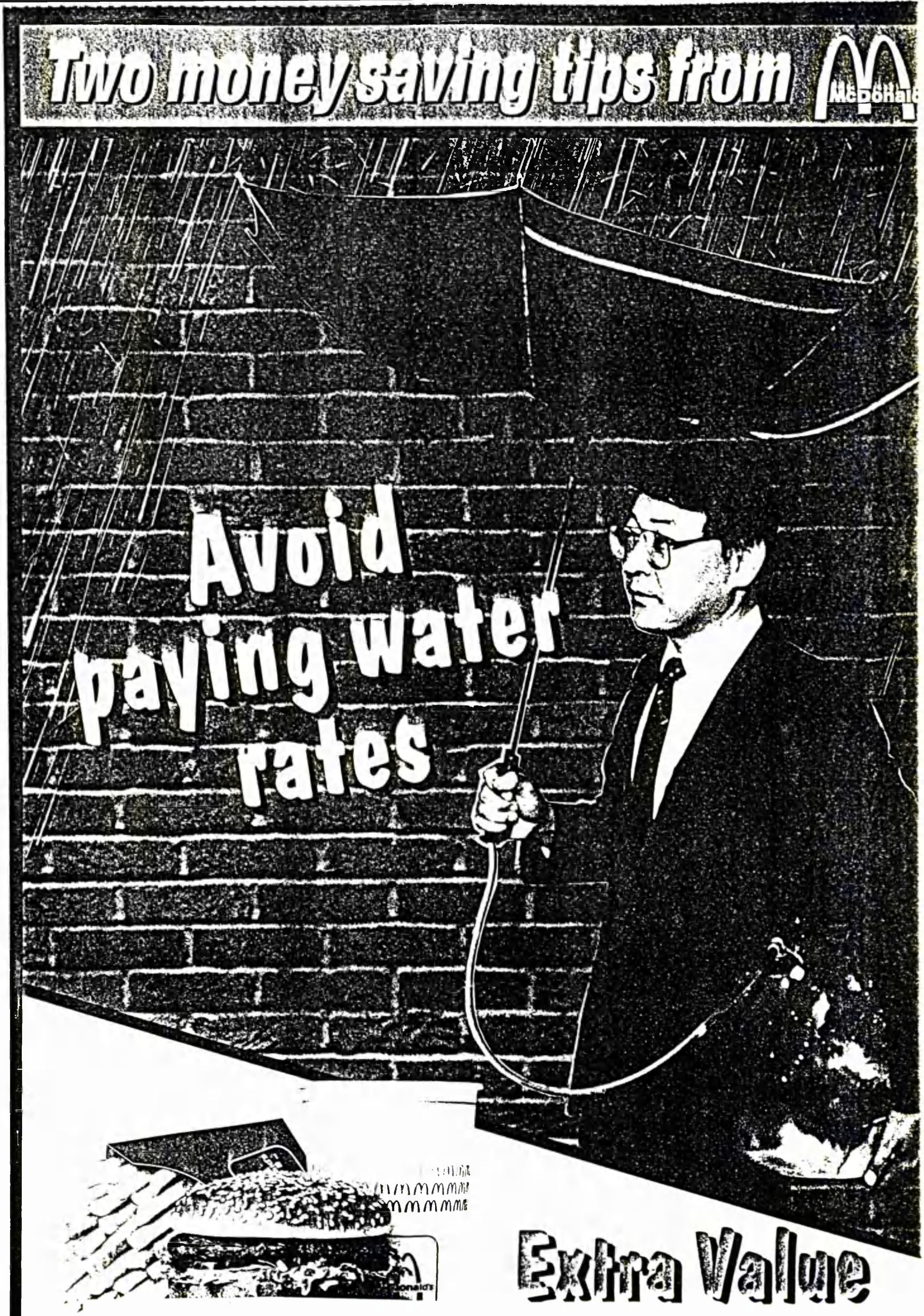


Figure 4.32 Is water perceived as an economic good ?

Chapter 5 Discussion: Anatomy of a Water Crisis

'water flows uphill to money and power'

Reisner, 1986

In this chapter, the development theory discussed in chapter 2 is tested against the empirically derived physical and socio-economic realities of the Ta'iz situation. These realities were presented in chapters 3 and 4. Where appropriate, new data are presented in this chapter to illustrate the points made.

The evidence given in chapter 4 suggests that the water shortage in Ta'iz not only had a significant impact on the social habits of the population, but that human activity largely contributed to the crisis in the first place. Water can 'flow uphill to money' (Reisner,1986), and this chapter begins with a summary of the economic context which underlies the social adaptations to the water shortage in section 5.1. Reisner continued by suggesting that 'water flows uphill to money and power'. Political ecology seeks to unravel the 'interactions of different actors pursuing their quite distinctive aims and interests' (Bryant and Bailey,1997;21) and section 5.2 comprises an actor-oriented analysis (ibid;24) of the actions of the powerful in determining water allocation in the Ta'iz area over the past thirty years. Within Bryant and Bailey's framework of political ecology (1997;21-24) the Ta'iz situation is problem specific – water shortage (reflected in declining groundwater levels and water quality) and regionally specific – that is, Ta'iz and the surrounding Upper Wadi Rasyan area.

Coase suggests that the legal system under which a market operates largely determines whether the transaction costs of making an exchange can be covered (ibid;717). In particular he identifies 'clarity in the law', 'an appropriate system of property rights' and whether 'they are enforced' (ibid;718) as necessary if trade is to be facilitated. Section 5.3 examines the existing legal framework in Yemen regarding water transfers from the specific standpoint of these three issues. Coase (1992;714) also asserts that appropriate institutions are needed to govern the process of exchange in a market economy. Water transfers in Yemen are no exception. Section 5.4 examines the existing institutions in the context of their appropriateness to facilitating water transfers.

An adequate examination of the origin of the aims and interests of the political actors that operate within, and manipulate, the legal and institutional frameworks, is beyond the scope of this study. However, a few observations regarding some prevailing belief systems concerning water allocation and the implications for development are given in section 5.5.

Finally, the problems of water resources management and efficient water allocation in Ta'iz have not occurred in isolation, but rather have attracted a considerable amount of interest and money from the development community. Section 5.6 considers the concept specific aspects (Bryant and Bailey,1997;21-24) of economic progress, equity provision and environmental protection in the water sector in the contexts of both current debates in the development/donor community and their involvement in Ta'iz.

5.1 The role and limitations of demand management in Ta'iz and the virtual water solution

> virtual water is provided 'at a price as cheap as the cheapest local source of water, that used in irrigation, and in amounts ....almost as large as the total water economy'

> 'a litre of wheat for a day's wages'
> Revelation 6:6

During the 1990's the international hydraulic community has progressed in its awareness of appropriate measures needed to alleviate water scarcity towards making the water go further rather than simply trying to find more water. Those measures are summarised under the umbrella term 'water demand management' (WDM).

The steps in awareness which take us towards formulating a demand management policy may be summarised as:

1. Water has a value
2. Water is an economic good
3. Water should 'gravitate' to the highest value use by:
    a) Productive Efficiency (promotes the reduction of waste and the more efficient technical use of water)
    b) Allocative Efficiency (promotes intersectoral water transfer)
4. Allocatively Efficient water transfers are facilitated locally via water markets and,
5. On a larger scale via virtual water (international water transfer)

Although the hydraulic actors in the city of Ta'iz, Yemen are mostly remote from the international discourse, to an extent, this progression has occurred *ipso facto*. It is suggested that, as a consequence of the needs and economic realities even if not by conscious awareness, the implementation of WDM principles is directly promoted by increasing water scarcity and that more water scarce regions are likely to have progressed further in their implementation than many water-rich areas.

5.1.1 Water has a value vs. Water as an economic good

That water has a value and that it should be treated as an economic good appear to be two sides of the same coin. The first, water having a value, is related to the benefits accruing from water. The second, water being treated as an economic good is related to the costs incurred in accessing water. They form separate steps in the awareness process, however, simply because there seems to be a time gap, if not decision-making gap between appreciating the value of water and being prepared to pay for it. Although many can appreciate some of the user aspects of water (drinking, irrigating, manufacturing, swimming etc.), the full value of water including its future value and value to non-users identified by Burrill (1998) is impossible to quantify. The UK motor industry is said to provide four times as many jobs in related provision of services needed to maintain it as there are people directly employed by it. This 'trickle-down' phenomenon is also observed in the water supply of Ta'iz where its value in terms of livelihood provision to those who trade, transport and treat it (as described in section 4.5) is considerable. The greatèr the losses of economies of scale in the private sector the more are the benefits in livelihood provision.

When it comes to paying for the water, the current development ethos informs us that the economic costs of its provision should be recovered. However, the awareness that water is not free, and, more importantly, should not be free is slow to permeate any society (Figure 4.32). Ta'iz provides some useful examples of different aspects of the cost of water:

Marginal Costs

The public piped water utility is failing to collect adequate revenues to even cover half of the running costs from an average charge of only 0.17 $\$/m^3$. Average incremental costs of alternative supplies currently being considered range from 0.5 to 1$\$/m^3$ from conventional potential groundwater sources to 2.5$\$/m^3$ for desalinated seawater (Handley,1999b). These estimates exclude the provision of sanitation and also salaries. In rough terms current tariffs are possibly around a quarter of the marginal cost. Although the public utility shows little indication of progress in treating water as an economic good, the expenditure by the public on water when all sources are considered (Figure 4.25) suggests otherwise. It is considered that the price paid by households reflects water's necessity status which forces a willingess-to-pay above and beyond capacity-to-afford and also forces water to become an economic good in consumer awareness. Pricing by the public utility, and the consumer attitude to the utility on the other hand suggest that water is a public right rather than an economic good. This problem is perceived by the author to be related to prevailing belief systems and also to the institutional and political context. These aspects are discussed in later sections. If marginal cost recovery by the public utility is to occur then significant changes in the utility will be needed, though consumer capacity-to-afford may not be enough.

In the agricultural sector, the irrigators of nearby Wadi Ad Dabbaab who also supply tankers were asked whether they would sell bulk supplies to the city of Ta'iz. Although they said they would, all made the proviso that in the case of scarcity irrigation would come first. This is despite the fact that returns to water from supplying tankers are better than from irrigation, or rather are not as bad. Farmers do not face up to the true marginal cost of irrigation, but then nor does the World Bank (Moench,1997;12). The reason the farmers do not is not that they are poor money managers. The 1980's remittances boom which paid for the wells blinded them to the real costs, and subsidies on pumps, irrigation equipment and diesel since has tightened the blindfold. The few who still have enough capital / power to drill are spurred on by the increasing scarcity of underground water, the exploitation of which still remains unchecked by regulation.

Opportunity Costs

Two examples are cited as evidencing the preparedness of consumers to pay significant opportunity costs. One is the queuing of people for water. The social benefits for rural women waiting their turn at the well (Ansell,1980, Maclagan,1995) may significantly offset the opportunity cost of being able to spend their time doing something else. The contrast between wealthier and poorer peoples' access to free water by children or men queuing and tankers by payment in the urban environment (Figure 4.12) suggests there is a household evaluation of opportunity cost in which time and money are exchanged.

The second example is reflected in the effort made by industrialists to ensure a reliable supply of water. The major industrialists interviewed all consider water provision in the context of days of production lost due to insufficient water supply. They therefore make opportunity cost driven decisions and are perhaps more in a position to do so because water is still a relatively small part of their total inputs budget.

Transaction Costs

The very existence of the water markets in Ta'iz indicates that the transaction costs incurred in these markets have been overcome. However whether the transaction costs of bulk rural –

urban transfers of water are met is another matter. The transactional cost of the World Bank 'experiment' in negotiating water transfers from Habir to Ta'iz has cost around $700,000 for a supply unlikely to provide more than 20 lit/sec to the city. This amount does not include the $8M compensation being paid nor the exploration costs ($2.5M). If the scheme lasts thirty years, the negotiation costs will be around 4cents/m^3. If the exploration costs are included and a more typical ten year life is assumed, then the transaction costs are 50cents/m^3. This cost represents around three times the price that the same water is sold for to the city consumer by the public utility.

Social Costs

Dellapenna (1995:155) points out the potential social costs involved in selling water and cites the potential loss of tax revenues to a community as an example. This cost might be considered a form of opportunity cost, and would certainly be a factor if, for instance, water sales to the city from agricultural use resulted in a decline in crop production, and hence a drop in zakaat due from the crops. Under-collection of zakaat and non-transparent returns to the community mitigate against the significance of this cost, and in any case, under Yemeni customs, irrigated crops are taxed at a lower rate than rainfed crops (a wrong economic signal to the irrigator). The little tax lost from the agricultural sector could be recovered through the water use activity in the sector the water is transferred to (industry more so than domestic use). However, the means of returning benefits accruing via taxes on irrigated products will have been lost to the water source communities through the water transfer.

5.1.2 Intrasectoral Productive Efficiency Measures

Discussions of transfers of water within the agricultural sector in the development literature tend to focus on irrigation methods and crop varieties and there is certainly scope for such measures in the Upper Rasyan catchment. The switch by farmers from coffee to qat production may be construed as one of the latter measures , although those who think qat uses as much water would contest this (see Weir 1985, Al-Hamdi,1998, Heidbrink,1994). However, three points are much more salient than the application of such measures. Firstly, regarding irrigation methods, savings in water as a consequence of switching to a more efficient irrigation system will mainly reduce 'losses' which would otherwise have recharged the aquifer. Savings from improved irrigation methods will be mainly in the energy (usually diesel) expended in pumping the water rather than in protection of the water resource itself. Secondly, because there is more potentially cultivable land than there is water to irrigate it, any savings in water will only result in the irrigation of a larger area rather than a reduction in water use, that is, water is the constraint, not land (Bromley,1986;593). This was clearly demonstrated in farmer decision making in Amran (Handley,1996b) and leads to the third point, that the principle of the 'tragedy of the common' groundwater is a ubiquitous driving force. As one farmer in Amran put it "if I were to try to reduce my water consumption" (specifically by installing drip irrigation in this instance) "my neighbour would get a larger slice of the resource without the expense I, the water-efficient farmer, have incurred" (ibid.).

Traditional rainwater harvesting methods transfer water efficiently from land with very poor cropping potential to marginal land where but for the extra run-on cropping would not be possible. Another ancient, indigenous productively efficient form of water use is rainwater harvesting from land and roofs in the rural and urban areas for domestic and animal use. A more recent development in the implementation of productive efficiency measures is industrial water recycling and industrialists are currently exploring further steps in this area. The reuse of domestic waste-water by agriculture has been poorly managed with degradation of the environment as a consequence (see section 3.7). Waste-water treatment is needed to make agricultural use a viable option, but at around 0.6$/m^3 the costs are probably prohibitive.

5.1.3 Intersectoral Allocatively Efficient Water Transfers via Markets

Table 5.1: Summary of water users and intersectoral transfers.

	Quantity Mm^3/yr	Price $/m^3
Rainfed and Stream-fed Agriculture	103	Free
Irrigated Agriculture	30	0.08 – 0.16
Rural Domestic Use	2.5	20 household hours/m^3
Urban Domestic Use	2.7	0.17
Industrial and Commercial Use	2.5	0.17 – 2.0*
Water Transfer: Rural Agriculture to Urban Domestic via tankers	0.5	2.0
Water Transfer: Rural Agriculture to Urban Domestic via NWSA Supplies (quantity pumped)	5	0.17
Water Transfer: Rural Agriculture to Urban Industrial via tankers and pipelines	2	0.5 – 2.0**
Water Transfer: Virtual Water imported from overseas to the area in grains	100***	0.11***

* NWSA / private tanker source
** Own tanker / private tanker source
*** See section 5.1.5.

With six discernible urban water markets and the reality of intersectoral reallocation of water resources, awareness and implementation of allocative efficiency measures in Ta'iz are surely well ahead of 'Northern' counterparts. However, the volume of water being transferred by agreement from irrigated areas with low (or rather negative) returns to water to domestic and industrial users who pay economically realistic rates is limited to around $2.5Mm^3/yr$ (shown underlined in Table 5.1)

Despite Falkenmark and Lundqvist's assertion that 'reliance on market mechanisms is often less than realistic in the 3rd world' (1995) and Dellapenna's claim that (1995;153) markets in water have never actually played much of a role, the very opposite has occurred in Ta'iz. Over 75% of the population have depended on the private market for drinking water costing around $20\$/m^3$ and up to 1/3 on tanker supplies for domestic supplies costing around $2\$/m^3$. In times of even more severe shortage participation in these markets increases further.

It might be asked why water markets have become so prevalent in Ta'iz and what has facilitated the intersectoral allocative transfers that are so difficult to establish in other places (Allan,in prep). A shortage of supply from the public utility, coupled with a decline in its quality and accentuated as the water shortage has deepened, has spawned the tanker and drinking water markets. The shortage has become so extreme that the physical constraint of moving bulky general domestic use water by tanker, or the local treatment of drinking water with all the loss of economies of scale involved, can still be funded at least by up to one-third and three-quarters of the community respectively. The high industrial returns to water combined with the significant political power of the industrialists has enabled them to meet their basic water needs through transfers from the agricultural sector.

In the view of Ward and Moench (Unpubl.) and this author the Ta'iz water markets are likely to expand. However, as noted in the instance of Yarim (Handley,1997a), the limit to expansion is not likely to be the availability of tankers or pipelines but of the resource, and water or its food equivalent has to be sought from outside the surface water catchment.

5.1.4 Suppressed Demand Management

It seems rather hypocritical for a Northern expert to espouse the merits of demand management to a Yemeni, at least to a Ta'izi, and then return home to her 'Northern' hydraulic lifestyle whilst the Yemeni goes home to his 25-30 l/c/d lifestyle. Suppressed demand is defined in the Ta'iz instance as the absence of choice to increase one's consumption. Essentially that choice is not open to most households, they simply have to make do with what they can get. A similar situation prevails in the rural areas where a lack of plumbing infrastructure adds to the problem of inadequate supply and limits consumption to 25 l/c/d or less. The adaptive capacity of Yemeni households in suppressed demand conditions to cope with the water stress is remarkable (Box 2). It is difficult to envisage, and unrealistic to expect, much improvement in end-user efficiency. If more water were to become available, then stronger demand management measures would be likely to be needed. Although suppressed demand results in, or equates with, reduced demand, it is neither a solution to inefficient use, nor a substitute for demand management.

Despite the adaptation to shortage of individual households there is a need for a similar adaptive capacity in the Yemeni institutions and political economy to redress the factors which have led to the shortages that have developed under their supervision. These issues are discussed in section 5.2&5.4 in relation to their political and institutional contexts.

Box 2: Ta'iz Water – The Reality (author quoted in World Bank, 1997)

"When the mains water finally arrives, all social engagements are cancelled and the mother and daughters will work from 6:00 am to 12:00 p.m. for the one or two days the water is connected. The washing has accumulated into a huge pile, some clothes are being worn a second time over and there are no clean clothes or bedding left in the house. The next day after the water stops is drying day. There is usually not enough room, so clothes are often draped on the roof over any object available – reinforcement bars, water tanks, etc. The next event is ironing. The whole cycle is about 4 – 5 days of constant water related activity by all female members of the household."

From the peak of the water crisis in August 1995 when water was coming once every 40 days.

5.1.5 International Allocatively Efficient Water Transfers via Virtual Water

The importance of imports of 'virtual water' embedded in grain, to the Middle East in particular, has been described by Allan (1998). Yemen is no exception, and has steadily increased its import of wheat and flour since the mid-1970's (Figure 5.1). In the period 1975 to 1996, total cereals imports have increased from 0.5M tonnes to 2.5M tonnes whilst domestic production has remained relatively static at around 0.5M tonnes (World Bank,1998a;Fig.2). That the dependency of this, one time 'bread basket of Arabia' on the international staples market began at exactly the same time as the migration of workers to Saudi Arabia and the Gulf in search of remittances is no coincidence. However, the return of a large portion of those workers in the wake of the Gulf War has not resulted in a decline in the import of grains. Local production of grains has not kept pace with the huge increase in population over the last 25 years, but rather, significant tracts of land which used to produce sorghum are now used for qat cultivation.

Ta'iz is no exception to the national picture. The household survey indicated that at least 91% of the population of the city purchased wheat or flour in bulk (50kg sacks) and the average household consumption was 24 sacks per year. Despite a preference for home-grown sorghum only 15% of households brought an average of 3.7 50kg sacks per year from the village, that is, one fortieth of the imported grain consumption. Ta'iz city population represents 2.7% of the national total and their wheat and flour consumption as indicated by the survey is almost exactly in the same proportion. If the city consumes an amount of wheat and flour close to the national average, then rural areas must also (although government subsidies provide incentives for leakages e.g. via smuggling). The equivalent quantity and price of virtual water indicated in Table 1 assume 1000 tonnes of water per tonne of wheat produced, that 4% of the national total reaches Ta'iz and the surrounding catchment of Upper Wadi Rasyan, and assumes the April 1998 street price of 770YR(5.9$)/50kg sack of wheat. That significant supplies of imported wheat and flour are being taken from the city depots to the rural areas, would explain the sacks seen on nearly every Toyota Landcruiser returning from city to village. Virtual water in Yemen has received two huge subsidies. Firstly the subsidy of the exporters paid to their farmers and secondly Yemeni subsidies to its importers. The result is the provision of virtual water at a price as cheap as the cheapest local source of water, that used in irrigation, and in amounts as large as the water used by local rainfed agriculture and almost as large as the total water economy (Table 5.1).

5.1.6 Some Equity Issues

Although the progression towards reallocating scarce water resources to higher value uses may make good economic sense, significant equity issues are raised. Among these are:

a) Compensation and the issue of protecting third party interests. That is, all those who had livelihoods dependent on the water sold in the selling community, not just the well owners.

b) The interests of those who cannot afford to purchase water from the markets, or who have to pay a significant portion of their income on water in order to survive. That is, 2/3 of the urban community who cannot afford tankers when the piped water runs out and 1/4 of those who cannot afford treated drinking water when the piped water is of inadequate quality.

c) Those who miss out on the 'predetermining allocative logic' of a piped supply, (Falkenmark and Lundqvist,1995;214), that is, those on the ever-expanding accretive edge of the city and/or those who cannot afford to connect.

d) Those who access less from the effectively subsidised piped system, that is, those without gardens and without many water using facilities available to the wealthy.

e) Those paying the externality of pollution, that is, those on the receiving end of domestic and industrial waste water and those without sewerage.

These people represent the losers in the water providing processes described in this section. Although the issues involved are beyond the scope of this section, and are reserved for later discussion, the inequitable consequences of water allocation must be noted.

5.1.7 Summary

It would appear that there is a difference in the application of WDM principles if not in awareness of them in the various water-use sectors of Ta'iz. In the irrigation sector where water, as opposed to land, is the constraint, productive efficiency demand management measures have little impact due to wider 'structural' issues of the price of diesel fuel, land availability and the commonality of groundwater. Besides the irrigation sector, those who do not act as though water were an economic good include the public domestic supply utility, and, it is suggested, the 'northern' development fraternity. In contrast, high levels of productive efficiency in water use by rainwater harvesting have been practised since the habitation of Arabia Felix began.

Also in contrast to the irrigation sector and the public utility, in the domestic and industrial sectors, where capital is a greater constraint, efficiency measures which come under the umbrella of demand management are seen to be applied and to work. Urban domestic and industrial users pay significant, though not full opportunity and transaction costs. Whether the marginal costs of domestic supplies will be met is perhaps more of an institutional issue than an economic one. Certainly domestic drinking water and industrial process water marginal costs are being met.

Those who do regard water as an economic good include the industrialists, those who trade, transport and treat it, and those who have to buy it to meet their basic drinking needs. The split between those who consider that Water Is an Economic Resource (WIER) and those that do not (WINER, Allan,in prep. terminology), is related to small volume high quality drinking water in the former camp versus large volume lower quality domestic / irrigation water users in the latter. The main exception to this rule is the industrialists who need quite large quantities of reasonable quality water and are ready to pay WIER prices. The reason that they can be the exception is the far greater returns they achieve from their water use when compared with other users (Table 4.12).

The fact that individual households and businesses have turned to the highly need-adaptive water market is essentially due to the failure of the public utility to provide adequate supplies. The adaptivity of those households and businesses to the water shortages reflects the suppressed demand conditions that have led to the proliferation of alternative water sources in adaptive markets. The growth of the markets has also been helped by the prevailing environment of political interests and legal pluralism that are examined in later sections.

Local water markets are, however, dwarfed by the scale of involvement in the international water market. The amount of virtual water imported from overseas in the form of grain underlines Yemen's dependence on World Water.

Perhaps the most significant problem in both the intra- or intersectoral reallocation of water but particularly the latter is one of equity. This is particularly so for those in the buying community who cannot afford it and those in the selling community who are not direct recipients of the benefits of the sale.

This section has demonstrated that there are significant economic incentives to promote the transfer of water from irrigation to domestic and industrial sectors, and food needs are met by the import of virtual water. Water transfers, however, do not occur on an adequate scale to meet even the modest current demand and reliance on virtual water is ignored. The reasons for these inconsistencies are explored in the next section.

5.2 Yemeni hydropolitical reality: economic sense vs. political expedience

'bil urf aw bil unf'
by agreement or by violence
Ali Abdullah Salih, 1995

So far in this chapter, we have discussed some of the economic incentives and constraints to the efficient allocation of water in the Ta'iz region. However, in the water use and allocation business 'economics are an illusion; politics are real' Reisner (1986). Allan also notes that the pursuit of productive efficiency measures are politically acceptable whereas the much more effective reallocative solutions to water scarcity advocated by economists and scientists are politically too costly (in prep;6.18). Section 5.1 demonstrated the economic sense of the reallocative hypothesis in the Ta'iz instance. This section explores whether the politically possible prevails at the expense of the economically sound.

Aptly describing the hydropolitics of Ta'iz, Migdal (1988) asserts that the accommodation between the state and other interest groups, their struggles and manoeuvres constitute the 'real politics' of the South. In this process, Hajer (1995;39) emphasises the importance of the 'sub-politics' of the concealed, individualised, micro-powers as opposed to the acts of a single sovereign. This section seeks to explore the 'real politics' and 'sub-politics' of some of the water issues affecting Ta'iz. In order to do this the national historical setting is very briefly examined. Then, based on the area of Al Hayma / Habir which has played so prominent a role in the water supply of Ta'iz and its demise, the following questions are asked :

a) Who are the actors, and

b) How have they influenced, or controlled water allocation?

c) Whether gains and losses in the resource capture game reflect power asymmetries.

The political influence of some wider regional, national and international issues on local water allocation are then discussed and the capacity to adapt to water scarcity by those involved is examined in conclusion.

5.2.1 The Political Map: Historical Roots of 'North' and 'South' Yemen

The history of Yemen can be characterised by the recurring theme of North – South opposition. Dresch (1989;11) states:

> "the northern tribes … from the end of the ninth century AD to 1962 were associated with a succession of Zaydi (Shi'ite) Imams … The southern mountains and the Tihamah have been predominantly Shafi'i (Sunni) for almost as long, being ruled by a succession of more or less powerful states and sometimes raided or dominated by the northerners."

Ta'iz lies within these southern mountains and has had its fair share of northern domination. Phases of northern domination include those of 1636 (to expel Turks) and 1823 (to avoid drought). Each time the northerners moved south permanently they ceased to be tribesmen and became landlords or peasants like the people around them (ibid;13) in a similar manner to the Bedouin raiders in Oman (Wilkinson;1977). Domination has been characterised by the extraction of taxes "by northern tribesmen attaching themselves to government officials in the south without any appointment by the state .. and stayed there permanently" (Dresch;229).

The overthrow of the Imamate in 1962 and the establishment of "the Republic constitutes an obvious fracture with the past with an equally obvious continuation of the tribal forms within it" (ibid;236). That continuation, in the opinion of many Ta'izis, includes the extraction of taxes from the region, particularly from the fledgling industries. They call Ta'iz 'Al baqara al huluub' – the milked cow. Taxes are widely perceived as the means by which the northern tribally-based government officials obtain their 'layla ^alawi' Toyota Landcruiser (or even more curvy 'Monika' 1999 model). The north – south divide appears as strong as ever and, despite being part of North Yemen prior to unification, Ta'iz places its affiliations firmly in the south.

The demise of Russian communism led to the end of effective sponsorship of South Yemen, and unification of the two Yemen's followed in 1990. Despite the honeymoon ending with the civil war in 1994 and the abolition of the southern-led socialist (Ishtiraki) party, exposure to socialism has at least left some notion that equity, instead of divinely appointed poverty, is an option. Indeed, some water projects were undertaken in the Ta'iz region under a socialist banner. Since 1994 the resurgence of more overtly Islamic interests in the form of the Islah opposition party has occupied much of the ruling Mu'tamar party's energies. Border bickering with Saudi and keeping the south under the thumb occupies most of the rest.

5.2.2 The case history of Al Hayma – Habir: The Political Actors

Figure 5.2 identifies some of the interlinkages of some of the more prominent actors in Habir and Al Hayma according to their area of influence and Figure 5.3 schematically depicts those areas. Box 3 introduces some of the main aspects of the actors in terms of their location of origin, religious sect, pecking order, party political affiliations and history/motives where known. [It should be noted that these are not 'hard' data and that the information is also not complete. The actors wax and wane in importance, change costumes frequently and do not follow a consistent script. Since the data are subjective it may be considered to border on the realm of opinion in some aspects.] Although using some field data of the author, the work of Abd Ar Rahman Al Iriani in the context of identifying stakeholders in water transfers and possibilities for establishing water user associations, is gratefully acknowledged.

Box 3: Political Actors in Al Hayma / Habir: Cast according to area and affiliation:
(Underline indicates heads of groupings who reside outside the area)

Habir / Ja'ashin / Al Qaa'ida
Sadiq Amin Abu Ras (Residence – San'a): Minister of Local Administration, ex Minister of Agriculture during negotiations over exploratory drilling in Habir. The son of the biggest shayx in the South of North Yemen. The most powerful person in the area. The Abu Ras family have supported the local population in resisting water supply to Ta'iz. Their dynasty are Zaydis originating from Al Jawf in the North and moved into the area in the 19th century. Mu'tamar.

Abdu Karim Abu Ras: quite popular cousin of Sadiq Amin. Mu'tamar. Son of Abdu Karim Abu Ras: MP. In a deal between Mu'tamar and Islah during the elections Islah were supposed to win so the leadership of Mu'tamar did not permit a candidate from Mu'tamar to stand. Abu Ras therefore nominated his son as an independent and won against the odds. In the post-election manoeuvres he joined Mu'tamar. His victory was a significant blow to both Islah and shayx Mansur (see below).

Mohammad Ahmed Mansur ibn Nasr (Residence – Ta'iz): Whatever party Sadiq Amin Abu Ras supports, shayx Mansur (as he is known) will support the opposite. Currently he therefore sides with Islah. Originally from Yafa' he is a Shafi'i. His grandfather was a good friend of the Turks and refused to give the zakaat to the Imam after the Turks gave the Imam the right to collect zakaat in Yemen. When the Turks left after the first world war the Imam confiscated 70% of the rich land of West Habir in lieu of unpaid zakaat and it is now owned by government as waqf (Ward and Moench;unpubl). The propensity to not pay governments continues today since he is the largest individual debtor to NWSA with an arrears water bill approaching 1million YR. NWSA debt collectors are turned away at gunpoint. His son is an Islah MP for the area.

Abd Ar Rahman Ad Dimnah: Is a shayx for West Habir under the lead of shayx Mansur. Party political affiliation is according to pragmatism, so he currently supports Islah candidates. Originating recently from north-east of Wadi Nakhlan and before that from Shar'ab (bayt al kamali) he is a Shafi'i but is also in marriage ties to the Zaydi Abu Ras clan.

Hamud Lutf: is a low-key shayx who owns most of the wells in the area. He is in the Mu'tamar camp, is Shafi'i, but has good relations with Islah. Abdo Amin is the son of the shayx of Al Maqlad. Through shrewd dealings he maintains good relations with all sides but supports Mu'tamar.

Abd Ar-Rahim Wazi': nephew of the late shayx Sadiq al Hamayir (see below) but follows the lead of the 26th Sept Association (the main irrigation and agricultural co-operative in East Habir under Sadiq Amin Abu Ras).

Al Hayma and Miqbaba
Sadiq Ali Mohammad Nu'man Al Hamayir (deceased) known as shayx Sadiq: used to dominate both Upper and Lower Al Hayma and benefited from agreeing to the development of the Hayma wellfield (see following section) but the family influence is declining. The clan are Al Alwani and originate from Hadhramout they are Shafi'i, but with strong Zaydi sentiments. Shayx Sadiq's sons are Noman (Mu'tamar) and Abas (Islah)

Abdul Karim Ali Abdu and Hamud Sirhan (over Wadi Urayq) are associated with the shayx Sadiq grouping and support Mu'tamar.

Al Said Abdul Bary Abdullah bin Husain (under the lead of Abdul Alim Hassan of Jabal Habashi but based in Ta'iz): gaining influence in Upper Hayma. He is from west of Hayma. This group of sufis are in fierce competition with Islah and are usually Mu'tamar. There is also is small group of sufis under Abd Ar Rahman Al Kadahi.

Most of Middle Hayma was Ishtiraki. After the civil war of '94 they converted mainly to Islah. Dr. Al Ahdal is the MP. He is from Al Ganad and is Islah. Miqbaba is Islah but is becoming more Mu'tamar. With the decline of shayx Sadiq's influence an association under Mohammed Sadaam has been formed in Miqbaba.

The case history of Al Hayma – Habir: The Events: 1976 - 1995

The following account of water-related events in and around Al Hayma are both the product and legacy of the actors mentioned in Box 3. The account serves as a basis for the subsequent hydropolitical discussion and analysis.

During the fieldwork and exploratory drilling in wadi Al Hayma from 1976 to commissioning in 1982-1983, several misconceptions seemed to have arisen. Some locals thought that NWSA were only to drill seven wells, and now there are over thirty (Ward and Moench, unpubl.). The farmers were told that the pumping of deeper wells drilled for NWSA would not affect their shallow dug wells because there was an aquiclude in between. When four years abstraction resulted in cessation of the perennial flow of the wadi and the dug wells had largely dried up, the absence of an aquiclude was all too apparent. $10M compensation for loss of crops had been promised (Tipton and Kalmbach, 1979) but none had been received. Local farmers appear to have been at least uninformed or misinformed regarding the implications the NWSA abstractions would have on them. The shayx of Lower Al Hayma, the late shayx Sadiq agreed to the drilling and managed to get three deeper, drilled wells out of the deal. They continue to supply his successors' lucious qat plantation via open channel irrigation to this day in the midst of an otherwise once fertile, now barren, valley (Photo 2).

Prior to the emergency drilling campaign in Al Hayma in 1987 the NWSA wells reached a maximum depth of 100 to 120m. The new wells included in the campaign were up to 500m deep, but government did not allow local farmers to deepen their wells. [Shayx Sadiq managed to obtain one of these deeper wells]. The locals then stopped the NWSA drilling. The army was brought in and allegedly took the school children hostages in the school (for a day) whilst the local men went into the mountains with their weapons. Five shayxs were imprisoned by political security in Ta'iz for five days. A first attempt to resolve the dispute by Sa'id 'ahmad Sa'id, head of the co-operatives at mudiiriyya (now nahiya) level, was rejected by the army. The local people then approached the governor (Al Yuusufi) and contacts in San'a requesting them to mediate. The Minister of Oil came down and succeeded in obtaining the release of the five shuyuux on condition that they signed an agreement to not hinder the progress of drilling. The sons of the shayxs guarded the drilling rig (part of necessary feigned commitment to the government position and to relieve the situation).

After it became known that the Habir area was of interest for exploratory drilling, in June 1992 some locals disconnected one of the government wells in the Xazaja area immediately to the south. It has since been claimed that this action was supported by the socialists who were seeking a local grievance from which to generate political mileage. The government responded by placing 20 trucks of soldiers from the Ta'iz military camp on stand by. Helicopters were sent on reconnaissance missions. Some socialists (Al ^amba) were imprisoned. The president's man in Ta'iz ('abd Al Kariim 'abdu Lillah, the deputy head of security) managed to get the electricity and water reconnected and a co-operation agreement from the locals was obtained. The agreement was forced under 'abd Al Kariim's threat "if you do anything more, I am not responsible for the consequences" and the troops were not sent in.

The interests of the Dhi Sufal area immediately to the north-east of the area shown on Figure 5.3 had been protected by Sadiq Abu Ras (Minister of Agriculture at the time). Through his efforts, a well drilled previously by military strength as part of the exploratory campaign for Ta'iz was connected to supply Al Qaa'ida instead. Exploratory drilling in Habir again met with local resistance in Dec 1993. All the main shuyuux in the area were invited up to San'a to hear the president's immortal words "you will co-operate with the drilling "'imma bil 'urf aw bil 'unf" – "either by custom (that is, gentleman's agreement) or by violence". In June 1995 Sadiq Abu Ras convinced the government that the five existing wells in the Dhi Sufal-Al Qaa'ida valley were the maximum number it was possible to equitably operate and succeeded in getting drilling attention moved to Habir.

In April 1995 a rig arrived to start drilling six exploratory wells in Habir (three in east and three in west Habir). The locals threw the drillers off site in the same month using petrol torches. Three different visits were made to the area by up to four ministers at once to discuss the problem. Visitors included the Ta'iz and Ibb governors, the minister of agriculture, the minister of water and electricity and the minister of civil services. All the shayxs involved were then summoned to Ibb and asked to promise to protect the drillers. They complained that they could not make promises regarding their irate peoples' behaviour, especially considering their people's mistrust of the government, reinforced by the Al Hayma disaster. Three shayxs were imprisoned in Ibb and four in Dhi Sufal until they agreed to sign an agreement of co-operation. Given the alternative of remaining in prison whilst the government used force to drill the wells they agreed to sign. The agreement incorporated a compensation package.

Hostilities flared up again in January 1996 when the government (NWSA) failed to deliver part of the compensation. The drilling was stopped, the governor responded by sending the troops in, so the villagers sent women and children to stop the troops. The women threw stones and tried to take the weapons from the soldiers and two women were seriously injured when one of the soldiers opened fire. Fortunately, further escalation was prevented when the local shayxs and the governor of Ibb intervened. The subsequent involvement in the area by the World Bank through the TWSSP (see section 5.4) has witnessed various extensions to the compensation package including the provision of water supplies to the nearby villages. This accounts for around 25% of the total yield of the three wells connected so far. With 50% of the remainder to be lost through leakages, a costly compensation package and considerable civil strife in hindsight it must be questioned whether the whole exercise was worth it.

SURDU had been conducting a dam feasibility study in Wadi Warazan, and in 1995 a rig went there to drill a site investigation borehole. Specifically because of the Al Hayma experience, the local shayxs were suspicious of any drilling, suspecting it was for the purpose of abstracting water for Ta'iz. On a pre-arranged day, 5000 armed men converged on the drill site and halted the drilling. The governor of Ta'iz came to negotiate and left again having agreed with the locals that no drilling for Ta'iz supplies would take place and no dam would be constructed.

As a final incident for consideration, the handling of the Ta'iz emergency drilling within the city during 1995 is worth noting. Although technically poorly planned and executed, with resulting poor yields, from a political perspective it was more successful. The governor pushed the project to help alleviate the water crisis (or was it to increase in his popularity in the city, or both?). Having raised finance for the drilling from local businesses, the major outstanding cost was the pumps. The governor requested the money from central government under threat of his resignation if it was not forthcoming. His bluff was called, he resigned, the money appeared and his resignation was refused (Al Ayyam;7/6/95, Yemen Times;12/6/95).

5.2.3 Some Observations

Although many observations could be drawn from these events some are particularly prominent:

Strong Society – Weak State

The Al Hayma – Habir incidents have demonstrated how state intervention can go amiss locally, and that struggles over environmental and socio-economic issues at the local micro-level can have a momentous impact on the state and its goal of predominance (Bryant;1998, Migdal;1988). Compared with many countries the ability of local communities to resist the government imposition of wells which would 'steal their water' demonstrates Yemen as having a strong society and a weak state (Migdal,1988). The phrase 'compared with many countries' is used on purpose because many Yemenis believe that even the consideration of using military intervention to drill, let alone allowing water to be abstracted for the city could never have occurred in the North of Yemen. They equate this high-handed government position to be tenable only because the tribes are not as strong in the south compared with the north where society is even stronger and the state even weaker.

Principal – Agent Problems and Knowledge Asymmetries

The actions of shayx Sadiq clearly demonstrated:

a) The potential for principal – agent abuses which became worse as the as the arena grew larger than the immediate locality. The agent (Sadiq) was given scope for opportunistic behaviour and received the welfare (water) of the principal (the local farmers).
b) How central institutions (NWSA) could offer an escape route from the demands of traditional institutions (the shayx role), undermining communal responsibilities.
c) The cause-effect relationship of the NWSA drilling on existing wells was not perceived by the man-in-the-field, in fact he was lied to. The perpetration of this particular principal (farmers) – agent (NWSA) abuse was only possible because of the knowledge asymmetry between them.
d) The decision to exclude people from using the resource did not result from exhaustion of the resource, but was consciously made beforehand (unlike Bromley, 1986;594).

The net result of these principal –agent abuses was that the hand dug wells of the many ran dry whilst the deep drilled wells of the few, particularly the agent, continue to yield to this day. This is a clear example of the control of one actor over the environment of others (Bryant,1993;11) and of resource capture that directly reflects power asymmetries. The declining influence of the agent's descendants over the same principals because of past abuses indicates an underlying 'democracy' in the shayx system.

Emblems and the Political Process

Hajer's concepts (1995) of an environmental emblem or rallying point and of the long process from local environmental problem to political issue status are apparent in the history of Al Hayma. The declining water level in Al Hayma was both an environmental and socio-economic problem. However, since an urban population with its tarmac, capital biases (Chambers,1983) has a stronger political voice (Falkenmark and Lundqvist,1995), the 'problem' surfaced as a drinking water supply issue, although it was actually part of the same problem. In the end, it took politicians (governors and ministers) to recognise the political mileage in it and turn a problem into an issue. One of those politicians (the governor of Ta'iz) saw the window of opportunity and forced the hand of the president in getting the pumps paid for. A sobering aspect for the windows-of-opportunity adherents is that the very fact that a crisis creates the window also means that the decisions taken are crisis-driven. As such they may result in only soothing the symptoms and have unpredictable, knee-jerk, non-optimum outcomes, as occurred, it is suggested, in the case of the governor's emergency drilling. Of course, to maintain the knowledge asymmetries, the general public are not informed of the failures (Yemen Times 21/8/95;Front Page, see Appendix C). The rise of Al Hayma to emblem status is confirmed every time a drilling rig (the most evocative emblem, incidentally) turns up on site. Each time a rig appears local leaders specifically mention Al Hayma as the reason the rig must depart.

5.2.4 Political 'Riyalities': self-interest in regional, national and international contexts

Equitable Local Water Transfers: Compensation vs. Opportunism

The distinction between the compensation of water source-area communities and opportunism on their part, particularly by the well owners, is slight. One task in establishing equitable water transfers is ensuring that compensation reaches the whole hydraulic community in rural source areas, that is, including those without wells but dependent on irrigated agriculture for their livelihoods (termed third parties). This is the greatest challenge to the World Bank efforts at agreeing water transfers from Habir to Ta'iz. The track record of government water transfer methods, with the benefit of the very few and the misuse of knowledge, has engendered a basic mistrust which may only be overcome by erring on the generous side. Being over-generous may be labelled opportunism, but it needs to be over-generosity to all. Erring on the generous side appears to be the private sector example of Hayel Said's Soap and Ghee factory in providing electricity, piped water and jobs to those affected by their abstractions. In fact, considering water transfers throughout the region, the relatively smooth farmer – tanker / private pipeline transfers are in marked contrast to the central government example. The essential difference between them is that the former involves money transfer and the latter does not. A commitment to purchase water from farmers, so that water flows one way and money the other, would appear to be the way ahead if transfers are to be more like market transactions than diplomatic negotiations (Sax,1994;13). However, shayx Sadiq is not likely to be the last political actor to benefit from government attempts to reallocate water at a level disproportionate to his original stake in the water.

National Issues: Diesel Prices and Water Law

It is a curious fact that a well owner can sell water to tankers or farmers for as little as 0.1\$/m^3, whilst NWSA cannot cover basic running costs (exclusive of maintenance, depreciation or salaries) when charging twice that price. The main difference in their running costs is the price of power. In approximate terms it costs the farmer 2YR(0.015\$)/m^3/100m lift (1998 diesel price of 10YR(0.077\$)/lit) compared with 9YR(0.07\$) for NWSA to lift one m^3 of water 100m by electricity. This difference in cost reflects the price of electricity to NWSA (charged at the maximum tariff) compared with the price of diesel to the farmer (charged at half the international level for oil exporters, Ward;1998). If irrigators made the mistake of purchasing an electric pump instead of diesel, the increase in electricity prices over the past few years will have forced them to give up irrigating (Handley,1996b). Very few farmers made this mistake. The government is effectively subsidising the power costs of irrigators and over-charging NWSA, who have to pass on this cost to the urban consumer. A strange twist in the tale is that the ministry that sells such costly electricity to NWSA is the same ministry that pays for it – the Ministry of Electricity and Water! Central government power pricing subsidises the well owner to use over 90% of the country's water to grow, amongst other things, lucrative amphetamines, whilst charging over four times as much to provide a meagre 25 lcd of poor quality water for domestic use.

The cessation of perverse water pricing (Mollinga,1998;254) through diesel subsidies would contribute to improving local resource management by changing the net benefits of resource use (Steenbergen,1996;204). However, Yemen's stance on power pricing makes both good political and economic sense, since those in political power are the landowners. This reality has been apparent each time the government (under World Bank structural adjustment incentive) changes the price of oil products. Since the onset of structural adjustment, the major cost in oil products has been borne by petrol (affecting the man in the street) rather than diesel (affecting the ruling landowner class). When the Prime Minister increased the price of diesel price in November 1995, the President appeased the landowner backlash by reducing the increase. Diesel price increases in October 1997 to 10YR(0.077\$)/lit were an attempt at covering the real production cost of 28YR(0.22\$)/lit (Al-Thawra 23/10/97) and sparked off road blockades by protesting farmers which resulted in three dead (Al Hayat 22/10/97). "MP's rejected the rationale forwarded by the Minister of Oil and Minerals who maintained that the increase in the price of diesel was inevitable in view of the government's Economic Reform Programs" (The Daily Chew, 25/10/97), but then, self-interest demands they reject it.

The same political 'riyalities' underlie the failure of attempts at passing a water law and in particular the regulation of drilling and well spacing. Despite water laws being drafted on several occasions, they have never even reached parliament. Not only does Yemen have Migdal's problem of the strong society of tribal chiefs resisting the state (1988), those chiefs are the state (The President in Dresch;1989;7) acting in self, not state, interest. In Yemen's case it is unwise to try to separate them too much (Steenbergen,1996;24,30,207-8).

International Issues – Virtual Water

Section 5.1 demonstrated Yemen's dependence on imported grains. This is an economic 'problemshed' solution for an environmental watershed problem. Allan (in prep) contrasts the economic sense of importing virtual water in grains with the political nonsense of food self-sufficiency and points out that governments reconcile the two by ensuring the former remains a silent fact and the latter (only) audible rhetoric simultaneously. This self-deception is possible because the truth of ships, docks, mills, trucks, warehouses and thousands of people collecting sacks is the unsanctioned, and hence, silent partner. A few minutes of a key speech by one man which contains a few stirring words about the harnessing of water resources by our great farmers and engineers is sanctioned and hence audible.

The process of wheat and flour importation is also highly politicised. Grain and flour subsidies through exchange rate differentials on 'essential imports' have previously selectively benefited those traders and politicians involved (Financial Times, 8/3/95). Irregularities have, at various times, reflected an attempt to drive people away from the cheaper government distribution points to the more expensive black market. Control of local distribution points, at least in Ta'iz, was transferred from opposition to ruling party in the run up to the 1997 elections when votes seemed to be won by the sackload (of flour provided).

5.2.5 Conclusions: Actors, Allocations and Asymmetries

The history of water allocation between Ta'iz and Habir/Al Hayma has demonstrated a multi-layered political arena in which local and national issues become inextricably enmeshed. Despite the party-political exterior, local political reality is about individuals, their grouping and splitting over issues and the single constant of self-preservation and nest-feathering. The political networks are complex, clan related and dominated (but not exclusively so). Political parties are manipulated by local political actors to their own ends and vice versa and 'events and struggles at the local level can have a momentous impact on … the state' (Migdal,1988;36). Governors, ministers and even the President have become involved in the struggle.

The issue of water reallocation has demonstrated that the political boundaries or affiliations and initiatives are a) complex, b) are dominated by the ever-changing networks of relationships, and c) always have an historical context. Borders are not watersheds. This is particularly apparent with the Ibb-Ta'iz border. Although problemsheds are more appropriate than watersheds in the regional context of domestic, industrial and food needs, watersheds are still the locally immediate context, and typically reflect current upstream – downstream inequalities.

Shifting the potential source area for Ta'iz's water has mainly followed the existing power asymmetries, although this argument is somewhat circular in that being able to direct water allocation is perhaps the ultimate indicator of power in a water-scarce region. The legitimacy of water reallocation is the subject of the next section.

5.3 Implications of legal pluralism for water allocations in Yemen

> 'Abraham reproved Abimelech because of the well of water
> which the servants of Abimelech had seized'
> Genesis 21:25

Trade in water is enabled on the basis of rules and regulations (Coase,1992;718). A complicating factor in Yemen, is the plurality of legal frameworks under which they operate which itself is identified as a weak state / strong society phenomenon (Migdal,1988). The absence of a water law, the institutions to enact it and the ability to enforce it demand an alternative means of agreed allocation of Yemeni life's most vital commodity – water. This section suggests that in Yemen, where local forms of (customary) law and courts (via the shayx) are predominant, legal pluralism is particularly appropriate. This section seeks to summarise the different sources of water law in Yemen and briefly discuss the application and effectiveness of those laws regarding water allocation, the markets they regulate, and the rules by which they regulate them.

5.3.1 Sources of Law

Four sources of law may be identified in Yemen; the Constitution, the Shari'a or Islamic law, Civil Articles and Customary Rules (Al-Eryani et al,1995 and Haddash,1998). The Shari'a is the ultimate source of law and the other sources are meant to be based on it. However, new legal problems arise with social and technological changes (Vincent,1991;200) which the days in which the Qur'aan was given neither foresaw nor legislated for. All four sources are therefore dependent in origin on its interpretation, which is a combination of qiya (deduction by analogy) and ijma' (consensus). The four main schools of Islamic law in Yemen (Hanafi, Maliki, Zaydi and Shafi'i) interpret Islamic law differently, which contributes to differences in the other three sources of law. Maktari (1971;3) identifies the influences of these schools in Yemen at different times and in different places, the Shafi'i school being of particular significance in his study of water rights in Lahj. Differences in law between the various schools are also identified in Al-Eryani et al (1995;48,50,58).

The Yemeni constitution is based on the Shari'a and the civil law is its formulation. Civil law "serves as a legal instrument to implement certain interpretations" which "are disputed among the various Islamic schools" (ibid;43). Similarly, customary water rights cannot be considered in isolation "since customs have to adhere to Shari'a" (ibid.) and again, some differences in customary law occur as a result of the law originating from different Islamic schools. Customary law is portrayed as the local adaptation of the shari'a and civil law, moulded by the specific conditions of use (historical and geographical) and is defined as:

"the continued repetition of certain actions or practices by a collectivity in the conviction that they are legally binding" (ibid;43)

Maktari identifies two types: 'adaa:

"The repetition of a thing [an action] invariably or mostly on the same pattern without reasoning" (1971;5,6)

and 'urf (which is the usual term used in the literature and in the Ta'iz locality, whether this meaning is intended or not):

"that which human nature accepts by reasoning, and is acceptable to man's nature or habit. It is also authoritative, but it is readily understood."

Codification of customary law is rare, however the three hundred-year-old 'Document of Seventy' cited in Al-Eryani et al (1995;44), the law of Sultan Fadl from 1950 (Maktari 1971;69) and the five-hundred-year old customary laws of Al Geberti in Wadi Zabid (TESCO, 1971;5) are examples of its codification.

5.3.2 Legal Applications to Water Allocations

A summary of the relationship of the various sources of law operating in Yemen to the shari'a with respect to some of the more prominent water rights as considered by those sources is given in Table 5.2 insofar as they can be tabulated. The table is intended to summarise Al-Eryani et al (1995;41-77) and provides some of the basis of the plurality of legal stances in Yemen regarding water rights.

Water Ownership

Major differences between the legal systems occur with respect to water ownership. "There are no customary rules which explicitly define the legal status of water" but there is a distinct contradiction between the constitution and the shari'a and also between the constitution and the civil law (ibid;46). The constitution uncompromisingly considers all water to be the property of the state (Haddash,1998). The constitution's position appears untenable on this point. Although of 'state interest', water in the view of the civil law and the shari'a (and therefore customary law) is *res nullius*, ('mubah', that is, 'of nobody').

Receptacles and Wells

A key issue in water ownership is whether the water is in a receptacle. Civil law considers water not in a receptacle to be state property whilst that in a container to be the property of the owner of the container. Thus, once the water is contained it becomes private property and hence saleable. Although this contradicts the constitution, some legal apologists try to construe water 'sales' as simply compensation for the cost of production. The second key issue stems from the question 'at what point can water be considered to be contained?' and specifically whether a well is a container. The Hanafi school and, for that matter the Law of Gravity, do not consider a well to be a receptacle, though, hydrogeologically, it may be considered a leaky one. That is, to be an effective well water must be able to leak into it, and if water can leak in it must be able to leak out. This is the fundamental difference between a well and a cistern. The rest of the Islamic schools and all the Yemeni sources of law do consider wells to be containers, and hence the water inside them to belong to the well owner. Hence, as a molecule of groundwater travels the 1mm across the seepage face of the well from the aquifer to the inside face of the well surface, its legal status changes from 'common' to owned. Put another way, 'an aquifer is freely accessible...to anyone who owns the overlying land' (Haddash,1998). This provides a huge legal incentive to drill wells.

Water Diversions

Haddash (1998) identifies a distinction between ancient water diversion rights and more recent rights of 'benefaction' where water is declared as state property. The constitution regards water diversion rights as a concession (which should therefore be regulated) whilst other sources of law submit to local custom. Civil law permits water from any source to be

Table 5.2: Relationships of Legal Systems to the Shari'a (After Al-Eryani et al 1995:41-77)

	Relationship to Shari'a	Codification	Water Related Articles
Constitution	Principles	Constitution	
Civil Law	Modern Formulation & Interpretaton of Schools	1399 Articles	38
Customary Law	Local / Regional Instrument of Implementation	Document of 70	3

Summary of Water Rights

	Includes	Constitution	Civil Law	Shari'a	Custom
Ownership - Recepticle	Legal Status of Water	State Property	Private Ownership		
Non-Recepticle	& ownership conditions	State Property	State Property	Common	
Water Diversion	Basis of Right	Concession to User	First come first served subject to custom		
(surface & groundwater	Transfer of Right		Water 'married' to land and transferred with it	water 'divorced' from land and can be sold or inherited separately	
Water Use	Priority		1.Drinking, 2.Animals, 3.Domestic, 4.Irrigation		
	Quantity		Prior users excess is available to others (based on original use)		
	Place (Water Transfers)		Water transfer banned if anothers' water right is harmed		
	Deficit			time shares proportional to land	
Water Administration	Allocation Systems			time shares proportional to land	
	Operation & Maintenance		Costs according to use share, protection from channel		
	Quantity & Quality Protection		Protection Zone Declared	Principles of Pollution Protection	1. Document of 70 - protection zone = well depth. 2. Drilled 500m, Dug- no rules

Summary of Rights of Servitude

	Shari'a	Civil Law
Irrigation Rights	Privately Owned, water / land divorce possible	Privately Owned but 'married' to land
Drinking Rights	1.Drinking, 2.Animals, 3.Domestic, 4.Irrigation	
Water Way Right		Water transport across land permitted for fair compensation
Drainage Right		Various rules to protect from flood damage and from downstream pollution

appropriated on the basis of seniority of claim and absence of harm to existing users (ibid.). Regarding the linkage between water and land, one interpretation of the shari'a ties water to the land and not to the landowner, whilst the other separates them.

Water Use and Administration

Common to all the sources of law is that for drinking purposes, all water is *res nullius* (common or mubah) providing the desperation of one party does not annul the rights of the other party (Al-Eryani et al;58). However, this stance is very minimalistic, as Ward and Moench (unpubl.) point out. It also directly challenges the practice of selling drinking water. For instance, a prominent Yemeni water bottling company, when asked by supporters of the shari'a why it sold water, replied that they did not sell water, just the bottle containing it. An interpretation of the shari'a forbidding the sale of water could also be an obstacle to intersectoral water transfers.

The free nature of water does not apply to all uses, and water for irrigation is not mubah if the new user will harm the senior benefactor (Haddash,1998). Under the shari'a surplus well water is free to be exploited on a seniority basis (Ward and Moench, unpubl.). The problem with this rule lies in determining what is a surplus. Surplus water could simply mean that water is present in a well irrespective of a long-term decline in water levels. If non-declining resources are to be determining the presence of surplus then the need for monitoring is implied. At different times (Caponera, 1973;213) and in different places (TESCO, 1971;5) the generally ubiquitous 'ala fil 'ala (upstream first) rule for stream and flood flow has been reversed by local custom. Serjeant (1964;55-56) also gives examples of local jurisdictions regarding the operation and maintenance of water channels based on customary law. Whatever system of stream and flood flow allocation operates, the supervision of the system seems to be usually by locally appointed figures who become more necessary and more obvious in times of shortage.

Regarding the protection area around a well, spring or flood course, the legal sources differ (Table 5.2). The oft-quoted 500m dug well and 1000m borehole spacing rule is a ministerial decree and not actually 'law' (Ward and Moench,unpubl.). Customary rules include the Document of Seventy that cites a protection radius around hand-dug wells equalling their depth.

Rights of Servitude

Rights of servitude, of which the irrigation right is a type (Haddash,1998), are defined as "the right of a certain property to obtain some kind of service from another property" (Al-Eryani et al 1995;53). The four rights concerning water and the respective position of the shari'a and the civil law are given in Table 5.2.

Five main outcomes of the rules described above are noted (developed from Ward and Moench unpubl.):

a) Free access to any source for individuals and livestock,

b) Upstream priority over spate flows

c) Landowners can drill anywhere on their land and abstract as much as they wish

d) Recognition of protection against 'harm' by new abstractors over existing ones

e) Some form of compensation to be expected for water traversing another's land

5.3.3 Local Reality and The Problem of Law Enforcement

Local reality dawns the day a drilling rig turns up in the neighbour's field. Mechanisms for judicial conflict settlement are in place at national (Supreme Court), governorate (Appeal Courts) and local level (Primary Courts) as are arbitration systems, that is, civil (using the judiciary) and customary or tribal (using the local shayx, up to shayx al mashayix level). The prior well owner, correctly thinking there is a moratorium on drilling without permit, will typically approach the SURDU extensionists or the Agricultural Office. In order to get an engineer to come out and confirm that there is a well being drilled, there is no permit and the new well is too close to his own well, he has to pay. The engineer's report is issued and strangely finds all these facts to be the opposite, because the new well owner has since paid a visit to Ta'iz and 'convinced' the civil servants otherwise. The senior well owner is not then likely to approach any government court because he knows that government law, or rather judges, will lean to the highest bidder and will take a long time over it (Vincent,1991). The disputing farmers may then seek a local shayx whom they both trust to give a fair jurisdiction. The jurisdiction may involve supplying the senior well owner with water if his well is affected or promising to cease pumping if a certain water level is reached. Although both parties must agree to abide by this jurisdiction whether this happens once pumping begins is another matter, but the impasse over drilling may have been overcome. Other would-be abstractors misuse their government contacts to simply conduct their drilling by military force with no attempt at a negotiated settlement. These accounts are intended as a 'representative case history' pieced together from several cases observed at different stages during fieldwork to the north-west of Ta'iz some of which are reported in Handley (1996a).

Another notable instance of particular importance to Ta'iz is where the 'junior' well driller is the government. This case history was discussed in detail in section 5.2 but a legal aspect is worth mentioning here. The ability of local well owners to block government drilling even when supported by military intervention demonstrates that the more local (bottom-up) the process of arbitration (that is, local customary law, court location and arbitrator), the more likely an acceptable solution will be found and law enforcement will be possible. This observation is also borne out by the instances given for Lahj (Maktari, 1971;131) and Wadi Dahr (Mundy, 1989;109).

Similar accounts of bribing government officials, injustice in the courts and local resistance to externally imposed rules are observed in most other areas of life such as paying tax, building a house, finding a job etc. The failure of the public water supply utility, NWSA, to carry out its legal responsibility to collect revenue is not always an institutional failure but, as in the case of powerful non-payers is sometimes a problem of law enforcement. These problems underline the importance of the presence of an indigenous albeit rather 'ad hoc' or customary legal system. This locally-relevant, cheaper, quicker and probably more just alternative makes a far greater contribution to conflict settlement than does the government system and demonstrates that legal pluralism can be advantageous.

5.3.4 Legal framework implications for institutions, markets and water resources

Although the jurisdiction of the Yemeni central government legal framework in conflict resolution may end at the San'a ringroad (Dresch,1989;16), it could have a major role in water resources protection. The effectiveness of two types of institution with respect to the Yemeni central government legal framework has particular significance for water resource sustainability. One is the institution that creates the law and the other is the institution(s) that monitors and enacts it. Despite many calls for a water law to regulate exploitation (Haddash,1998, Vincent 1991;201) and the writing of several drafts (World Bank,1993;16), none has actually been forthcoming. The ineffective High Water Council and its Technical Secretariat have been superseded by the creation of NWRA which has been invested with responsibility for water resources strategy, planning and regulation (Ward,1998). NWRA's ability to win the trust of local well owners and involve them as stakeholders in the policing of their own resource is likely to largely determine whether a passed water law can actually be implemented.

Where the national legal and institutional frameworks have failed to ensure allocatively efficient use of water the markets have fared better. Some question the legal validity of markets, or at least suggest they need to be legalised (Dellapenna,1995;154) whilst others see their existence *ipso facto* as sufficient validity (Ward;1998). The latter view is perhaps more applicable in a weak state/ strong society such as Yemen where the legal validity of an existing Government or formal institution may be perceived as a largely irrelevant issue.

The sale of irrigation water at different prices for different crops may set a precedent for customary rules regarding water sales on which to base negotiations for water transfers (Ward and Moench,unpubl.). However, irregularities in operating procedures by markets beg the intervention of some form of regulation. The urban public is particularly in need of protection from over-pricing, poor water quality and public health threats from water supplied by tanker, water treatment companies and even by the public utility.

The exploitation of water resources by operators within water markets does not protect the resource. In addition, it neither provides water for the poor at the demand end nor protects livelihoods of those not directly involved in the transfers at the supply end. Access to water resources is controlled by a small, relatively wealthy portion of the population (Ward and Moench,unpubl.) and well owner's claims of exclusive rights over groundwater abstractions meets with fierce opposition by other farmers (NWRA,1998a). The legal incapacity to protect the environment where government law does not hold sway and to provide equity form a major obstacle to the sustainability of any allocatively efficient measures which might be implemented in the Ta'iz area. This legal incapacity is a form of second order scarcity (Ohlsson,1999).

The relevance of the legal empowerment and validity of institutions and markets for the potential to establish water transfers, particularly intersectoral transfers, are likely to depend most on the predominant social setting. Some role for central government regulation is envisaged, particularly in the provision of equity in the urban setting. However, beyond the Ta'iz ringroad, where any water transfers are to be sourced, the local customary legal framework is predominant and government civil law enforcement is limited.

Yemen is well known for its legal pluralism. This pluralism extends as far as water law. The players in the water allocation game not only face the moving goal posts of development initiatives and technological change, but also different sets of rules under different referees.

Some players use pluralism to advantage, and law aimed at providing equity and order may sometimes miss the mark in this plural environment. However, the fact that several water allocation games are being played at once means that there may at least be speedier and more just legal alternatives.

5.4 Institutional Appropriateness: Matters of Function and Scale

The plurality of legal frameworks in Yemen is reflected in a similar plurality of institutional frameworks in which they operate. Several games of water allocation and several sets of players are involved. The problem of water scarcity reveals itself to the public in the form of inadequate provision of services. Although some productively efficient solutions can be applied, these immediately perceived problems are a subset of the wider issues of allocatively efficient solutions and, when food needs are included, of virtual water solutions. Both the immediate and wider problems and solutions have an institutional context. As evidenced in section 5.1, the problems and solutions at all scales involve water transactions. Coase suggests there is 'little sense….to discuss the process of exchange without specifying the institutional setting within which trading takes place' (1992;718). In this section, some of the institutions involved in water management in Ta'iz are described and their contribution to the problems and solutions discussed. In conclusion, the possible future role of institutions in the water sector is briefly considered in the context of current development initiatives.

5.4.1 Introduction: Immediate Problems and Broader Issues

It is suggested that the immediate water related problems and issues facing the general public in Ta'iz centre around the provision of the following services:

a) urban domestic and industrial water supplies,
b) rural domestic water supplies, and
c) waste water disposal facilities.

In particular, these services need to be provided at cost recovery / economic prices, whilst at the same time safe-guarding public health, and promoting productive efficiency so as to protect the resource from over-abstraction and pollution.

In addition there is a problem of enabling steps towards intersectoral, allocatively efficient water use, through water transfer arrangements negotiated with sufficient support of the stakeholders to ensure conflict is minimised.

[Productive efficiency in the irrigation sector has not been included in the above list, partly because:

a) it does not serve to protect the resource, and
b) the institutions involved in irrigation are also involved in the problems mentioned above and are discussed in that context.

Also the water aspect of securing an adequate food supply is not discussed in this section primarily because it is a political issue rather than an institutional one. The institutions needed to ensure food provision, via virtual water, are in place and functioning reasonably well.]

5.4.2 The Institutions

There are many institutions involved in the water sector in Yemen. However, in the context of the specific problems of water supply and disposal and allocative solutions, some institutions are much more relevant than others and greater emphasis is given to them here. The institutions which have overseen the emergence of the problems and which have attempted to address them are described below with respect to:

a) their contribution to the problems and
b) to the solutions
c) their adequacy as service providers / reallocative enablers
d) the roles of institutional plurality and
e) institutional adaptive capacity

These issues are discussed in the conclusions. In order to avoid a narrowness of scope it is helpful to divide the institutions into Government / non-Government and Traditional / non-Traditional. The government / non-government distinction is made in preference to a formal / non-formal division since the origin of an institution is far more significant to the Yemeni, than its degree of formality. Institutional formality is a function of legal status which is discussed in section 5.3.

Government Institutions

The relationships between central government ministries and their departments and the specific offices and projects found in Ta'iz and externally derived donor involvement are summarised in Figure 5.4 and their responsibilities in Table 5.3.

Table 5.3 Responsibilities of government institutions involved in the Ta'iz water sector (developed from Hansma and Hermans 1997,Table 5.1):

Institution	Responsibility
Rural and Urban Role	
Governor's Office	Government of Ta'iz governorate, including civil law and order.
NWRA	Water resources policy and management.
TWSSP	Financially, technically and institutionally facilitate water transfer to Ta'iz.
Rural Emphasis	
Agricultural Office	Execution of agricultural law; dams and irrigation schemes; other agricultural fields.
AREA	Research and extension for agriculture.
CACB	Provision of development finance for farmers.
GAREWS	Rural water and electricity supply.
IDAS	Enhance self-help capacity of farmers.
Local Councils (LC's)	Promote and manage local, rural development including water supplies and irrigation.
LWCP	Implementation of water monitoring, irrigation, and forestry projects.
SURDU	Rural development including irrigation, extension, monitoring.
Urban Emphasis	
NWSA	Urban water and sewerage supply.
TSWSSSR	Help NWSA branches towards a more autonomous and commercial basis, and encourage PSP in urban water supply and sanitation provision.

A chronological sequence of involvement of various institutions in aspects of water resources management in the region may be discerned, and is reflected in the order in which they are described below. Some of these institutions are only mentioned briefly below because of their secondary involvement.

LDA's – LCCD's – LC's

The following comments are based on Joshi (1995). Development in rural areas and small towns has centred on Local Development Associations between 1973 and 1985, Local Councils for Co-operative Development from 1985 until the early 90's and Local Councils currently. In North Yemen, over 200 LDA's were established by the early 80's and were two-thirds locally financed, one-third government financed. During the period 1973-1984, 4,244 water projects were constructed. Local finance included a considerable portion from remittances, and attempts by central government to control and co-ordinate the LDA activities led to mistrust, a decline in local contributions, and the LDA's eventual demise. The LCCD's were an attempt at reviving local development initiatives and were to be supervised by the governor and other central government officials. This arrangement again resulted in a well earned lack of trust by the principals of the agents, and the LCCD's, faced with no real power to create or administer projects beyond the firm control of the state, became completely paralysed and its members disenchanted and frustrated. The mistrust and paralysis, not to mention drying up of remittances, is the legacy of the current Local Councils, effectively disqualifying them as an acceptable player in water transfer negotiations, the provision of water facilities or the management of water resources.

CACB

The following comments are based on Ward et al (1998) and World Bank (1998a). The Co-operative and Agricultural Credit Bank is the third largest branch network in Yemen and is the main credit institution for agriculture. It was established specifically to encourage development in that sector. With interest rates running typically above 30%pa, loans from the bank are particularly attractive at 7-9%pa. The LCCD's are required by law to deposit their funds with the CACB. However, the CACB does far better placing these 'captive deposits' in interest bearing accounts with other banks, than via providing loans to farmers. 43% of the CACB's funds are long term soft loans from external sources. Most loans from the CACB to farmers are for the purchase of irrigation wells or equipment. The CACB's loan recovery rate is only 60%, and if it were not subsidised it would have to charge 59% interest. The bank is overstaffed (only 9 loans allocated per year per employee) and farmers accuse those employees of principal-agent irregularities (Handley,1996a). The result is that most small farmers would never want to approach the CACB for a loan. Outstanding debtors are the 'big shots'. The courts refuse to adjudicate when land title is collateral and will not adjudicate interest because it is 'unislamic'. The result is that the only source of credit for the agricultural sector, the CACB, provides the wrong signals to the farmer (with effective subsidy of irrigation) and has provided scant investment in the sector very inefficiently and inequitably.

SURDU and GAREWS (LWCP, AREA and IDAS)

The Southern Uplands Rural Development Unit is passing over its responsibility for rural water supply to the General Authority of Rural Electricity and Water Supply. However, the latter organisation has a track record of not completing the village water supply projects it began. Problems of lack of maintenance of projects that were completed and of constructing 'blueprint, top-down' schemes without reference to village needs are also common (Handley,1996a;26 and Handley,1996b;Table3).

The Land and Water Conservation Project, the Agricultural Research and Extension Authority and the Innovation Development in the Agricultural Sector project, together with SURDU are all involved in irrigation projects, and IDAS has also been involved in some minor rural water supplies (Hansma and Hermans,1997). These organisations all operate in the rural sector and there is considerable overlap and duplication of responsibilities between them. 6.4% of the rural population of Yemen are provided with public piped water supplies and only 3.8% in the Ta'iz governorate (Table 4.13) suggesting this key activity is very inadequately and inefficiently addressed.

SURDU and the Agricultural Office are accused by farmers of principal-agent irregularities when determining whether a farmer can drill a well near his neighbours. The recommended 500m spacing for dug wells and 1km for drilled wells appears to be flaunted or adhered to depending on who is the highest bidder.

NWSA

The National Water and Sanitation Authority was created in 1973 and is part of the Ministry of Electricity and Water. Some performance indicators are given in Table 5.4.

Table 5.4: National and Ta'iz NWSA performance indicators, 1997. (NWSA data and Handley,1999b).

Performance Indicators	Nationally	Ta'iz Branch
Water Sold m^3/yr/employee	12,000	6,500*
Connections / employee	63	78
Electricity as % of revenue	21	60%
Wages as % of revenue	43	60%
Outstanding Accounts	14 months	? > 6 months
Unaccounted-for-Water	31%	> 44%
Losses $M/yr.**	1	0.34

* The Ta'iz branch has 462 employees of whom 46 are over the retirement age and 26 have died but whose families continue to receive salaries.
** No allowance for depreciation is included.

The table aptly demonstrates the consequences of treating water as public good. Branches have been obliged to charge a national tariff too low for cost recovery and branch revenues are sent to head office and re-disbursed to branches through non-transparent budgetary processes (Davies and Sahooly,1996). Branches are overstaffed, there are no job descriptions, standards or codes, and performance or merit play little part in rewards or promotion (ibid.). The knock-on effects are inadequate pay, lack of job satisfaction, a poor working environment and a declining skills base so typical of weak institutions (Coopers & Lybrand, 1992). Many staff need a second job and there is widespread 'rent-seeking' and increasing unaccounted-for-water. In addition, a fundamental change is needed in NWSA, if it is to become more consumer oriented and the ugly scenes at the NWSA offices of consumer blaming supplier for shortages and vice versa are to be less frequent. Although these problems permeate most of NWSA, they are particularly acute in the Ta'iz branch.

The provision of sewerage connections in Ta'iz has not kept pace with water connections (Figure 5.5), which in turn has not kept up with population growth (Figure 4.18). The declining water resource base has resulted in less water being pumped, and one advantage of falling production is that losses are reduced. Contrary to Berkoff's recommendation to use rotational deliveries in water scarce situations (1994), reduced water supplies in Ta'iz have been observed to result in a vicious circle of increased corrosion and hence increased leakage (Figure 5.6). Water rationing causes pipes to be exposed to air and water alternately resulting in more rapid corrosion, low quality water produces more rapid corrosion of storage tanks and lower flows in the sewerage network results in higher concentrations of sewage which corrodes the sewer pipework.

The worst legacy of NWSA, in the context of potential water transfers, is that government institutions are perceived as having lied to the people of Al Hayma regarding the affect of abstraction for the city on the farmer's wells. They are also accused of having struck a dirty deal with the local shayx in order to drill the city wells. This reputation has spread throughout the Upper Wadi Rasyan catchment and beyond, and is immediately raised as an objection to any proposals for exploratory drilling for city supplies. Contrary to Dellapenna (1995;155), state system sceptics are not only justified in doubting whether experts can acquire the information to arrive at the right conclusions, in the Ta'iz case they are not sceptical enough. Even if the right conclusions are reached, will the state fully inform the stakeholders of the conclusions?

TSWSSSR

Because of the institutional problems faced by NWSA, the Technical Secretariat for Water Supply and Sanitation Sector Reform has, in consultation with NWSA, embarked on a programme of sector reform. The programme has three main phases (Davies and Sahooly,1996, Kalbermatten,1998):

a) The establishment of the branches on an commercially viable autonomous basis,

b) The conversion of the branches to fully autonomous Regional Corporations and

c) The encouragement of private sector participation in water supply and sanitation activities.

The first phase includes branch autonomy in establishing cost-covering tariffs and salary incentives and in hiring and firing. Community participation in the operation of the utility is also on the agenda, as well as reduction of unaccounted-for-water and the promotion of good customer relations and improvement in service quality. These aspects of the technical secretariat's reform agenda are at present lacking in the Ta'iz instance, and the branch has been singled out as being too difficult to reform until after most other branches will have entered the programme (ibid.).

The Governor's Office

With the failure of the Al Hayma wellfield in the summer of 1995, the Governor of Ta'iz embarked on an 'emergency' drilling programme within the city limits of Ta'iz. Although local businessmen were prepared to pay for the drilling, the Governor demanded payment by central government for the most expensive item, the submersible pumps, under threat of his resignation. The Governor was advised to monitor well drilling and yields. However this was not done, and the rushed completion of 18 wells resulted in an average well yield of only 3.5 lit/sec, which is still declining, (Dubay,1996) and derogation of existing wells. Incorrect connection of the pumps to the existing system and operational malpractice by NWSA has resulted in pumps running dry and overheating, wells pumping against each other and significant leakages. A more useful intervention by the Governor's office has been in negotiations with rural communities and shayxs over the water transfers to the city discussed in section 5.2.

HWC - NWRA

Berkoff identified a typical historical development of water entities (1994):

a) water agencies are established to meet a specific need,

b) activities related to that use are delegated to autonomous entities reporting to the parent department,

c) the agency covers all aspects of the water use and acts according to its own needs and biases,

d) and the result is competition and inefficiency.

Table 5.5: Traditional Yemeni Support Systems Relating to Water Use (after Joshi,1995):

Support System	Description
Al-Ana or Al-shamla	Communal 'voluntary' work. Penalties for those not 'volunteering. Well digging, bridges, dams, rebuilding after calamities.
Al-Muthaha	Mutual support among neighbouring farmers – irrigation equipment, labour etc
Al-Ta'awun fi Majal Al-ray	Co-operation in irrigation – one farmer is responsible for distributing water collected during rainfall.

In particular, co-operation in irrigation is apparent. Indigenous mechanisms of water allocation relate not only to the distribution of collected rainfall, but also in the allocation of ghayl (stream-fed) irrigation observed throughout the Ta'iz region (Handley,1996a;23-4) and further afield (Varisco,1983). Usually 'invisible' to the observer, the 'suruub al miiyaah' manager (water distributor) takes on a more prominent role as water becomes scarcer. Corporate response to water scarcity is an ancient feature of Yemeni rural life, a fact reflected more recently in the harnessing of remittances for water projects (for instance at Al Sina, World Bank,1997) and also commercial ones (Handley,1996a).

The Shayx

Probably the key institution in water management (and most other affairs of any importance) in the rural area is the shayx. This style of informal self-government, although not as tribal as in the North of Yemen, typically runs in families until someone performs particularly poorly. The shayx is usually a senior member elected by local families on the basis of his knowledge of customary law and shari'a and, ideally, for his maturity and impartiality. The literature and fieldwork are replete with accounts of principal-agent and preference aggregation abuses (Johnson,1996 terminology) by some shuyuux (see section 5.2) although others may better represent their principals (Handley,1996a;24,26). In either case, and at all locations visited during fieldwork, the shayx's word was final, a fact crucial to the success of the more recent non-traditional initiatives described below. The shayx is the management domain (Manzungu,1999;164) and cannot be ignored or bypassed in any stage of water management initiatives without the likelihood of jeopardising the initiative. It is vital to recognise their power, the limits to it, to inform them, to win their confidence and to work through them. They are the local political reality. Even with the recent trends of democratisation in Yemen, the inability of central government to implement law and order and collect taxes points to a continuing role for the shuyuux in local government. Many of the more prominent 'shuyuux al-mashaayix' (leaders of shayxs) also get involved in national government (Joshi,1995).

Summary

The relevance and role of these two non-Government, traditional institutions stand in direct contrast to that of the Government institutions. Although there is a tradition of co-operation this has been limited to irrigation and rural water supply. The shayx system is also open to principal-agent abuses, but can and must be worked through, rather than around.

Non-governmental, Non-traditional institutions

TWSSP

The work of the World Bank in the Ta'iz region has demonstrated that there is a tradition of self-help in local, indigenous rural development in general, and in water provision for agricultural and domestic purposes in particular (World Bank,1998a;Annex 5). The relatively recent establishment of indigenous co-operatives in the fields of agriculture and irrigation but also for other purposes (Handley,1996b, Ward,1998), indicates the continuance of that tradition, and provides a potential basis for future initiatives.

The Ta'iz Water Supply and Sanitation Project has been established by the World Bank in 1997 to help facilitate relief of the failing city's water supply. It has considered the co-operatives or such similar non-traditional institution as potentially capable of negotiating rural-urban water transfers and distributing compensation equitably (World Bank,1998b). Apart from supply side aspects and incorporation of public utility reforms in co-ordination with the GTZ sponsored TSWSSSR, the project also seeks to promote stakeholder participation in rural-urban water transfers through the establishment of committees / water user associations perhaps formed from existing co-operatives. NWRA similarly seeks to promote the involvement of stakeholder groups in building consensus over water resource management strategies in the area (NWRA,1998b).

Private Sector Participation (PSP)

The major area of indigenous initiatives in water supply has been in the private sector. The potential for private sector involvement in urban water supply and sanitation is currently being explored to varying degrees in many parts of the world (Brook-Cowen,1997). Partly encouraged by the reality of the water markets already operating, both the TSWSSSR and the TWSSP have recognised the potential of PSP in Yemen and Ta'iz specifically. As indicated in section 4.5, markets have responded quickly to demand and provide a much needed service. The markets have adapted, and function more efficiently than the public sector. However, there are limitations to the extent to which the private sector can take on large scale water provision. Apart from relatively small operations by individuals and small companies supplying tanker and treated water, the larger companies are reticent regarding involvement in the water sector. The two largest industrial groups in Ta'iz have contemplated involvement in bulk water supply to the city, but, apart from needing technical assistance to do so, they also have the following reservations:

a) The shortage of water resources (how can water resources be managed if there are none to manage?)
b) The water quality problems (the scale of investment in treatment makes it unattractive)
c) Current perceived management and operation problems in NWSA
d) The run down state of the current facilities
e) Lack of clarity regarding how company management, operation and objectives would be able to integrate with or adapt to NWSA branch management operation and objectives.
f) Fear of public opinion and reaction if any problems occur
g) Mistrust regarding whether the government would truly give the private sector a free hand
h) No guarantee that they will be able to recover revenues

Within the scope of PSP being discussed (ibid.), both groups envisaged their potential involvement being limited to service contracts, though the possibility of a concession for specific areas of Ta'iz was contemplated. Options requiring any greater investment or involving more of the city were considered too risky.

In addition to PSP in the urban sector, the largest company in Ta'iz has provided water and electricity supplies to villages as compensation for environmental damage and livelihood deterioration, as a promotional tool, or simply as a form of 'zakaat' to needy communities. Private businessmen working in the Gulf and Saudi Arabia have also made a considerable contribution towards providing water supplies in some rural home areas, on both commercial and philanthropic bases (see section 4.3). Despite these private initiatives in rural and urban areas, if the utilities were privatised, questions of equity provision and the importance they would give to protecting the environment are still relevant (Hildyard,1998;18 and Allan,in prep;5.32).

Summary

Two major non-governmental, non-traditional institutions may be identified as currently involved in water supply in the Ta'iz area. The World Bank initiative has established the only institution directed specifically at the problem of reallocating water from rural to urban areas through stakeholder participation possibly via co-operatives or newly formed water user associations. Although the private sector has made some contribution to improving water supplies in rural areas, there is more reticence to get involved in large scale urban supplies.

5.4.3 Discussion – the Combination of Scale and Function

Scale

It is suggested that the appropriateness of institutional arrangements for the efficient provision of water needs might best be examined from the viewpoint of the scale and function of those arrangements. Regarding function, water provision may be divided into productively and allocatively efficient provision, with productive aspects subdivided according to sector. Regarding scale, institutions may be divided into village (or even Wadi), city (or regional) and national. Section 2.6.2 demonstrated that in the application of institutional theories to Yemeni water problems, there is a distinction on the basis of the scale from local to national institutions (Table 2.3). These distinctions are related to the urban / rural location in which the institutions seek to address the water management problems described above.

The national (government) institution is perceived, not undeservedly, by the local pole as untrustworthy and as only being interested in 'stealing our water – and then wasting it'. Those who think that centralised institutions have good potential for co-ordination and integration (Guggenheim,1991) obviously have not worked with NWSA. Similarly those who prefer the state systems, because they are supposed to deal with problems more rationally before they become crises than can the private sector (Dellapenna,1995;155), obviously have not lived through the Ta'iz water crisis. The 'participation pessimists' correctly favour legal reforms to improve the efficiency of formal institutions. However, if they discount the non-formal, local, institutions when it comes to the most important issue of water transfers, they will become non-participation pessimists. Part of the solution, it is considered, is the scaling down or decentralisation of the national, government institution towards something more amenable to, and perhaps even representative of, the local pole.

At the local pole, one of the problems of negotiating water transfers, or for that matter of providing rural water supplies, is finding a 'representative' body with which to negotiate. Relative to the urban situation, rural societal structure and responsibility are more clearly demarcated. Even so, the 'participation optimists', who believe that non-formal institutions can transmit community demands, may prove to be participation over-optimists. As mentioned, both principal-agent and preference aggregation problems can occur when negotiating with some shayxs. Also, on a wellfield scale, the size of local institution (shayx or whatever) is often too small, as in the Hayma-Habir example, to represent those stakeholders who would be affected by water transfers. As a result, the 'mish-mash' of local web-like institutions and political borders have to be bridged in the negotiations, with considerable addition to transaction costs and the risk of not arriving at any settlement negotiated with all interest groups. Part of the solution at this pole is the scaling up of local institutions into a representative body with which to negotiate.

Both activities are needed, the scaling down or decentralisation of the government institution and the scaling up of the local micro-institutions into a representative body at a more 'catchment-based' scale.

Function

Ta'iz people relate differently to water; as users for drinking, domestic use, industrial use agricultural use and as traders (or potential traders) in water, and the institutions centre around these water functions. The existing government institutions have been inadequate in their provision of drinking water and sanitation due to a combination of institutional overlap (in rural areas), inefficiency and principal-agent irregularities. In providing for irrigators, they have transmitted the wrong economic signals in terms of allocative efficiency. The industrial sector has essentially met its own water needs without recourse to outside institutions, and small scale trade in water has also been self-regulating.

To enable larger scale water transfers from irrigation to allocatively more efficient uses Hansma and Hermans (1997) suggest the manipulation of existing institutional webs which relate to the water functions. The World Bank experiment with water user associations in Miqbaba and Al Hayma is an alternative attempt at the creation of new institutions, though based on traditions of self-help and co-operation. Both these models are forms of decentralisation away from Government institutional intervention. Regarding equity provision, the non-Government institutions, although still prone to principal-agent irregularities, are much more relevant, and trusted than government ones at least at the village scale.

Some suggest environmental protection is a central government function, however, self-limitation of abstraction and pollution from below is likely to be much more effective than authoritarianism from above in a weak state/strong society. Although 'urf prevails over shari'a, the concept of ijmaa' and local consensus, rather than the imposition of non-indigenous rules, are much closer to the cultural heart and is a more sustainable basis for decision-making. A key measure is therefore the involvement of the informal local stakeholders via indigenous institutions for policing.

A more realistic and relevant function for central government is the provision of the right macro-economic signals instead of the wrong ones (diesel and wheat price, subsidised loans, agency technical assistance etc.) to promote allocative efficiency. The reason they do not was explored in section 5.2. Also, determination of safe yields and pollution limits, and instruction on how to monitor and interpret the observations may still best be provided by central government function via a regional agency.

5.4.4 Conclusion – The Potential for Local Water Management

The respective titles of UNDP and World Bank projects in Yemen of 'Strengthening of Water Resources Management Capabilities' and 'Decentralised Management' reflects recent thinking in development involvement in the South. In both cases, institutional appropriateness is perceived as the target. If aid is not to result in even less being achieved and even more skimming off by bureaucrats, then the recipient institutions will need to be locally accountable. The TSWSSSR programme, aimed at decentralising the provision of water and sanitation services, at least in the urban area, directly addresses the need to make more efficient use of the water. The TWSSP initiative seeks to promote the equitable representation of the supply area communities in water transfer negotiations and attempts to bridge the urban-rural (and government agency-local community) gap between consumer and source areas. Both these projects seek local stakeholder participation in the entities they aim to reform / create.

Potential for Collective Action

By 1995 the historical legacy of Al Hayma was a rightly placed mistrust of central government (via its agencies) which had spread far beyond the Upper Rasyan area. From 1995 the TWSSP initiative has experimented with promoting grass-roots stakeholder participation in water transfers. In Steenbergen terminology the TWSSP is acting as a facilitator (and financier) of the second order transaction costs of institutional change (1996;198). Those costs have been huge and time consuming (Ostrom,1999;201) and may yet prove too expensive to result in successful formation of institutions. There may have been a critical moment (contrary to Steenbergen,1996;202) in 1976, when the institutions needed to be in place to negotiate, or refuse, the planned end of irrigated agriculture (Leggette et al, 1977). Although critical moments can often only be detected with hindsight, near total depletion has resulted in the present reality of relative water scarcity for most, bordering on absolute water scarcity for some.

Despite the comments of those who think that scarcity or resource depletion should galvanize people into collective action (Mahdi,1986;193, Thompson,1988;67), at least in (new) water acquisition (Uphoff et al,1990;30), cooperation has not been automatic (Lam,1994;282) in Al Hayma, or Al Malika (Table 4.3), or many other Yemeni water depletion situations. In the irrigation literature 'new' water may be available through more efficient operation of irrigation schemes, but not where there are limited and declining groundwater resources and inefficiencies are already recouped by recirculation.

Why doesn't scarcity result in collective action in Yemen in general and in Al-Hayma / Ta'iz in particular? In the TWSSP experiment, many of the prerequisites for institutional change and operation (ibid,34-37,47,304-6, Mahdi,1986;192, Ostrom,1986;607-9,618) were pursued and constraints avoided (Mollinga,1998;246 et seq). It is difficult to imagine more investment in second order transaction costs in the pursuit of so little water. Perhaps never in the history of development has so much been spent by so many to secure so little. Despite this, two crucial elements have been missing, it is suggested. The first relates to the purpose of collective action in terms of supplying water to Ta'iz. This activity is essentially perceived as an external imposition of insufficient economic interest to the source area inhabitants. The second is the basic lack of trust between potential co-operators. At the best of times mistrust permeates Yemeni society, and is part of the underlying belief systems discussed in the next section, but in this instance, it has been reinforced very effectively by the Al Hayma experience.

Many writers note the importance of 'policy by process' as opposed to 'policy by prescription' in water management (Mackintosh,1992). The Ta'iz case suggests the policy (if there has been any policy at all) has been 'get water to the city by fair means or foul'. The means has contributed to the mistrust. Although this 'policy by default' approximates more closely to process than prescription, process has meant opportunism (Mollinga,1998;239) in which the actors have been few, consultation negligible, and contingency the order of the day (ibid;242,263).

However, the irrigation literature is mono-sectoral and hence limited to the productive efficiency approach. Solutions to the Ta'iz water shortage lie in allocative efficiency and have to address much wider issues. The present relationship between local and government institution (upper diagram), reflected in, is contrasted with a proposed model (lower diagram) in which most water management functions are managed locally (arrows indicate a cause-effect relationship):

Present Situation

		Scale	
F	Local Institution		Government Institution
U			
N	'Take' mentality	========→	inefficient water provision
C			
T	Conflict over 'stolen water'	========→	unacceptable reallocation
I	allocative inefficiency	←========	wrong economic signals
O			
N	Resentment of Impact And blame of government	========→	oversight of environmental disaster

Proposed Institutional Model

		Scale	
F	Local Institution		Government Institution
U			
N	Efficient Local Provision	←=========	technical help
C			
T	Acceptable Reallocation	←=========	right economic signals
I			
O	Environmental Policing	←=========	policy guidelines
N			

For equitable water resources management, the development community will have to ensure that decision-making roles by stakeholders reflect the level of the latter's stake in water rather than simply the current power asymmetries. For instance, Ward (1998) identifies drinkers with a basic need stake, users with livelihood stakes and owners with rights at stake. These stakes reflect the different roles and levels of importance water holds in their lives. If local communities are to heed calls for water resource protection from derogation and pollution they, according to their stake, and nobody else, need to own and police it. Otherwise the curtain is likely to rise on the next scene of the 'tragedy of the commons'. Establishing stake-weighted institutions that have hydraulic control and responsibility will be a severe test.

At the national level, the task of providing the right macro-economic signals to promote allocatively efficient water transfers remains the key central government role, whether or not there is political will to adopt it. The government institution with the closest mandate to identifying and effecting allocatively efficient policy is NWRA. The non-transparent performance of central government institutions in the removal of water from rural areas to the city in the past has placed the NWRA fledgling under the communities' microscope.

5.5 The Contribution of Knowledge and Belief Systems to the Degree of Sanction of Discourse on the Allocation of Water and some Implications for Development

Whether politicians really have a free hand in policy determination has been questioned (Foucault,1971, Mollinga,1998;20). An alternative model in which interacting and competing interests of the powerful define and legitimise acceptable discourse has been proposed (Tripp,1996 in Allan,1999a). Within these boundaries, discourse is termed 'sanctioned' or permitted, beyond which lies the wilderness of 'unsanctioned' discourse. The boundaries are blurred, vary for different communities and may change with time given an appropriate crisis or 'window of opportunity'. This section seeks to demonstrate that belief systems and knowledge define those boundaries, directly influencing the degree of sanction discourse on the allocation of water receives, and hence directly affecting the extent to which allocative measures can or cannot be introduced.

Beliefs about some issues that relate to water allocation commonly held in Yemen are briefly considered together with beliefs regarding related issues of the state, equity and the environment. The extent to which beliefs and knowledge can influence water policy is discussed, and from this vantage-point, various water-allocative issues in development are examined and the influence of beliefs and knowledge on the degree to which discourse on them is sanctioned is considered.

5.5.1 Belief Systems: Facts vs. Truths

The importance of belief systems in determining what is politically feasible in water allocation has been argued by Allan (in prep;chapter 6). Before considering the prevailing belief systems in Yemen regarding water, and in order to avoid confusion over terminology it is important to make some distinctions. There seems to be a confusion in the literature

(Atkinson,1991;53) between facts and truths. It is not surprising that this confusion may also be found amongst Arabic speakers, where 'haqaa'iq' is commonly used to cover both terms. To improve the objectivity of the following analysis and discussion it would be appropriate to define these terms.

Fact: an observable (often measurable) phenomenon that could be verified by witnesses e.g. it rained here today or water flows downhill.

Truth: an opinion adhered to. For convenience we will subdivide truths into true truths and false truths:

True Truths: opinions based on a reasonable interpretation of the facts e.g. water has value (an interpretation of the fact that tanker drivers pay x riyals for water at the well), or the national food deficit is made up by the import of virtual water (an interpretation of national food statistics)

False Truths: opinions not based on an interpretation of the facts or based on an unreasonable interpretation of the facts e.g. water out of the tap should be free. (This interpretation is based on a combination of an unreasonable interpretation of the fact that rainfall is free and/or failing to interpret the fact that costs are involved in the installation, operation and maintenance of infrastructure needed to get rainfall fit for consumption from the tap).

By definition false facts are termed lies, and when interpreted may yield false truths.

The difference between true truths and false truths is, of course, gradational. The truthfulness of a truth is also confused when truthfulness is based on the strength of adherence to the truth, rather than reasonableness of the interpretation or the extent to which facts support the interpretation. The problem for water managers is that most of the truths they deal with lie towards the middle of the spectrum where the interpretations become more tenuous, mainly due to the absence of complete scientific fact and unknowns in the method of interpretation (Thompson,1995;25). The resulting uncertainty provides scope for the certitudes (ibid;27,28). There are also some instances of unreasonable interpretation of the facts, reasonable interpretations of false facts etc. Despite the problems of interpreting information, it is hoped that the distinctions between facts, true truths and false truths will aid the debate.

There are also types of truth with origins not related to the interpretation of observations. These include religious truths (derived from holy writings or revered interpretations thereof) and social norms and traditions. It is also useful to distinguish conscious truths, which are verbalised, and unconscious truths and partly conscious motivations (Giddens,1984;chapter 2), which are assumed, and can often only be detected by outsiders. These latter forms are often the most powerful because they are not perceived. They can therefore only be challenged with difficulty and tend to be excluded from the sanctioned discourse. They are often ubiquitous, invisible and have been in place for as long as people can remember.

An issue distinct from categories of 'truths' is the impact of truths on human behaviour. In some instances behaviour may bear no resemblance to the truths expressed or, put another way, be termed 'voting with one's feet', or hypocrisy. For example, the motto "God, the state, the revolution" versus the reality "me, my family, my tribe", or depending on grain imports whilst emphasising food self-sufficiency.

5.5.2 Some Water-Related Truths

Starting with religious truth, curiously omitting air, it is stated that "people are partners in three (things): water, fire and grass" (translation, Haddash;1998). The interpretation of this verse has formed a firm 'belief status' basis for establishing the unreasonable perception of water as a free public good by some (ibid.). This position stands in stark contrast to the emerging view (at least amongst the intellectuals) of water as an economic good.

The absence of discourse over virtual water's national security role is maintained by several commonly held truths including national food security based on indigenous agricultural output, the social elevation of meat-eating and the necessity of procreation for the provision of labour and income now and in one's old age. Respectively, these truths obscure the facts, and increase the demand for agricultural and domestic water. Also, the assumption that agriculture has prior right to water over industry is fostered by the unconscious truth of having one's heart in the soil and the village (Dresch,1989;133,306-7).

There are many traditional belief systems regarding water which apply particularly to village life that caution the romanticism surrounding indigenous knowledge, which currently emanates from the belief systems of some branches of Northern academia. Drinking too much water is generally believed to be harmful, particularly for pregnant women and for children with diarrhoea, and skin with boils, sores or measles is not washed (Ansell,1980). The belief that men should get priority access to clean drinking water over women, and that women should collect water when there is no motorised transport and men when there is (Mclagan,1994) raises the question of whether male politicians and policy makers hold a smaller stake in water issues than women.

Related to the need for clean water for religious ceremonial ablutions in Islam, there is widespread reticence in the Middle East regarding the use of waste water that has been recycled in a sewage treatment plant for domestic purposes. Other than highly expensive desalinisation of seawater, the recycling of wastewater would provide the greatest potential future source of water for Ta'iz (Handley,1999b). Although the domestic use of waste water is a necessity for the inhabitants of St John's Wood and the rest of London, this option has been rejected by Ta'iz people on religious grounds, a clear example of belief systems determining water policy.

Views of the State

The state is not me, nor my family nor my tribe and therefore is to be avoided or manipulated for the purpose of society, my society. The belief that corruption and bribery, taught from childhood by the ubiquitous cheating in exams, are a necessary part of life particularly when dealing with government appears to be one of the 'unconscious truths' of Yemen. Coupled with a poor track record of government handling of local water issues, it is not surprising that surveys of public opinion find a poor estimation of government (Hansma and Hermans,1997, Handley,1996a). Migdal (1988;40) states that government earns the right to rule by providing services / meeting needs. In Yemen there is an expectancy that the government should provide infrastructure (Lackner, in World Bank, 1998b;Annex 8) and piped water supplies in particular. Dresch links this to the historical pattern of northern tribal extraction of wealth from the south, commenting "the more one takes, indeed, the more one expects" (1989;373). The 'take mentality' has been the experience of many who work in development, leading some to conclude that Yemen is not ready for that development (Chaudhry, pers comm.). Although the expectancy for government to provide is prevalent, contrary to Migdal (1988;30,40) that provision does not seem to impart the right to rule. This phenomenon appears to be closer to the weak state that expects little of its citizens (Myrdal,1968).

Views of Equity

Whether equity in water allocation and provision is everyone's goal must not be assumed (Mahdi,1986;194):

> "And we raise some of them above others in ranks"

and:

> "with respect to sustenance, Allah has favoured some over other"

(Al-Zukhruf 43:32 and Al-Nahl 16:71, respectively, Lichtenthaler,1999,19-20). The widely accepted interpretation of this verse (ibid.) amounts to a passive acceptance, even expectation, of divinely appointed poverty, or the divine lack of right of commoners and opens the way to the institutionalisation of inequality (Mollinga,1998;238, Thompson,1995;31).

A farmer drilled a well right over a spring source and then sold the water from a pipe to the same downstream users who used to get it free by right from the stream. The drilling took place by military force because the farmer had good contacts in the army. This is one of many instances of inequitable changes in water allocation in the Ta'iz area in which oppressed and oppressor accept the new status quo. Although conflict over water resources and allocative measures is extremely common in Yemen (e.g. Al Wahdawi,17/3/98), once resource capture has occurred the injured parties seem all too readily to accept the new status quo. Because of gravity this tends to be the downstreamers losing out to the upstreamers (Varisco,1983).

Views of Environment

Despite the comments of some (Hansma and Hermans,1997;35), there is a considerable awareness of many 'lay' people regarding environmental issues. Low quality water and the pollution that causes it is a sore point amongst those who have to use it, although they often feel powerless to take corrective action. Similar awareness is evident amongst those faced with declining water levels, most of whom show a better grasp of hydrogeological principles than their Northern counterparts, although there are a few 'limitless underground lake' believers and awareness of how much water is lost in the reticulation system is low. Even urban domestic water consumers know when tap water is of insufficient quality to make a good cup of tea. Like their rural counterparts they are very particular about which water source is used for which purpose (Ansell,1980) and have at least some awareness of declining water availability and increased pollution. Because these impacts can be seen, smelt and tasted, the layman is not totally disqualified from analysing the situation and commenting on it (Hajer,1995;10). However, the cause of water shortages is mostly blamed on declining rainfall (Handley,1996a) rather than on human activity. Although shortages are felt more acutely in dryer years no long-term climatic trend is apparent over the monitored period, although the increased abstraction pattern is very apparent. At least declining rainfall is politically easier to accept than increased abstraction, since one has less responsibility for vengeance against the offender (God) than if one's neighbour were the cause (Allan,in prep;6.5).

There is wide adherence to the belief that the construction of dams is the solution to the country's water resources problems (Handley,1996b) a concept which even gains Presidential voice (Yemen Times 11/3/96). This belief may be related to images of Yemen's former greatness during the time of the original Marib dam which even has Qur'anic support. However, there is a tendency for dams to favour upstreamers over downstreamers, silt up, and encourage malaria and bilharzia. Small, already silted-up 'dams' distributed equitably down the valley, where crops could be grown on the silt and the water does not remain on the surface long enough to breed the larvae and snails, would be much more effective. The Yemenis certainly believe in these structures – they are called terraces.

5.5.3 Types of Knowledge and their Roles

Reasons why the foreign expert's advice may be ignored (Morton,1994;45) are part of a wider debate concerning knowledge which might best be introduced by an example. At an IDAS workshop, in Ta'iz in December 1995, a group of local experts and stakeholders were asked about the major water-related problems facing agriculture and the possible solutions. They had to first nominate the problems and then cast two votes for the most serious in their opinion, all by secret ballot. Because some of the wider causes (diesel prices, lack of drilling regulation, population growth) and initial steps to solution (monitoring, policing) were not included in the first ballot, a foreign development worker nominated them. However, they still attracted no votes, which all went to water use efficiency measures. This confirms the observation of Allan (in prep;6.18) that productive efficiency is politically the cheapest form of discourse. The reason it is politically cheap is that it does not challenge the old knowledge or belief systems. The new knowledge, aspects of which were put forward by the development worker, is politically too expensive to consider and remained firmly unsanctioned at the workshop. Although the new knowledge can become 'mutual' in that foreign and local expert can share it, (Giddens,1984) that change has not yet occurred significantly in Yemen where belief systems prevail. A return to the post-colonial 'developer knows best' is not being proposed here, but rather a hybridity of the best of new and old knowledge (Bryant,1998;14). A further complication arises because of the belief systems concerning knowledge. The accumulation of knowledge through monitoring does not seem important and knowledge gained is guarded closely. Attempts to obtain information, either primary or secondary, are treated with deep suspicion, particularly when Yemenis are requesting it. This does not bode well for development goals of institutional capacity building.

Since power and knowledge are synonymous (Atkinson,1991;61) an issue of equity aspects of knowledge is raised. Like most of the Middle East, the virtual water issue is publicly maintained as a Yemeni blind spot (Allan,1997, Golman,1997, see also section 5.1.5) and the topic of sustainability remains the enclave of the enlightened rich (Chambers,1986;10) in San'a, if it is anyone's. The absence of action over the polluted Wadis of Hidran and Rasyan reflects the absence of any environmental discourse to which their representatives could contribute. Adequate policy-changing discourse does not exist because the problem is in an area of new knowledge, it is unsanctioned and it is not perceived by those involved in discourse. Within the 'risk society' terminology of Beck (1999), the risk for Ta'iz is that there is insufficient water to keep everyone fed, watered, clean and in jobs in the current status quo. The earlier chapters have demonstrated the 'scientific' factuality of this 'risk statement' (ibid;76), however the political value of the statement lacks an adequately 'new knowledge-informed' audience to facilitate the risk becoming a threat. No policy change will occur because the discoursers do not feel the risks.

5.5.4 Implications for Development

This chapter has proposed that the water shortage of Ta'iz can be explained by successive layers of causation physical, economic, institutional, legal, and political and this section proposes that belief systems directly influence them. Into this context the developer enters (Manzungu,1999;159) with her 'new knowledge'. The development of development in the post-colonial era has followed a sequence roughly similar to these layers. Morton (1994) and Jewitt (1994) note a shift in emphasis from a) industrialisation/modernisation to b) agriculture/integrated rural development, then c) structural adjustment of macro-economics to d) institutional/human capabilities, and now, in the irrigation literature, e) policy reform (Manzungu,1999;10). Although the environment is missing from this list, Serageldin (1994) points out a shift in emphasis in the water sector from the old agenda of providing household services to the new agenda of environmentally sustainable development, but wonders if the old agenda is still on the table.

The history of development in Ta'iz can be related to Morton's and Serageldin's models but is less complete. The provision of the Kennedy scheme in the mid 1960's and emphases on agriculture, evidenced by the plethora of donor supported agricultural institutions in the city, are old agenda. More recent structural adjustment of macroeconomics is seen in the activity of the World Bank at national level, and the latest development of institution/human capabilities is an emphasis of UNDP, World Bank and GTZ initiatives at national and regional level. One might ask, however, what happened to industrialisation, why is agriculture still on the agenda and why hasn't the new agenda of environmental sustainability appeared on the table? The answers, it is suggested, relate to the extent to which discourse about these issues is sanctioned. These questions and related issues are discussed below in an approximate order of decreasing sanction, beginning with the sanctioned and ending with issues unsanctioned even in Northern discourse on development.

Irrigation, Diesel Prices and Water Law

Irrigation has been the direct recipient of development aid in the past, via import subsidies, cheap loans, fruit import bans and diesel subsidies and indirectly through the government agencies in the irrigation sector. It also continues to be supported, at least locally by the World Bank negotiated compensation package in Habir, which includes wells and dams for irrigation (World Bank,1998b). In fact, Yemen's proportion of total World Bank lending for irrigation is second only to Egypt's (Berkoff,1994;5). Yemen is much more likely than Egypt to use up the loans, and the groundwater the loans enable to be mined, growing amphetamines. The economic nonsense of irrigation and the extent to which subsidised diesel prices give the wrong economic signals to irrigators have already been demonstrated (sections 4.1.4 and 5.2.4). Government support of this status quo is reinforced by the absence of a water law, facilitating enhanced nest-feathering for the land-owning ruling elite in accordance with the prevailing belief systems regarding equity.

Water and Sanitation Supply Projects

Even though such projects are 'old agenda' the development agencies seem to commit themselves to them easily enough in Ta'iz, as well as in many other towns and cities in Yemen (Gitec Dorsch,1989, SAWAS,1997, Dar Al Handasah,1997). The predetermining allocative logic (Falkenmark and Lundqvist,1995;214) of these schemes has certainly led to inequitable access. Although the trend towards commercialisation and privatisation in the name of institutional development may lead to improved operational efficiencies (Davies and Sahooly,1996), it remains to be seen whether equity is addressed (Allan,in prep;5.33). Discourse regarding whether the provision of urban services creates jobs and attracts more people from the countryside, or put another way, urbanisation breeds urbanisation, seems to fall in the unsanctioned category. The high cost of sanitation provision (Serageldin,1994) often ensures that it remains only a nominal appendage to project titles, is the first item to be dropped when budgets are threatened, and the environmental consequences of that decision are ignored.

Industry

Industrial development and modernisation have been out of fashion in development circles for some time. On the surface this would place Allan's plea (1992;12) for water to be transferred from uneconomic irrigation to hard currency earning / job creating industries firmly in the unsanctioned category, at least in Northern development discourse. The fact that Ta'iz industry earns 275 times more capital and provides 21 times more jobs than the irrigation sector supports Allan's plea (section 4.2.2). The historical levels of industrial pollution in Ta'iz are the major drawback to this argument. However, with several of the major industries looking seriously at waste water treatment and the only treatment in the city at the moment being by industry, there is significant potential to overcome this objection. Government legislation, with monitoring and enforcement, regarding industrial pollution is still much needed, but should also be targeted at domestic waste. Urban domestic wastewater accounts for around 50% more pollutants entering the surface water and groundwater than industrial wastewater does. This stands in marked contrast to the development literature reporting on Ta'iz which seems to spot the speck in the eye of industrial pollution and miss the plank of domestic pollution on the few occasions it does mention the environment. Perhaps this is because the development recommendations also want to avoid commitments to domestic wastewater treatment, and they do it by pointing the finger at industry.

Virtual Water

Closely related to the irrigation/industry debate is the issue of food self-sufficiency versus virtual water. The argument runs that widening the economic base (particularly through the development of industry) will not only provide livelihoods but will also earn the country more currency with which to buy food staples from the world market. In the case of Ta'iz, industrial development would pay for food imports even if the latter had no subsidies either from the Northern exporters or from Yemen. However, the siege mentality of national food self-sufficiency remains one of the most unmoveable beliefs for Yemenis, whose hearts are in the village and the soil as much as the Israelis' were in the kibbutz forty years ago.

Demography

Perhaps the most limiting factor for sustainable development is the population growth rate (Allan,in prep). The population problem is not simply a fixation of the environmental movement (Jewitt,1994). Yemen is still in the steepest part of the demographic transition (Figure 4.29). The national average is 3.5% pa and the city growth rate over double that figure. At that growth rate, even if all the potable water (<1500μS/cm) were to be abstracted from all the major wadis in a 50Km radius and unaccounted for losses reduced to 20% a population of 1.1M people (by 2013) could be provided with only 30 lit/day. This abstraction would have a similar impact on irrigation to that which occurred in Wadi Al Hayma, that is, its termination. Every other factor related to water transfers mentioned up to this point in the discussion pales into insignificance if the demographic issue is not faced. However birth control, or children by choice, remains firmly in the realms of very unsanctioned discourse (Allan,in prep;6.4). One can only assume that before long people will seek employment elsewhere and that the pressure to migrate to other parts of the Arabian Peninsula will increase. Government could consider offering industry incentives to establish new factories on the coast and use their returns to water to pay for desalination.

Tax, Corruption, Law and Order

Morton (1994) notes that the failure to collect tax, deal with corruption and enforce law and order (see section 5.3.3) are root causes of the poverty of Southern nations, and yet that these issues are not allowed to be challenged by the development process. These failures are characteristic of the politically powerful (Ostrom,1999;199) of weak states, and have a similar debilitating affect in Yemen. For instance, Saqqaf (1985) reports that only 38% of tax due is collected. Although the World Bank has raised the issues of tax collection and corruption (Hildyard,1998;43), since Al-Hamdi there has not been much sign of progress in Yemen.

Measures of Economic Development: GDP, Remittances, and National Budgets

Whether GDP is an accurate measure of economic development is questioned by World Wildlife Fund (1996). Assessing Yemen's economic development is also difficult. There is a significant smuggling economy and over 60% of foreign currency transactions never enter the banking system (Yemen Times 12/6/95). Prior to the Gulf War (1990), the scale of remittances not banked was huge. Much of these funds were invested rather in irrigation and houses in the villages and towns and in setting up small businesses. From the urban household water use survey (Handley,1999a) it was possible to estimate the value of the land, houses, vehicles and a few major household items belonging to the Ta'iz householders. The average value of these things alone, not including any other items such as business assets, was $62,000/household if land in the village was included and $47,000/household if it was not. When it is also considered that 40-50% of the budget is spent on defence (Saqqaf;1985, Yemen Times;17/4/95) it must be questioned whether aid to Yemen is equitable for the rest of the world, that is, whether other nations might not be more worthy recipients.

Education

Dixon and Hamilton (1996) found the human asset capital stock of countries to directly correlate with the mean years of education per capita. Investment in education is no doubt laudable, and Milroy's hypothesis that education was a cause of terrace degradation (1994) is rejected (emigration was a much more likely cause). In the search for water for Ta'iz, the failure to conduct pumping tests correctly raises the question of the role of education in development. Although this particular example contributes directly to the on-going water problem, it is symptomatic of institutional failure resulting from indigenous educational weaknesses. It is suggested that the potential for institutional reform and improved social adaptive capacity are ultimately limited by the quality of the staff within those institutions, which in turn is largely determined by the educational system to which the staff have been exposed.

The Yemeni education system should be examined, particularly if development funding in the water sector is to be channelled through education and training. Firstly the rote memory system mentality which is developed as a first stage of education in the Qur'anic schools seems to permeate to the highest levels of education. This results in a lack of ability to apply knowledge on the basis of principles. Secondly the extent of cheating in exams raises questions regarding the value of qualifications. This leads on to the rarely perceived problem of having a higher respect for qualifications over experience (contrast Manzungu,1999;159 and Berkoff,1994;47) than occurs in the North. Fourthly, having invested in the education of tomorrow's forward thinking hydraulic scientific community, some of the most able emigrate (Morton's brain drain,1994;47) whilst others find there are no jobs through which to turn qualifications into experience (ibid.). Fifthly, the educational content imparted by the North to the South is becoming so high-tech that it is creating a screen-glued elite of technocrats who disdain dirty grass roots field work and indigenous knowledge and become even more detached from the problems than did the old style 'technology transfer' development method.

The Development Process

In terms of the layered model of water shortage causation (section 1.3), the focus of development seems to have moved progressively closer to the core, through successive emphases on the physical supply of water, macro-economics and now institutional issues. However, it must be questioned whether Southern governments will allow development agencies to encroach any further, that is, whether legal frameworks, political interests or, ultimately inherent belief systems will be allowed to be challenged.

Faced with 25-30 l/c/d of low grade water in Ta'iz and the consistent plea for spare parts for rural supply schemes, it would appear that most consumers need Serageldin's old agenda (1994) of household services provision. The existence of the World Bank's Ta'iz Water Supply and Sanitation Project also recognises this need. Although needful, Allan considers that 'comprehensive pipe water schemes can only be introduced sustainably into strong and diverse economies' where the institutions can 'deliver a flow of funds to operate and sustain them' (in prep;5.32). Because this does not yet exist in Yemen and because urbanisation continues apace, it might be suggested that in pursuing piped water schemes development is only creating the need it seeks to meet. This raises perhaps the most unsanctioned topic for discourse of all; the development process itself.

Knee-jerk emergencies and windows of opportunity for what?

Winpenny (1994;83) commented that short term development measures introduced, for example in an emergency, might have a strong immediate, positive impact which would be likely to tail off. Such has been the case in Ta'iz, where lurching from one 'emergency' to the next has been the norm. With the provision of inadequate quality water once every three weeks under 'normal' circumstances, it could be contested that water provision in Ta'iz is in a continual state of emergency. However, the coincidence of a low rainfall year and a political opportunist in power tends to result in an 'emergency' or 'window of opportunity' (Kingdon,1984). Thus it is difficult to discern whether the window is an opportunity for economic/scientific common sense to prevail, or is a 'window of political opportunity'. To date, the emergencies seem to have resulted in panic drilling, that is, jobs and money for whoever can get involved, and the irrational nature of handling the emergency ensures there will be another one in a few year's time. The short-termist attitude which seems to accompany the emergencies has resulted in a new scheme of some kind every seven or eight years on average, a point which some development agencies seem to ignore when planning the next one.

State – Development Agency Symbiosis

Migdal (1988;21) links the role and effectiveness of the state domestically to its place in the world of states. This especially proves true in the Ta'iz development arena, if development agencies align themselves with central government, which they have to work through at least to get their residence permits, giving the government legitimacy (Vincent,1991;210). Making field visits in one of the President's layla 'alawis both confirms the allegiance and dangles World Bank dollars before the locals, winning at least superficial allegiance to those associated. All political levels from the local shayx to the President and his party will want to be seen to be a vital part of the mechanism that results in development funding ending up in the locality. How much slips through the nets of those involved and arrives at the intended destination is another matter, but as long as a large enough amount does, then both political and financial mileage can be made by those involved, and aid can remain part of the problem as well as part of the solution (Hildyard,1998;48).

Jobs for the Boys

Lastly, it must be questioned who gets involved on the donor side and why. In the pursuit of more appropriate development, Northern academia seem happy to keep moving the goalposts. The fact that this provides opportunity for publications and attracting research grants or 'academic consumables' (Yoshida,1999) is not coincidental (Bryant,1998;13). It is curious that on the basis of lucrative data intensive studies (Chambers and Carruthers,1986;2), consultants propose schemes that can fail (e.g. Al Hayma) without being sued for getting their numbers wrong. Perhaps this is because the water runs out five years later instead of two weeks later as in the dewatering sector. Even in the name of institutional capacity building there has still not been a well-conducted pumping test in the Ta'iz area. It is not surprising that development workers give-up, when they know their advice will be ignored (Morton,1994, Allan,in prep;6.17), the infrastructure will not be maintained whatever is done with the institutions, and funds and equipment will continue to find their way into the wrong hands.

Summary

This section has demonstrated that deeply held beliefs, conscious and sub-conscious, contribute to determining what can be discussed and what cannot in the field of water allocation. Many facets of Yemeni life impinge on the water allocation nexus and the degree to which discourse on them is sanctioned or unsanctioned determines what contribution they can make, if any, to keeping the population fed and watered.

The inability to sanction discourse on existing/potential water shortage causes/solutions is not only a Yemeni problem. Northern development discourse can also exclude key issues. The next section examines some of the limitations of Northern sustainable development models in the Ta'iz context.

5.6 Equitably, Environmentally and Economically Sustainable Development

The history of water allocation and use in Ta'iz provides a useful context against which to test the relevance of the different schools of thought regarding the theory and practice of sustainable development.

5.6.1 Introduction: Getting Things in Perspective: Environment and Equity

'The poor and needy search for water, but there is none'
Isaiah 41:17

In chapter three, the extent of degradation of the water environment was investigated and it was demonstrated that water levels had declined between Habir and Al Burayhi, in Hawban, Wadi Hidran and beneath the city of Ta'iz. The result has been declining wadi flows, declining well yields and in many instances the drying up of wells. The area affected accounts for around one third of the total stream / groundwater irrigated land of the Upper Wadi Rasyan catchment that was irrigated at the height of groundwater development in 1985. A further quarter of this total has been polluted directly by urban domestic and industrial waste water. The two portions do not coincide, resulting in over half the stream / groundwater irrigated land becoming environmentally degraded.

Chambers (1983) identifies a deprivation trap into which the powerless, vulnerable, physically weak, poor and isolated downwardly spiral. He notes that the rural and urban poor are particularly susceptible to this process and Berkoff (1994) also suggests that underprovision of water and sanitation is typically skewed towards the urban poor. The following summary demonstrates that both these observations are applicable to Ta'iz. In chapter four, the provision of water and sanitation services, and also the contribution water makes towards providing livelihoods, were examined. In these contexts, it is worth raising the equity related questions of whose livelihoods and whose quality of living are affected by either water allocation practices or degradation of the water environment.

Water and sanitation services

In over 80% of rural areas, women continue to carry water distances averaging 1.7 Km and spend two hours per day doing it. In the city, the poorer 60% of the population spend 50% longer fetching water (around 10 hours per week) and twice as many poorer children are involved compared with the wealthier 40% of the population. The poorer 60% spend an average of 6% of their income on water compared with 2% for the wealthier 40%. Two-thirds of the urban community cannot afford tankers and one-quarter have to drink water of lower quality than recommended by WHO because they cannot afford treated drinking water. Water tankers are more expensive for poorer families, and those recently moved into the city, who have to build their houses at the city edges face higher tanker charges, have less access to public water supply and sanitation services. The wealthy also benefit more from the subsidised public supply and sanitation because they have far more water consuming facilities and gardens. Poor sanitation facilities are also beginning to affect the growing rural population and those downstream of the city and the factories are forced to use polluted water, and know it.

Livelihoods

The agricultural sector has been especially affected by water level declines. The wealthier, more powerful landowners can deepen wells to chase the retreating resource, hence stealing it from under the feet of the poorer ones. Principal-agent problems prevail in negotiations for compensation for water reallocation and 3rd party interests tend to be underprotected. The pollution of groundwater and soil in once fertile wadis has affected all downstream of the city, and poorer farmers adjacent to industrial plants have had to abandon land or sell cheaply. Although returns to water in terms of livelihood provision are far better in industry than in agriculture, pay differentials are rather inequitable in the sector.

Choosing a Model: The Sustainable Development Triangle

Current discourse on development appears to revolve around three basic aims; economic progress (or growth measured in some manner such as per capita GDP), equity provision (a more even distribution of goods, or, less often mentioned, 'bads') and environmental protection (from resource depletion or, taking it further, even resource reconstruction). These aims can be envisaged as separate axes or poles (Figure 5.7). The emphases of two distinct schools of thought or debate can also be related to these axes; the political ecologists and the Karshenas / EKcurve camp. The practice of the international donor community operating within the Yemeni water sector can be viewed against this theoretical background.

5.6.2 Theoretical Background: Political Ecology:

Environmental Protection, Equity Provision but no Economic Progress

Political Ecology has contributed the concept of a politicised environment and demonstrates that environmental problems cannot be understood in isolation from their political and economic contexts (Bryant and Bailey,1997:28). Shadowing the shift in development rationale, very similar trends can be traced in the political ecology debate. Eckersley (1997) traces three phases; Participation, Survival and Emancipation. In the first phase, excluded groups sought to ensure a more equitable distribution of environmental goods (ibid;9). This 'more for all' approach was displaced by the 'survival' phase of 'no more for some' as the worldview moved away from a 'cowboy's new frontier' view of limitless environmental resources (Pearce,1993;2). Instead of 'participation' in taming the water resources of the new frontier by the 'hydraulic mission', a 'survivalist' 'spaceship-type-earth' worldview of limited finite resources became ascendant (ibid.). The shift to 'emancipation' involved a change in the perception of the institution capable of implementing 'no more for all' from Leviathan top-down enforcement (Lam,1994;15) to bottom-up self-applied restriction on consumption by an conserver society aware of its responsibilities to future generations. The emancipation stage has also questioned the very notion of material progress (Eckersley,1997;17) and because Northern rates of consumption are so high, it is implicitly suggesting 'less for some'. The three stages are conceived schematically in Figure 5.7. Although the participation stage embraced economic progress, the survivalist stage viewed economic progress and environmental protection as opposites and the emancipation stage completed their antithesis.

5.6.3 The Karshenas / EKcurve Debate:

Economic Progress and Perhaps Environmental Protection but no Equity Provision

The current stance of the political ecologists, or at least of the deep ecologists, assumes that economic progress is simply incompatible with protecting the environment. This assumption is directly questioned by Karshenas (1992;iii and 22). In essence following the Environmental Kuznets Curve (EKC) model, Karshenas observes 'an unmistakable complementary relation between employment generation and environmental generation' so that 'the more advanced a country and the higher its technological level, the cleaner its environment becomes' (ibid.).

On the basis of Northern post-industrial nations Karshenas' hypothesis states that it is possible to reconstruct a cleaner environment, but that it is first necessary to undergo some environmental degradation (theoretical curve, Figure 2.1b) as the economy is strengthened. He contrasts the political ecology view that economic progress and environmental protection are mutually exclusive and 'traded-off' against each other versus his own view that the two can be 'complementary'. As discussed in section 2.7, others strongly contest the theory that the history of development in Northern nations supports the validity of this view (World Wildlife Fund,1996). Many countries do not seem to have 'turned the curve', that is, their environments are still deteriorating. This forms one major objection to the Karshenas hypothesis. However, the fact that he places environment on one axis and economic growth on an axis perpendicular to it, rather than the political ecologists' polarisation of these variables, at least gives some hope, if not scope, for the development that some economies (such as Yemen's) need. However constructing axes without data indicating that there is a turn on the 'EKcurve' does not prove anything.

Southern countries in particular show no signs of turning the curve, however, Karshenas specifically addresses this issue by differentiating between Northern and Southern development. The latter is hampered by what he terms 'forced environmental degradation' observed as an 'unambiguous complementarity between economic underdevelopment and environmental degradation' (ibid.14). The cause is identified as a 'low rate of increase of man-made capital stock, technological backwardness and stagnation, combined with a population growth which eats into the natural capital stock' (ibid.). In this situation, he prescribes a rate of economic growth which should be 'sufficient to cater for the basic needs of the population' (ibid.10), and on this basis defines sustainable development as a 'feasible' 'minimum socially desired rate of long-term growth'. 'Long-term' means tolerating the shorter-term environmental deterioration now in anticipation of turning the curve in the future. The curve may be the donkey's carrot always lying tantalisingly ahead and maintained there by population growth. Catering for the basic needs of the population is a rather ambiguous term. Where do basic water needs stop? Drink, food, domestic water, livelihoods? Each of these stages needs more water.

At this point it is worth evaluating Ta'iz in terms of Karshenas and vice versa.
Firstly, the water situation in Ta'iz is unsustainable. The 1995 water crisis proved that the system could not maintain its productivity when subject to stress or shock (Conway's definition of unsustainability,1986).

One would expect Ta'iz to fit Karshenas' definition of forced environmental degradation (above). However, two different situations are apparent: the rural areas where environmental degradation is measured primarily in terms of declining water levels, and the city together with its downstream impacted areas which are characterised by polluted surface and groundwaters. In the rural areas, rather than environmental degradation being a result of the pursuit of maximising agricultural production to feed an increasing population (Karshenas;1992;23), more and more irrigation has been used for growing cash crops such as qat, whilst virtual water in imported wheat has made up the deficit and fed the growing population. This is not forced environmental degradation but chosen environmental degradation by Hardin's selfish hedonists (1968). In the city, urbanisation has bred urbanisation and concentrated population, resulting in a deteriorating environment of increased pollution. The fact that increasing pollution remains unchecked is considered to be primarily due to the absence of institutional and legal frameworks to make the polluter pay.

This is a reflection of Yemen's limited (social) institutional adaptive capacity (Ohlsson,1999 and Turton,1999c).

Karshenas asserts that dealing with the root cause of population increase is less amenable to policy intervention than are technological change and employment provision (1992;24). Technological change has certainly contributed to the cause of environmental degradation in Ta'iz with the development of tubewells and pumps. In contrast, on the basis of the huge differences between agriculture and industry in returns to water, it can be emphatically stated that technological change in the form of a growing industrial base, is a more viable solution to the problems of 'forced environmental degradation', since:

a) Industry addresses the problems of a stagnant economy, underemployment, technological backwardness and low levels of man-made capital (ibid.) by providing employment which has higher returns to water and technological levels than other existing forms of employment. It also employs more people and creates more wealth in absolute terms than the alternative livelihoods and increases the level of infrastructure (man-made capital).
b) Industry feeds the population in an indirect way by underpinning a stronger and more diverse economy (Allan,in prep;6.5) which could facilitate the purchase of grains from the world market.

If handled badly, however, industrial development causes, and in Ta'iz has caused, further environmental degradation, just as the political ecologists suggest. If handled well, with enforced regulation, industry can be made to return used water to the environment at acceptable quality, and hence follow the Karshenas model. Indeed there are many signs that at least the major industries of Ta'iz are willing to adequately treat waste water without being forced to. The political ecologists in rejecting industry (the very soul of capitalism, Atkinson,1991;5) may in fact have thrown out the baby with the dirty bath water.

Economic signals and preferences emanating from central government do not seem to encourage the Ta'iz domestic sector to treat its waste water. There are therefore two problems. One problem is the handling by government (with or without legislation) of both industrial water users and especially domestic water suppliers. It is precisely this point that Ohlsson's (1999) and Turton's (1999c) comments regarding 'social adaptive capacity' of politicians and governments addresses. The observations regarding the failure to pass a water law and the failure of government to enforce law begs the question whether low 'social adaptive capacity' is synonymous with a weak state/strong society such as Yemen. The second problem is that the donors have also largely failed to acknowledge the contribution industry makes to intersectoral allocatively efficient water use and to the solution of environmental degradation. Relative to support for irrigation, the donors have provided little if any encouragement towards industrial development, and government and donor incentives to industry to treat waste are lacking. Together with their emphasis on irrigation, this suggests they too may be lacking the 'social adaptive capacity' to embrace environmental issues. The two problems of inadequate legislation / enforcement and ignoring the contribution industry could make to cleaning up its act together with the role the private sector plays in providing water suggests the authoritarian state and free-market allies of the emancipatory theorists should not have been totally rejected (Eckersley,1992;28).

Finally, there are two facets of the Karshenas model which remain unclear. Regarding the reconstruction of environmental capital there is the 'Problem of Historical Datums'. What abstraction rates should we be aiming at? Allan (1994a;3) asks whether past patterns of use should be taken into account. In Al Hayma, donors, government and farmers alike talk about consumption levels of 15 years ago, when groundwater abstraction for irrigation was at its height. Surely, for environmental recovery in Ta'iz, levels of 30 years ago would be more appropriate? If the Hittite race still existed, the Palestinian – Israeli argument over the West Bank might be solved – or at least have another contender from a few thousand years earlier. The historical datum issue also isolates the fundamental problem for Ta'iz. Water scarcity is such that it is impossible to return to any previous levels of agricultural water use because the population has increased so much in the mean time. We cannot reproduce the past because of today's population level. Virtual water and modern medicine to a large extent mitigate against the ancient means of population control of famine and plague, leaving war as the alternative. If we accept the level of population growth and seek to feed and water it, then we must look to technological change for a solution (Karshenas,1992;24). Indeed in Ta'iz technological development in the form of industry has done most to meet the population's livelihood needs.

The second, and more serious flaw in the Karshenas model, is that although the model finds a harmony for environmental protection and economic development, it ignores equity. Falkenmark and Lundqvist (1995) and Laird (1991;17) also raise the issue of economic progress and equity provision. In particular the population of Ta'iz demonstrates that the haves can invest the fruit of their economic progress in water transfers (by tanker or whatever) and create their mini-paradise, whilst the have-nots downstream experience declining water availability and quality and rising water prices. This phenomenon reflects the power asymmetries of actors controlling the environments of others which Redclift points out (1987;49) to be a particularly Southern feature. The Karshenas/EKcurves may hold true for the haves, but for the have-nots it moves towards the minimum environmental capital and minimum economic well-being quadrant of the graph (Figure 2.1b). World Wildlife Fund (1996;25) says 'if the benefits from economic growth accrue to a small minority of the population, only this small minority will be in the position to demand a cleaner environment'. Such is the case in Ta'iz.

There are also indications in Ta'iz that the EKcurve haves/have-nots split is not just local. Whether Proctor and Gamble, Shell, Rothmans, Crown Paints etc will be as rigorous upon themselves regarding their impact on the environment as they have to be in their home countries is not yet apparent. Wealthier countries may prove to be exporting the 'unsustainability' effects viz. negative environmental impact of their consumption patterns to Ta'iz (World Wildlife Fund;1996;10).

5.6.4 Conclusions: Can you have your water and drink it? Donor Agency Practice:

Economic Progress and Equity Provision, but only Lip-Service to Environmental Protection

Since initial development drives for modernism and industrial and agricultural development, environmental issues have come to the fore, contributing to adding the word 'sustainable' to the development debate. Development then shifted to a bottom-up participatory / stakeholder institutional emphasis. However the development community does not seem to be as radical as the deep ecologists and still assumes material progress where there is 'all for some and some for all', at least in the water sector (Delft,1991). Donor activity in Ta'iz, even today, comprises dams and wells for irrigation in the compensation packages for rural-urban water transfers. Irrigation productive efficiency measures are proposed, despite the fact that these will only produce 'efficient unsustainability', and treatment of sewage continues to be dropped from the agenda. The reality of donor activity causes one to question whether the 'environmental bit' is really just an 'add on' of secondary importance (Redclift,1987;14).

Within the sustainable development debate three camps, and their biases, have been identified (Figure 5.7) and can be related to the Hippocritical-style cultural theorist approach (Thompson,1995;32). Political (deep) ecology promotes environmental protection at the expense of economic progress. For a region with the economic limitations of Ta'iz, that expense may be excessive. Karshenas (1992) tries to reconcile economic progress and environmental protection, but at the same time ignores the inequitable distribution of both the environmental and economic goods and bads (Thompson's Bauer?). Whether there will be a turn in the curve for the majority of the population remains to be seen. To date, industry has been the technological innovation to address the problems of a stagnant economy, underemployment, technological backwardness and low levels of man-made capital as well as provide food by facilitating an economy which can pay for virtual water. In rejecting industrial development, the political ecologists may have thrown out the baby with the bath water. Perhaps economic progress and environmental enhancement can go together (Serageldin;1994;94) but we still need to clean up in order to survive rather than postponing the clean up until we are surviving more comfortably. To initiate the clean up some economic signals from government and donors would be welcome. Donor agencies (Thompson's FAO planner?) appear to shy away from environmental protection, despite paying it lip-service.

5.7 Conclusion: Individual, Economic, Institutional, and Political 'Social' Adaptive Capacity to water shortage and The Integrated Holistic Model

The ability to innovate in the face of complex challenges such as the water shortage of Ta'iz is a reflection of social adaptive capacity (Turton,1999b;10from Ohlsson,1998 and 1999). Allan (1999a;3) finds the required innovation in water policy reform, needed to improve water use efficiency via institutional reform lacking in 'weak states'. The failure of Yemeni government institutions to cope with water shortage defines its 'weak state' status. However, this chapter has demonstrated that political self-interest at all scales, from shayx to central government ministries, and above, have also been a fundamental obstacle to water use efficiency. In contrast, there are also several indications of significant social adaptive capacity to water shortage in Yemen.

Firstly, there is the enormous adaptive capacity demonstrated by the change in behavioural patterns of individuals in response to water shortage in the city (Section 4.4). In this instance the extent of adaptation is the greatest, the scale is the smallest (individual households) and the incentives to adapt are the strongest (survivalist, need-driven adaptation). Secondly, the preparedness of individuals to sell water to tankers and industry with the formation of markets (section 4.5) and the development of private rural water supply schemes are forms of economic response to water shortage and reflect economic adaptive capacity. Thirdly, the establishment of water user associations and water related initiatives (such as irrigation co-operatives and community supply schemes) in some rural areas (section 5.4) represent a more communal response to water shortage or institutional adaptive capacity. Fourthly, the negotiations of community representatives with government over water transfers such as has occurred in Al Hayma and Habir, is a form of political adaptive capacity to an external shortage. The degree to which the community or just the representatives benefit from the outcome may reflect the democracy of the process, but in either case there was capacity to adapt (section 5.4). These four examples form a sequence of increasing institutional scale and, necessary to that increase, an increase in political profile and, perhaps not incidentally, volume of water involved.

The term 'social' adaptive capacity is intended to cover a range of contributing factors including economic (Turton,1999c;13), socio-political (Allan,1999b) and institutional (Allan,1999a;3). Discussion is typically in the context of central government initiatives whereas the Ta'iz examples of adaptation to water shortage mentioned above are all facilitated by individuals apart from central government. (Even in the fourth example water transfer is facilitated by local shayxs not central government). The solution to this contradiction lies in Turton's assertion that social adaptive capacity is a function of government legitimacy (1999c;13). In Ta'iz, and probably many other strong society – weak states, the local indigenous, informal mode of government is simply more legitimate than more centralised forms. In conclusion, there can be some measure of social adaptive capacity in a weak state providing the process of allocative reform starts as a bottom-up process at the local 'informal' level of real politik and uses those equally indigenous institutional and legal frameworks in which it has traditionally operated. Central government will have to be politically more transparent if it is to earn the trust to enable it to play a more significant role in water transfers as negotiator or even buyer, in the form of NWSA, in the future. In order to facilitate institutional change it has been suggested that central government should not become a bargainer at all (Steenbergen,1996;204).

In the context of Yemen, the holistic model of layered causation in the allocation of water proposed in the introduction:

Political =>	Legal =>	Institutional =>	Economic =>	<= Social =>	<= Physical

fails at a number of points. In the strong society – weak state of Yemen, it is discovered that state-originated legal frameworks and institutions become irrelevant at the local level. The very level at which water reallocation is most needed. Instead, local and/or traditional legal and institutional arrangements are the main vehicles of allocation. Indeed the political interests which underlie or work through those arrangements are themselves a reflection of specific local individuals rather than any Northern party-political model. Perhaps so pervasive and obvious they can be overlooked are the belief systems which drive the political interests and determine the political possibilities. The local political reality is embodied in the shayx, who is also the dominant institutional reality. This duality of function can be traced to an extent up to national level ("the state is part of the tribes", The President, in Dresch,1989;7). Alongside this traditional structure is a fledgling bureaucracy under a civil code created by the parliamentary process. This is the more typical Northern model described in the introduction and shown above. It is suggested that in Yemen there lies a spectrum between these two models (Figure 5.8). Opportunity for principal agent abuses are greatest in the 'law-less' middle. Yemen may also be considered as in a transition from the Southern to the Northern model. It must be hoped that in attempting to transfer, Yemen does not get caught in the middle. Finally, the lack of action on protecting the water environment suggests this aspect only exists in rhetoric.

The two co-existing Yemeni models are depicted another way in Figure 5.9. The political decision maker has various inputs (four are shown, with belief systems coming from the 'heart'). There are two main means of providing economic signals (or determining the economically possible) to direct. The questions of which mechanism will prevail locally in the future, and which economic signals the political decision maker will give, remain. At the moment indigenous mechanisms prevail and agricultural water use is economically favoured.

Figure 5.10 is an attempt at an alternative conceptual model for sustainable development. It proposes that the environmentalists are essentially correct in assuming that economic progress, if available to all, would result in environmental degradation. Each situation has a different starting point with respect to the Malthusian limit. If there is no social adaptive capacity to change the environmental consequences (water scarcity for instance) of development, then the trajectory continues into further degradation. Social adaptive capacity (Ohlsson,1999 and Turton,1999c) via whatever form of regulation, such as economic signals, and via whatever means of enforcing it, participation pessimist top-down, or participation optimist bottom-up variety, is vital if there is to be any hope of environmental reconstruction.

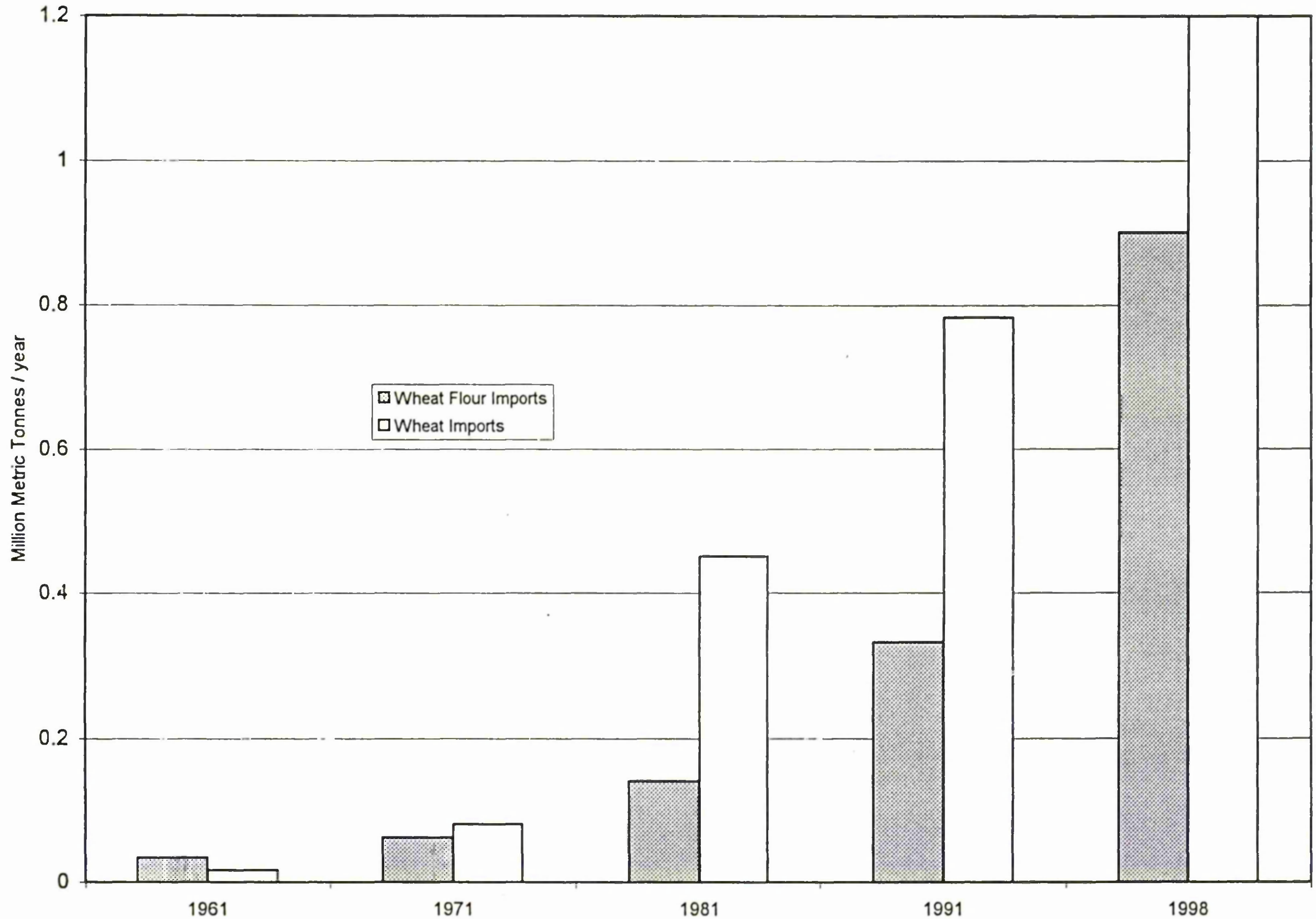
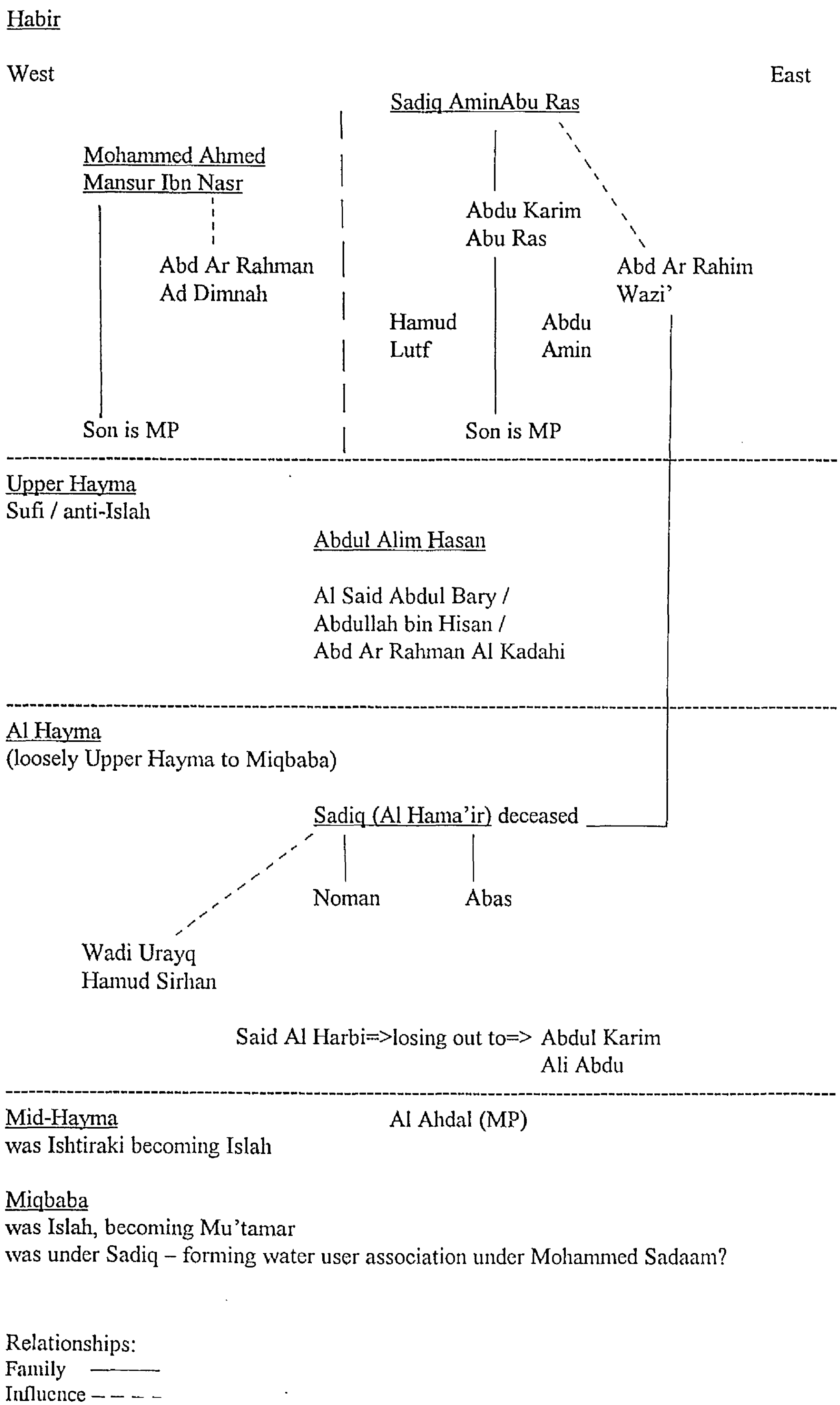


Figure 5.1 : Virtual Water Imported to Yemen. (FAO. Agrostat).

Figure 5.2 Political Structure of Habir – Al Hayma



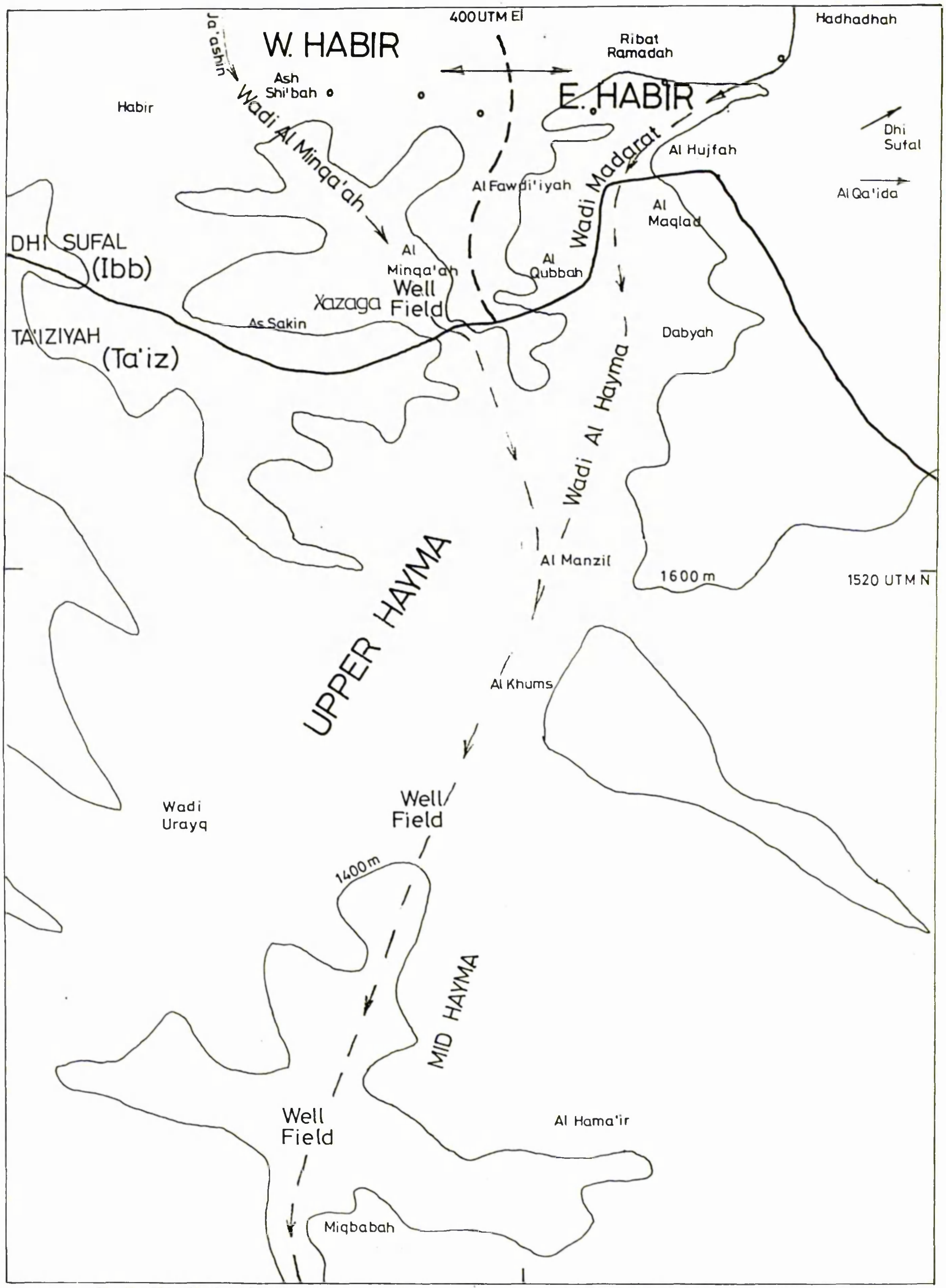
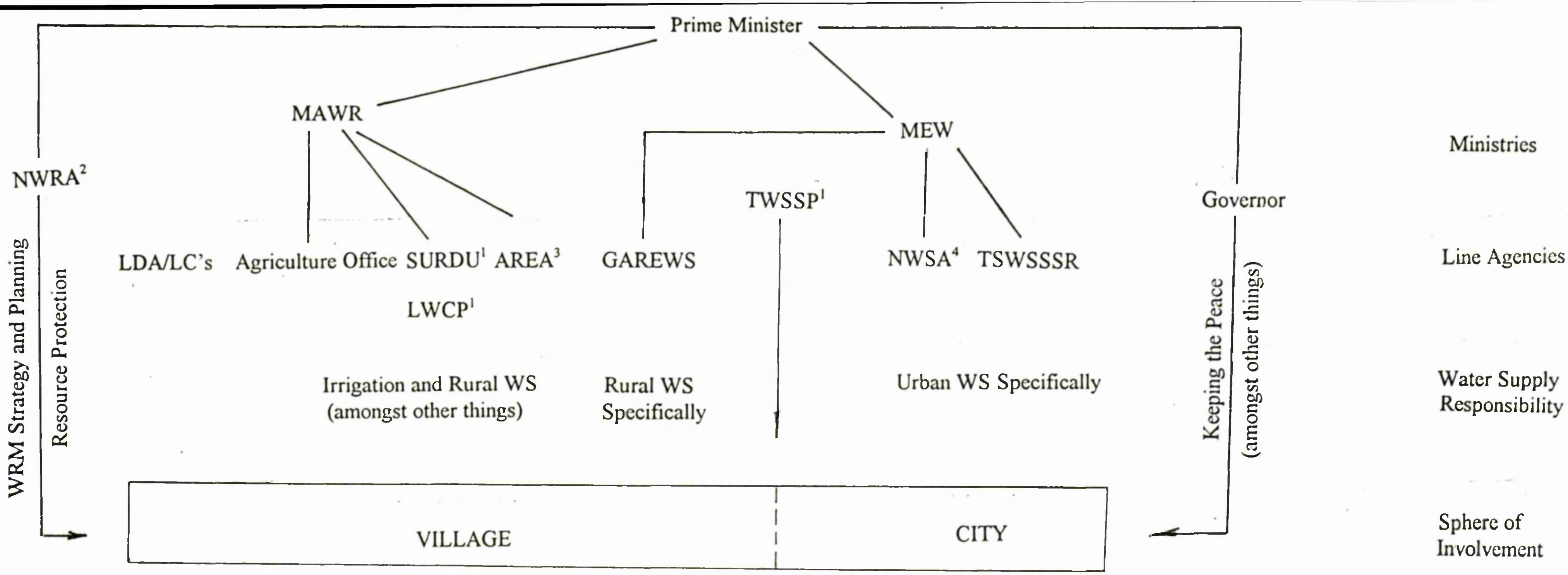


FIG.5.3 DHI SUFAL-HABIR - AL HAYMA HYDROPOLITICS

PRE 1975 SURFACE FLOW
PRESENT SPATE FLOWS
ADMINISTRATIVE BOUNDARY
∘ NEW HABIR WELLS FOR TA'IZ SUPPLY
0 1 2Km



Donors input via MPD and comprise:

1 World Bank
2 UNDP (and Dutch aid)
3 GTZ - IDAS
4 GTZ - TSWSSSR

Figure 5.4 : Government Institutions and Donor Projects involved in the water sector in Ta'iz

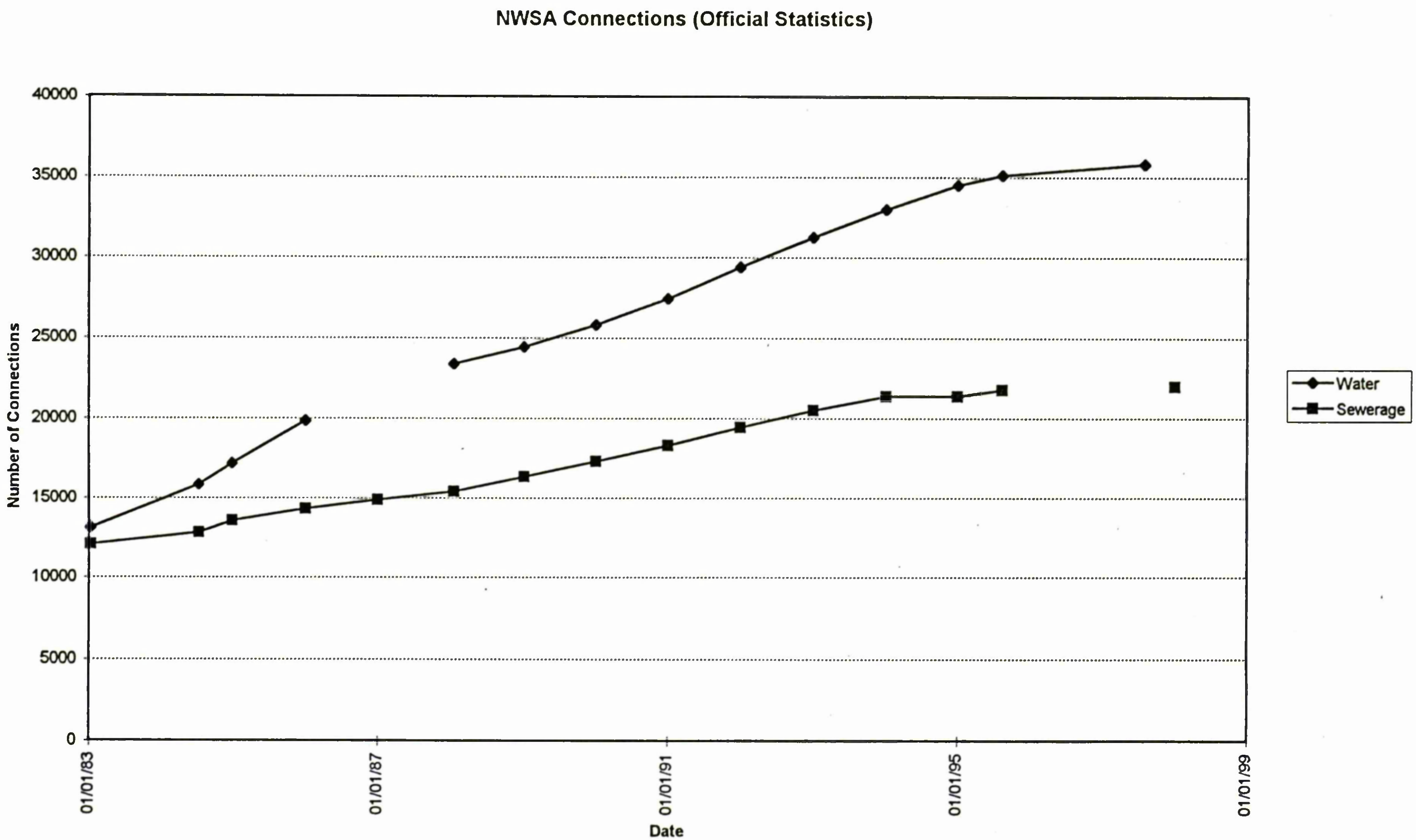


Figure 5.5: NWSA Water and Sewerage Connections

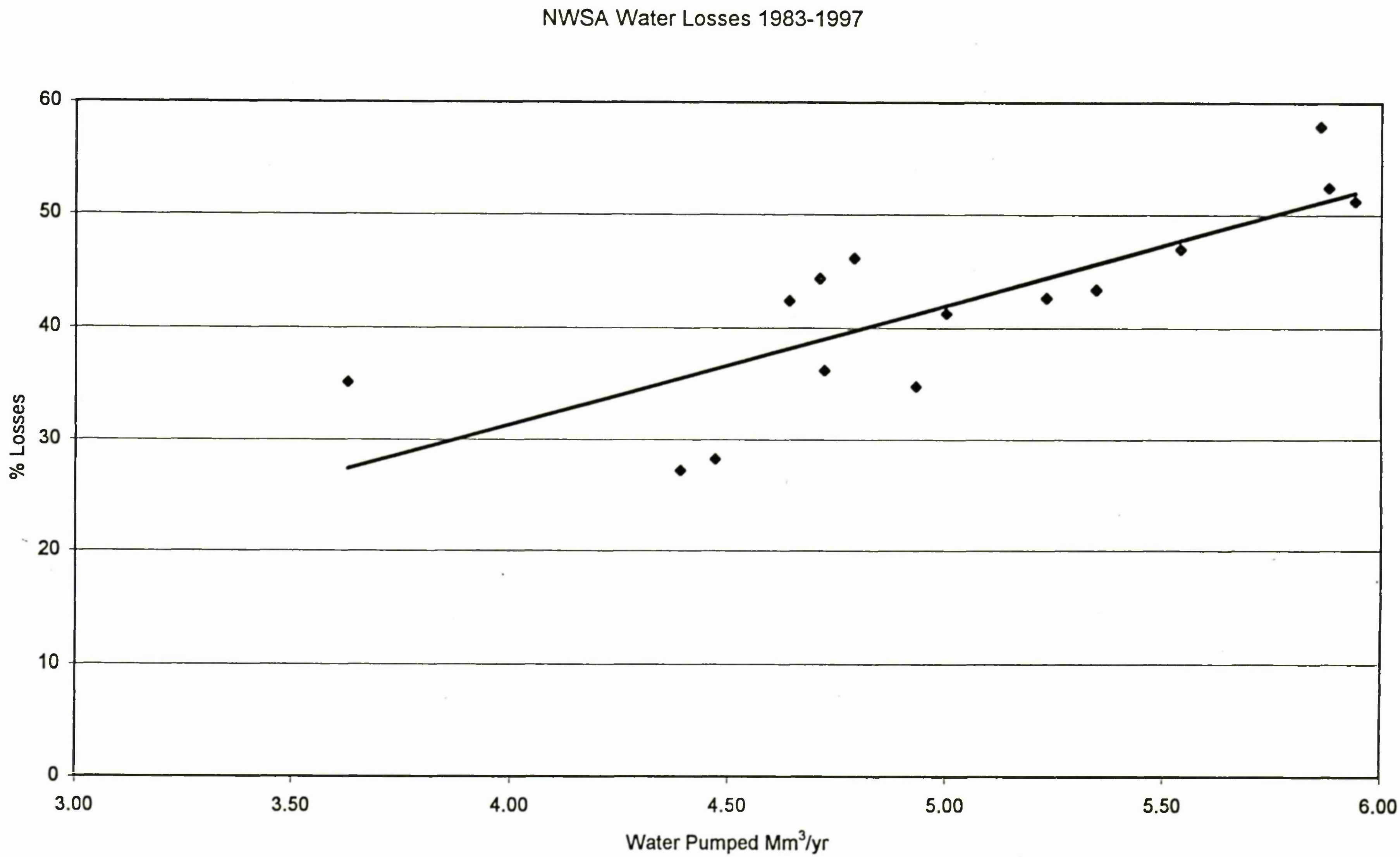


Figure 5.6: Increase in proportion of water losses with increased supply

Figure 5.7 The Unequilateral Triangle of Sustainable Development

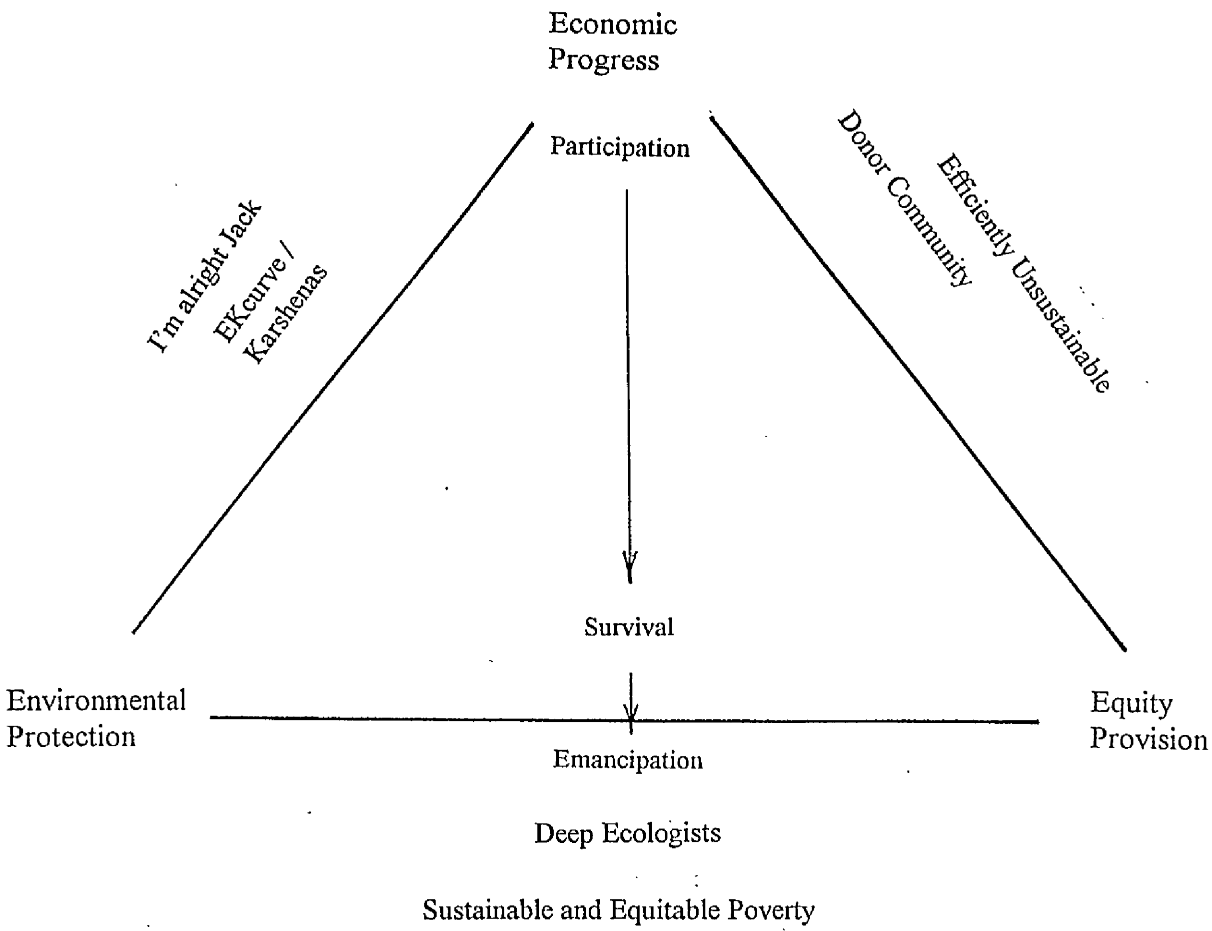


Figure 5.8 Urban-Rural / National-Local Spectrum of Allocative Causation

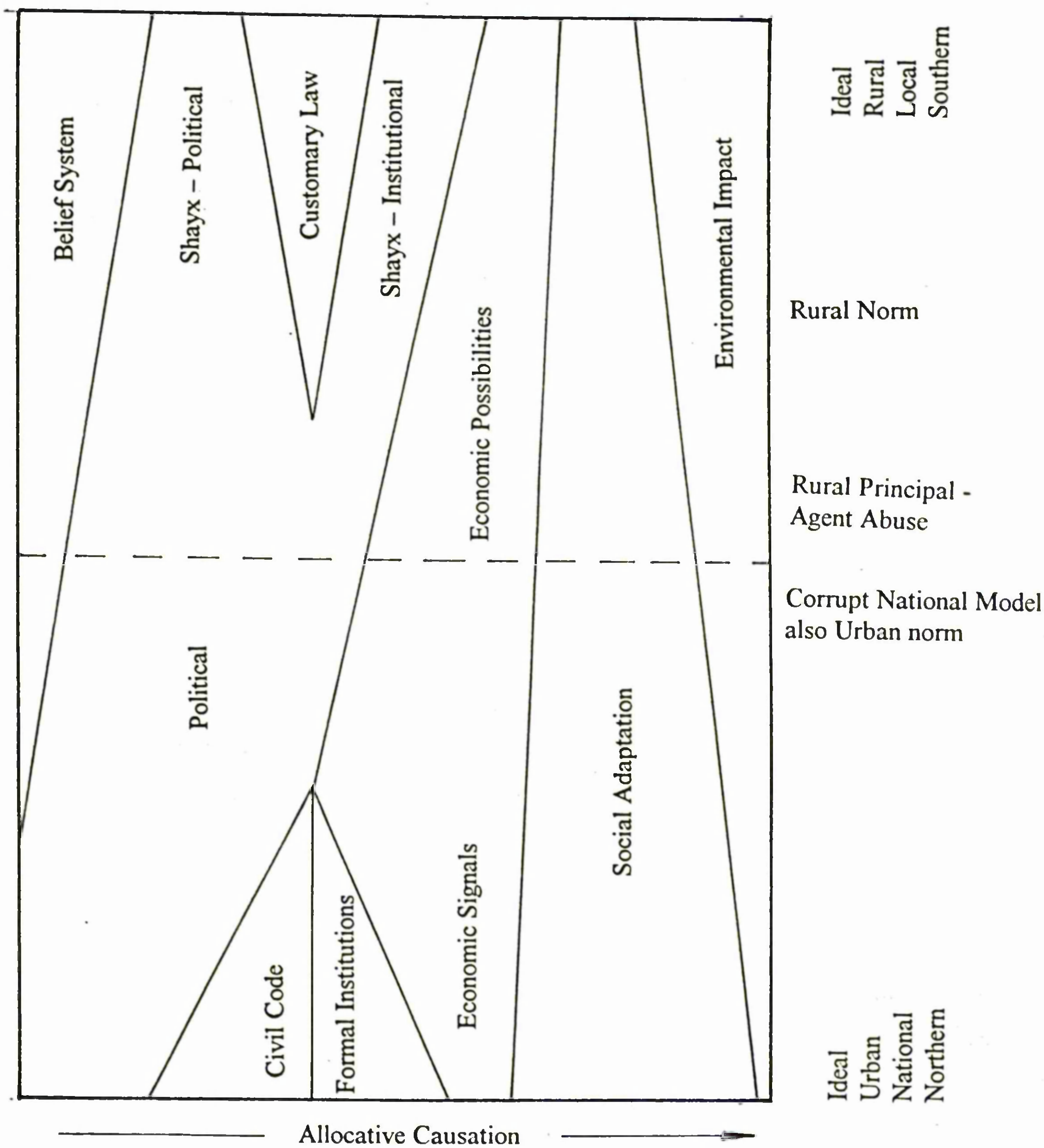


Figure 5.9 The Allocative Process

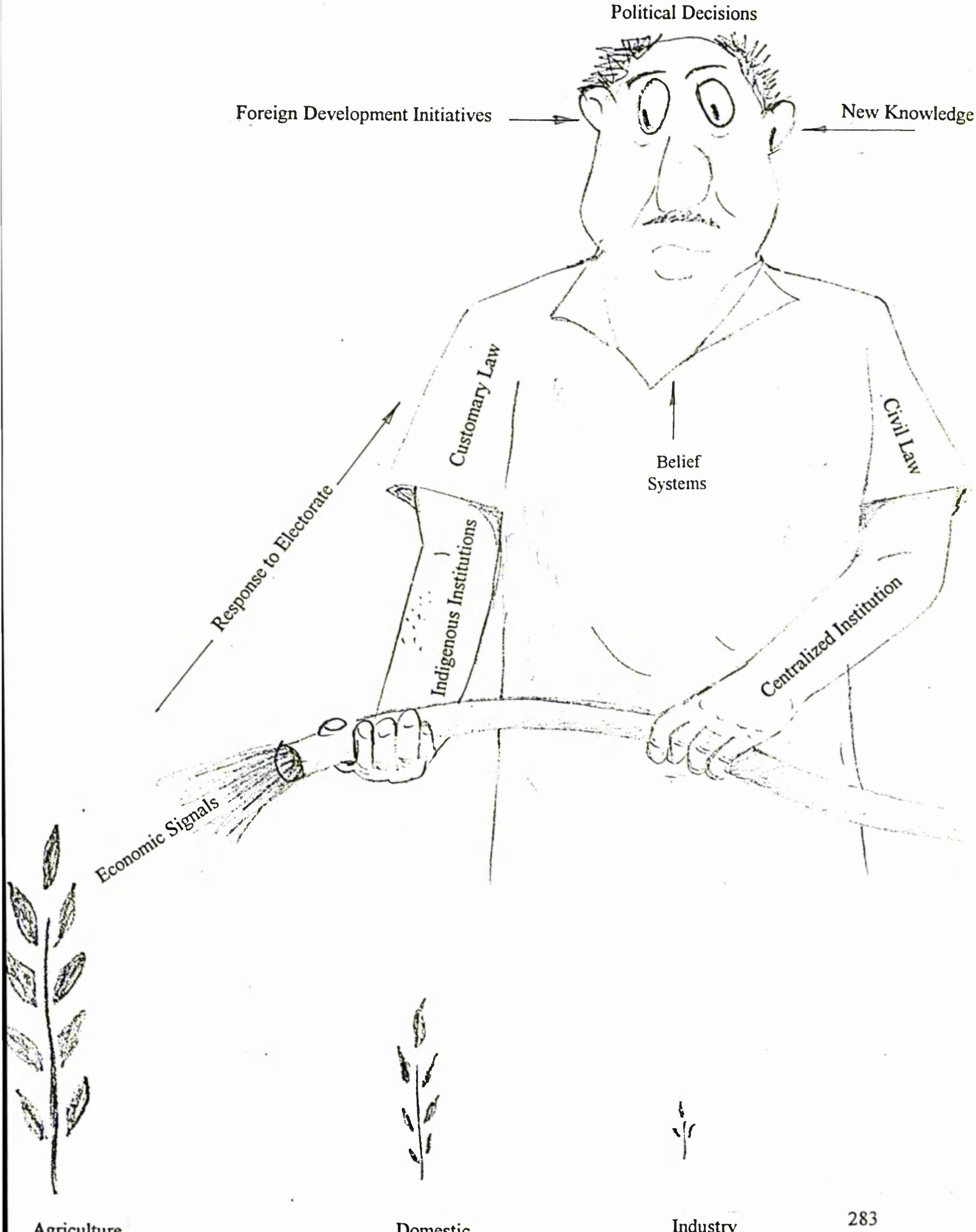
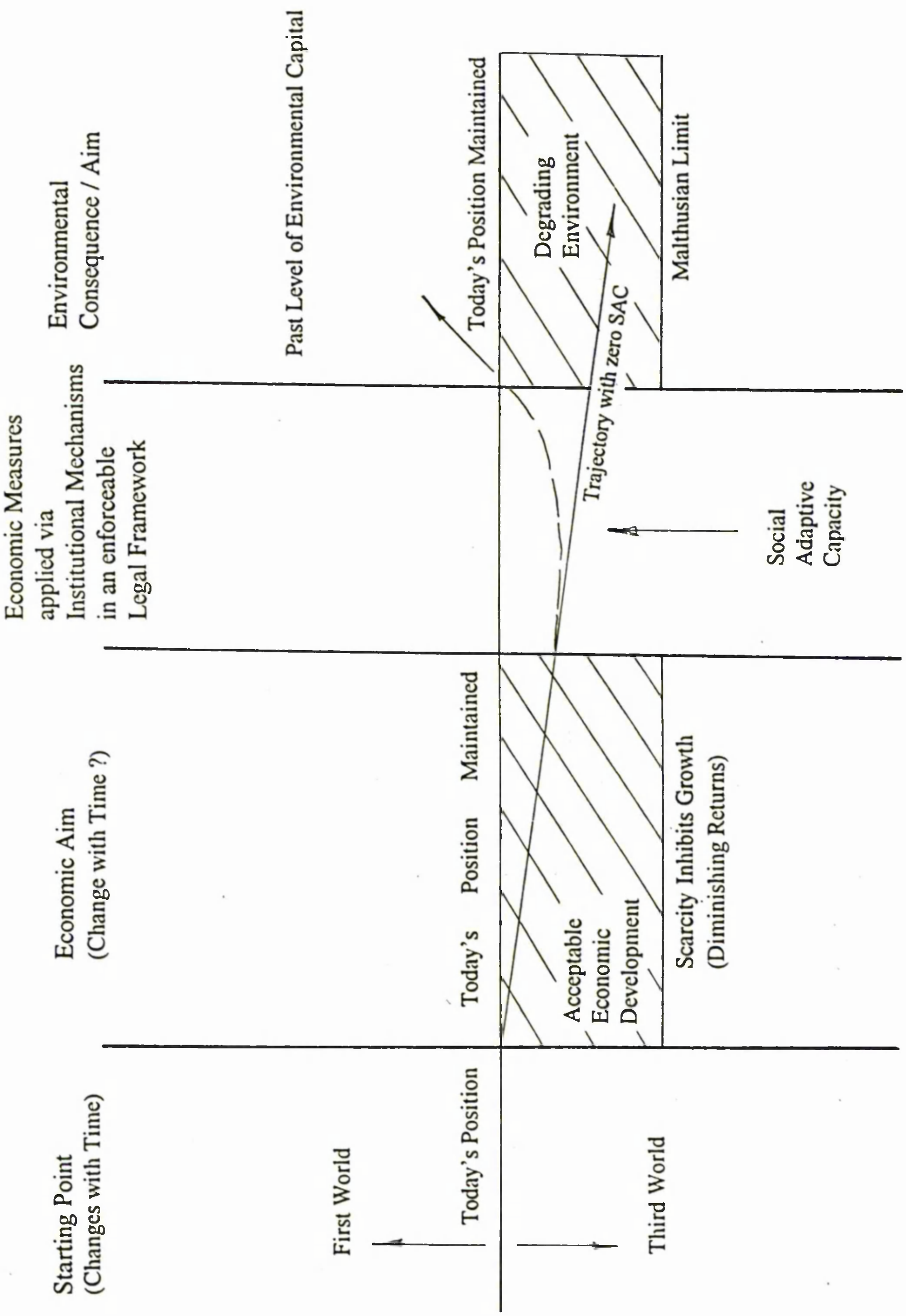


Figure 5.10 A sustainable development model



Chapter 6 Conclusions

A summary of the problems causing the water shortage in Ta'iz points clearly to the need for an integrated holistic approach to water resources management. By the end of the 1990's, it had become clear that 'integration' was not an easy process; contention is the norm in user relations over water (Allan et al 1999). Integrated water resource management has proved to be an extremely alien concept, though vital to the understanding of the Ta'iz story of combined resource and management failure. The history of the shortage so far necessarily ends with the completion of fieldwork in the Upper Rasyan Catchment in 1998. In concluding, some consideration is given to the significance of the shortage and the lessons derived from it beyond these temporal and spatial points.

6.1 Key Issues

Water Reallocation: the need for economic diversity

Perhaps the most important point arising from this study is the small amount of water that could be made available for reallocation. A mere $30Mm^3/yr$ is the best estimate of renewable groundwater from the Upper Rasyan Catchment to meet the drinking, domestic and livelihood needs of around 3/4M people. The food needs are mainly being met by a reallocation of water from overseas in the form of grain imports. Their virtual water content accounts for over three times the amount of water found in Ta'iz's renewable groundwater. Economic diversity towards allocatively more efficient uses of water provides the capacity to afford grain imports. In the debate over whether to produce cash crops or industrial output with the little water available (Otchet,1999) the deciding factor in an economist inspired world is the relative returns to water. In Ta'iz, industrial use of water brings 2300 times more income and over 300 times more jobs per m^3 of water than does irrigation. The cessation of irrigation in the area is not advocated. It would not solve the problem. A reallocation of a small part of irrigation's 75% share of the renewable resource to industry would help, however. A 10% reduction in irrigation water use could produce a 250% increase in industrial use if reallocation were feasible (section 4.2.2).

Strong Society – Weak State Implications: the need for political credibility and institutional appropriateness

The reallocation of water has been feasible on a small scale through water markets, but transfers from rural areas to meet the growing urban demand by government has met with armed conflict and produced significant environmental impact. The armed conflict was fostered by mistrust of government on the part of the source area communities, which in turn was brought about by abuses of their agent-principal relationship. Although such abuses also sometimes characterise local traditional indigenous power structures, these structures operate on the basis of customary law via traditional non-formal institutions that are, respectively, more enforceable, and considered more appropriate and efficient in the local context. Political leadership at the local level is individualistic and family-based rather than tribal, and the adoption of national party-politics by those individuals is on a purely pragmatic basis. Local political leadership wins greater credibility than government because of the latter's poor track record and 'distance' from the issues. Yemeni North - South relations also play a part in this distancing. The government also fails in the role it could fulfil – in providing the right macro-economic signals to promote reallocation to higher value uses of water. Traditions of community co-operation in rural areas have, in a few instances, paved the way for the establishment of co-operatives involved in water related activities and, with some donor input, water user associations. The tendency towards local rather than government based power structures reflects and demonstrates that the region is characterised by a strong society and a weak state. In fact, Brumfiel's definition of a state 'in which governmental institutions monopolise the use of legal force' (1980) suggests Yemen is not a state. To be effective, water reallocation initiatives have to operate within this non-state context.

Population Growth: still on the agenda

If unaccounted-for-water was reduced to 20%, and all the renewable groundwater in a 30km radius were brought to Ta'iz, only 30 l/c/d water could be provided in 2013 if all irrigated agriculture were to cease. The impossibility of such a plan both physically and socio-politically underlines the fact that the most onerous factor affecting the area's water needs is the city's 8%p.a. population growth rate. Any supply side development of those meagre renewable water resources is only buying time (Turton, 1999d;1). The only other supply alternatives are desalination at over $2.5/m^3 and/or domestic water recycling, which is unacceptable on religious grounds.

The Sustainable Development Balance:

Economic Progress, Environmental Protection and Equity Provision

The people of Ta'iz receive less water than the WHO guideline (28 l/c/d), and the water they do receive is of poorer quality than the WHO recommended minimum (that is, it is in excess of 1500 μS/cm). Such circumstances demand development initiatives. Economic progress, in the form of infrastructure renewal and utility reform, are necessary ingredients. The pollution of over half the catchment's groundwater and surface water, and declining water levels in key aquifers, demand environmental protection initiatives. The poorer 60% of the population spend more on water than the World Bank recommended maximum. The result is an average of half an hour per day queuing for free water in the city and carrying it 1.7 km in rural areas. This price is mostly paid by children and women respectively. Equity provision is therefore on the agenda. The need for a balance of all three; equity provision, economic progress and environmental protection is apparent.

Summary: the shortage of social adaptive capacity

Water shortage in Ta'iz has forced many individuals to change their water use practices. The modifications of demographic and religious practices demanded by the shortage are a severe challenge to an individual's belief systems, and hence, social adaptive capacity. On a larger scale, the underlying belief system of political self-interest, which constrains reallocative initiatives and silences the role of virtual water, is also unlikely to adapt to the shortage.

6.2 Beyond Ta'iz

Ta'iz Tomorrow

The observations of the Ta'iz water crisis were snapshots in an evolving situation. Whilst belief systems may change very slowly, population levels, the amount of imported grain to feed it, and technology development and the extent of environmental degradation it causes have changed rather quickly. Optimists hope there is a demographic transition. There is no sign of a decline in the birth rate to date. The growth in tubewell/diesel driven pump technology was fuelled financially by remittances from Saudi and the Gulf and literally by the discovery of some local oil. The environmental consequences suggest black gold brings a mixed blessing. The problem of trying to return to the environmental condition before significant groundwater development occurred is that the damage has already been done. At current trends, population growth is likely to prevent the EKcurve being turned. Beyond the ten year horizon, the sectoral reallocation issue becomes irrelevant because it cannot find enough water. The only solutions after that lie in virtual water for staples provision, industrial development (with regulated waste disposal) for livelihood provision, and, in the absence of waste water treatment, desalination for industrial and domestic needs. The latter measure would require a regional economic strength that can give one million people in the city the capacity to afford water at over $\$2.5/m^3$. That cost could be halved if industry moved to the coast since this would avoid the 1400m water lift and 100km pipeline needed. However, even then it is doubtful that the water would be affordable to most Yemenis.

Ta'iz's struggle to achieve a balance in the water allocation nexus of economic growth, environmental protection and equity provision can also be viewed from the vantage point of Northern development models of society and the state.

In the North, failure to protect the environment began to be noticed after a century of industrial modernity had damaged it (Giddens,1990, Allan,1999b;2). Since then the environment issue has ascended to the point where, today, Northern industry, in the light of perceived 'risks' to the environment, has started to take a more precautionary approach to the use of natural resources (ibid.). This shift in perception and policy has been termed 'reflexive modernity' (Beck,1992). The social theory of Beck and Giddens is relevant to the North, where Northern awareness of 'risks' has resulted from assimilation from the media by communities and their politicians of the 'new knowledge'.

Where does Ta'iz lie within this scheme? Allan (1999b;3) gives four reasons why the South will find it difficult adapting to the message of the 'new water knowledge' that takes its inspiration from principles of economic efficiency and environmental sustainability, of which water reallocation and birth control are a part:

a) Deeply held beliefs and expectations about water that contradict the message
b) Lack of susceptibility to the notions of environmental risk
c) Lack of political, social, economic and technical capacities to respond to the message
d) Awareness by the government policy makers of the economic and technical impediments and, more importantly, political prices to be paid in applying the message.

Although all four points are true of Yemen, they assume central government initiatives in water policy reform will have an impact. The limited institutional capabilities of central government, and the limit of its rule at the San'a ringroad, indicate that the processes of state building involving the development of a bureaucracy and the disarmament of the people (Weber,1978) have not yet taken place. Yemen lies at least as far from applying the 'new knowledge' than any other polity in the South. Besides the incongruity of encompassing Southern state development within Northern models, is the fact that those models are themselves part of an evolving literature that forever moves the goalposts where today's solution for yesterday's problem is the cause of tomorrow's problem.

Ta'iz Elsewhere

How relevant is the example of Ta'iz to other situations, or, put another way, how typical is Ta'iz? If only six main features could be chosen to describe Ta'iz they would be:

a) The Problem - The non-availability of water is extreme (around 25 l/c/d)
b) The Main Cause - The population growth rate is particularly high (around 8%p.a.)
c) An Evaporating Hope - The annual rainfall though slightly greater than London's (around 600mm/yr) is still inadequate.
d) The Current Food Solution - The population is highly dependent on virtual water (equivalent to around 75% of all the water used in all sectors) and is unaware of the real water deficit
e) A Short-term Solution - reallocation - The proportions of industrial and domestic sector water use are small at only 2% and 4% of total water use, respectively.
f) A Potential Long-term Solution - desalination – is likely to prove too costly because of the lift needed (1400m).

It is hoped that the extremity of the Ta'iz predicament makes Ta'iz sufficiently different from other cities that its experience remains a slim risk rather than a real threat. The lessons are still worth learning.

Water stress in Ta'iz has suppressed the demand for water, nullifying the potential contribution of demand management methods. The population distribution within Yemen (or for that matter, the Arabian peninsula) approximately matches the rainfall distribution. Yemen, and particularly the regions of Ibb and Ta'iz receive the most rain and are the most populous. Theoretically, there is no major maldistribution of people relative to water, and although there is plenty of rainfall, it occurs over too small an area and evaporates too fast, resulting in little runoff. Within the context of such natural shortage relative to the population, human activity has greatly aggravated the problem. For the time being, virtual water provides the silent solution to the food requirement whilst Yemen and cheap grain still have access to the world market. Although this could free up water for reallocation to higher value uses, currently only intrasectoral transfer to qat is evident in any significant quantity. Without a demographic transition, even the reallocation issue is only a short-term solution, and is exacerbated by the problem of unchecked pollution. If pursued, the push-pull of livelihood provision by developing industry at the coast could be good news for Ta'iz water supply (and bad news for the voiceless corals).

6.3 H_2Olism: Our Man in Habir

This study sought to demonstrate that water allocation 'has too many component parts to be understandable if one limits oneself to one of the many established academic domains' (Hajer,1995;2). In the light of the lessons from the water situation in Ta'iz, it is suggested that a 'poverty of disciplinary narrowness' (Atkinson,1991;21) would prevent an analysis adequate to address the problems and solutions of water allocation. Although successive physical, economic, institutional, legal, political and belief system layers contribute increasing complexity to an understanding of the water problems, they do provide a fuller one. A succession of experts would undoubtedly provide an academically sounder set of reports. It is suggested, however, that the gaps between the disciplines bring incoherence to the message.

So it seemed as we returned from our field visit to the farmer in Habir on World Water Day. The encounter had a specific spatial and temporal context. The farmer irrigated his crop within a few hundred yards of the most productive exploration borehole in the area that could supply Ta'iz. Permission to drill had taken almost a decade of negotiations, compensation, and bloodshed because the government had previously 'stolen' the water from the adjacent aquifer, and farmers, immediately downstream. Government misuse of information and corruption, and opportunism by the locally powerful were all involved. The borehole is still not connected to the Ta'iz pipeline. The farmer, unlike any of the visiting experts, was well aware of all of this. Although his water came from an entirely different source than that of the drilled well, the arrival of a group of 'developers', some of who were foreigners, in an expensive vehicle largely determined the farmer's tactics.

On our return from the field we sat down to eat (some virtual water) and drink (some of the locally privately purified water) with the Governor. Before the meal we washed our hands in water brought by private tanker from a (polluted) wadi and stored in locally made tanks. The complete absence of a single drop of 'government' water on the premises reflected the water shortage described in this study. The fact that neither we, nor the rest of the 400,000 inhabitants either starved or died of thirst that day reflects the adaptive capacity of a society left to its own devices. (Some might have had water borne tummy bugs). It is difficult to understand these watery realities without an H_2Olistic approach.

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Photographs

Photo 1: Domestic Use of Untreated Sewage Effluent. Washing clothes in Wadi Malih at the confluence with Wadi Hidran in full knowledge that the source is the untreated Ta'iz domestic sewage outfall.

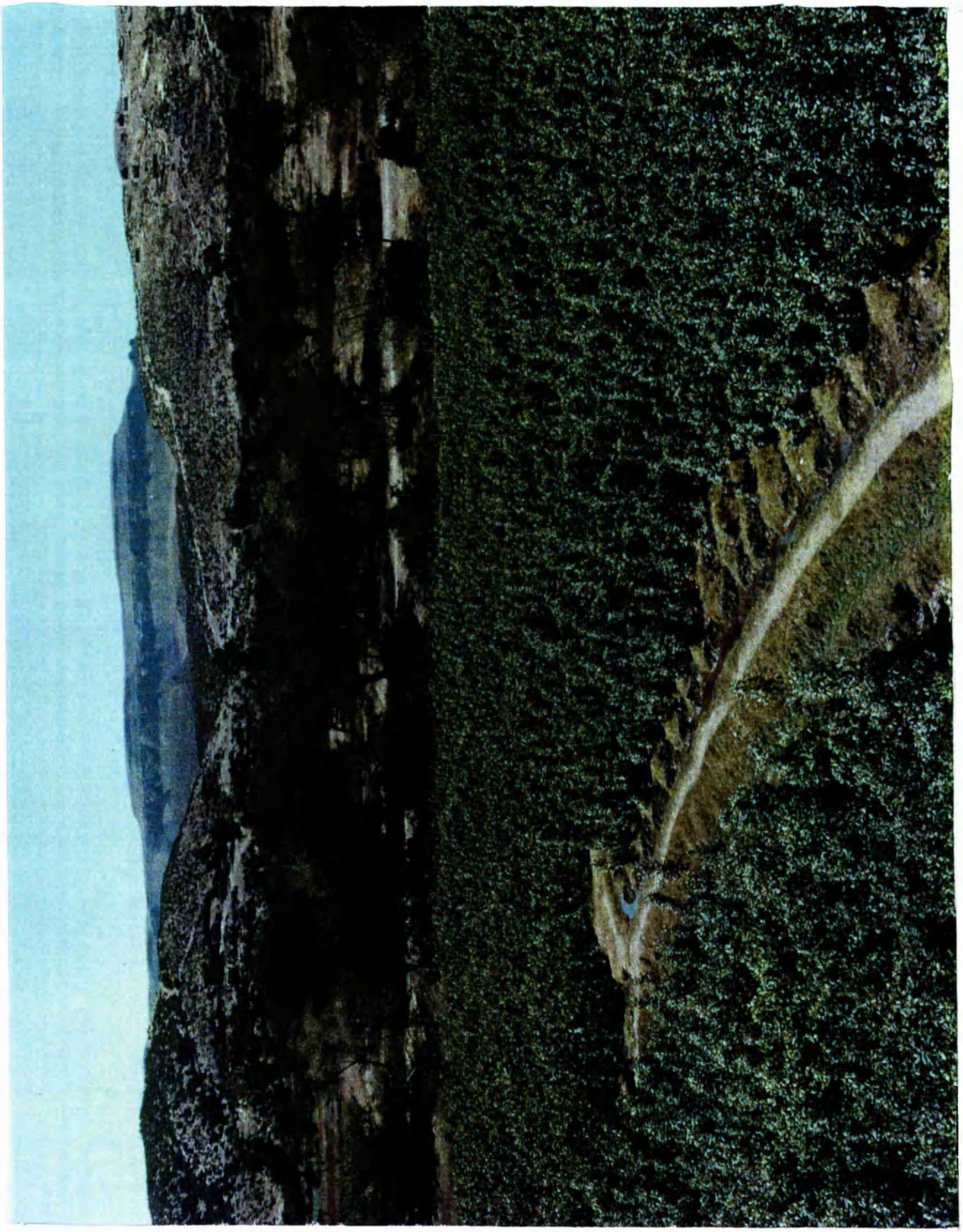

Photo 2 Inequitable Water Allocation. Shayx Sadiq's qat irrigated via open channel from one of the wells obtained from the agreement to allow the government to drill others for the Ta'iz water supply. One environmental impact was the dessication of the rest of the valley as the fields beyond the qat testify.

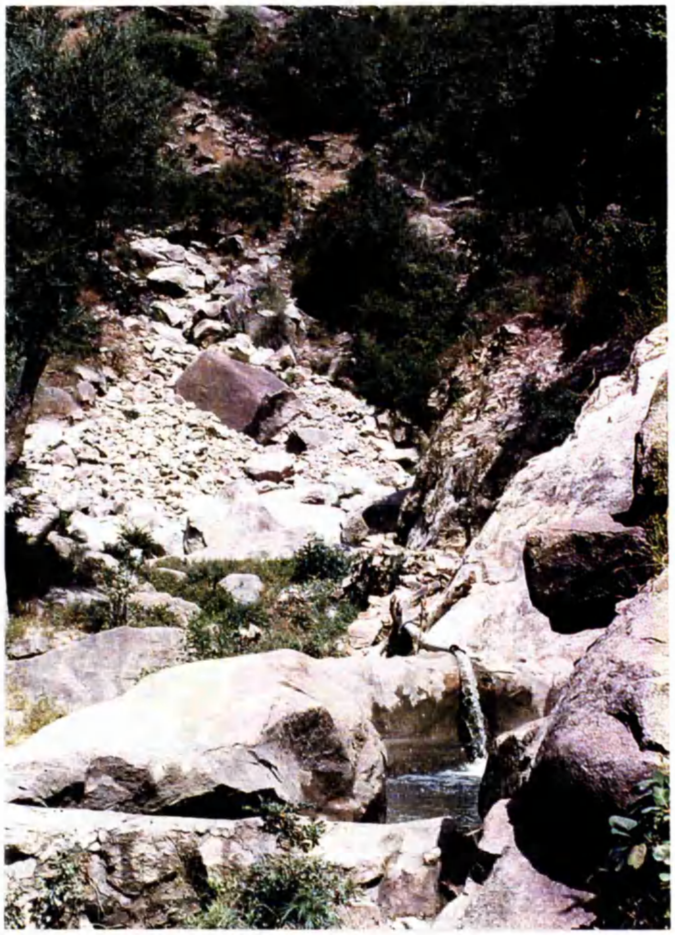

Photo 3: Water Diversion Structure Tapping Sub-Surface Wadi Flow. Wadi Nibaq irrigation source.

Photo 4: Wadi Terrace Erosion. Wadi Nibaq. Wadi flow has eroded the terraces revealing the intervening walls between three terrace levels.

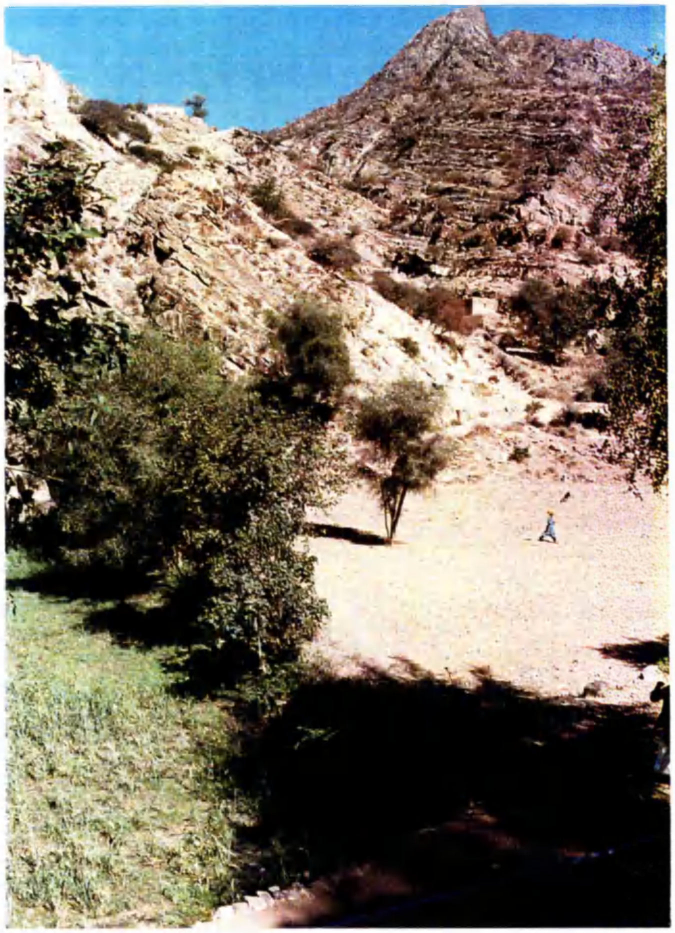

Photo 5 Artesian Flow from Fault-Bounded Tawilah Sandstone. Shar'ab. The hill to the right is composed of volcanics, whilst that to the left Tawilah Sandstone. The field to the left is 15cm deep in water which emanates from the contact. The pipe (lower right) supplies 4000 houses from a well drilled in the Tawilah Sandstone outcrop.

Photo 6 Environmental Degradation: Factory waste-water lagoon and Ta'iz dump.

Appendices

Appendix A

English and Arabic versions of Urban Survey Questionnaire

UNDDSMS Project YEM/010 - Household Survey - Taiz - Questionnaire

1a-c Questionnaire Number		Area Number		Date	
1d-f Location Number		Area Name		Interviewer	
1g-i House Number		Check Survey Mngr		Check Interviwer	

2a No. of Floors Occupied by Family Interviewed		**2d House Type**	
2b Relationship of Respondent to Head of Household		Apartment	
2c Number of People in Household		Detatched	
		Detatched + Garden	
		Temporary Structure	

Water source	A Dabba	B Bottled	C Free Mosque/Tap	D Tanker	E NWSA Project	F Private Piped	G Other (Specify)
3a Which water do you use?							
(Circle)	5/10/20 lit	1/2 lit	3/5/10/20 li	L/S			
3b How many units are used?	dabba/day	bottle/day	dabba/day	tanker/mo			m3/mo
3c How many units were used in the crisis?	dabba/day	bottle/day	dabba/day	tanker/mo			
3d If this is different from now, what has changed? (**Enter**: Reliability, Quality, Price, Ease of Access, Other (State))							
3e How much do you pay ?	YR/dabba	YR/bottle		YR/tanker	YR/mo	YR/mo	YR/m3
3f How much did you pay during the crisis? (YR/unit)	YR/dabba	YR/bottle		YR/tanker	YR/mo	YR/mo	
3g What price do you pay in winter? (YR/unit)	YR/dabba	YR/bottle		YR/tanker	YR/mo	YR/mo	YR/mo
3h What price do you pay in summer? (YR/unit)	YR/dabba	YR/bottle		YR/tanker	YR/mo	YR/mo	YR/mo

4a How much water does your household use in a day?	lit/day
4b Do you give or sell water to anyone? (Y/N)	
4c If so, how much per day? (lit)	lit/day
4d How much do they pay per month? (YR)	YR/mo

	A	B	C	D	E	F	G
4e How often do you get water from each source? (1=every day, 7=every week, 30=every month etc.)							

Water source	Dabba	Bottled	Free Mosque/Tap	Tanker	NWSA Project	Private Piped	Other (Specify)
5a Which source do you prefer ? (**Rank**)							
5b Why ?							

(**Enter**: Reliability, Quality, Price, Ease of Access, Other (State))

5c Which is the most reliable for you? (**Rank**)							

6a Which source do you use for:	Dabba	Bottled	Free Mosque/Tap	Tanker	NWSA Project	Private Piped	Other (Specify)	Rank Importance	Rank Quantity
Drinking									
Cooking									
Bathing									
Washing Clothes									
Cleaning									
Toilet									
Livestock (note if use waste water)									
Garden									
Other (Specify)									

6b For which Task do you boil water? Which Source is it from? (Match Task and Source in table above and write * in cell)

6c Which is the most important water use? (**Rank** in order of importance in column marked importance)

6d Which activity uses the most water ? (**Rank** in order of consumption in column marked quantity)

6e Is the quality adequate for the use? (Y/N)							
7a How long does it take to bring the water (minutes) ?							

7b Do you own a vehicle ?	Pickup	Car	Taxi	Truck	4WD
7c Do you bring water in it? (Y/N)					

How many animals need watering?	Sheep	Goats	Cows	Chicken
7d Now				
7e During NWSA crisis				

Water Storage	Tank	Undergrou	Containers	Other	Don't Store
8a How much water can you store in: ?	m3	m3	lit		
8b How many days will it last?					
8c Do you collect rainfall ? (Y/N)					

	Toilet Flush	Toilet Non-Flush	Sink	Washing Machine	Water Heater	Shower	Bath
Do you have any of the following? (Y/N)							
9a (For toilets and sinks ask how many)							
9b Do you share any with other people? (Y/N)							

9c How many rooms are there to clean, excluding bathroom but including kitchen? [ ]

	Dont Know	Cess Pit	Sewers	Drains	Other (State)
9d What system do you use for waste water disposal?					
9e If cess pit, how often is it emptied?					

	Rent	Electricity	Water	Clothes	Education	Qat	Food	Transport	Health
10 Which of these do you spend most on in a month? **(Rank)**									

	None	Health	Convenien	Cleanlines	Other (State)
11 What problems does your family experience now because of the water shortage in Taiz? **(Dont give answers)**					
12 What would be the impact on your family if you had to reduce consumption now? **(Dont give answers)**					
13 If you could get more water what would the benefits be? **(Dont give answers)**					

14a Do you and your family have any health problems at present? (Y/N) [ ]

	Dont Know	Water	Other (state)
14b What is the cause? **(Dont give answers)**			

15 Does the water situation affect the health of your family? (Y/N) [ ] If yes, positively or negatively? (+/-) [ ]

Piped Connections	NWSA	Private
16a How many days ago did you receive water?		
16b How often does water come now? (days)		
16c How many people use the water from this connection?		
16d How much did it cost to connect?		
16e Do you have a meter?		
16f How often are you billed? (1=monthly, 3=3 monthly)		

	No Mains	Expensive	Landlord won't pay	Bad quality	Unreliable	Infrequent	Other (Specify)
17a For those not connected to NWSA: If not connected to NWSA, Why not?							
17b Would you connect if you had opportunity? (Y/N)							
17c If not, why not? (Dont give answer)							

17d Do you own or rent the house? [ ]

17e How much do you think it costs to connect to NWSA? [ ] (DK=Dont Know)

	NWSA	Private
18a If you could choose between connecting to NWSA and a private piped supply, which would you choose?		

18b Why? (Enter: Reliability, Quality, Price (Cheap), Ease of Access, Other (State)) (Dont give answer) [ ]

18c Do you think a private scheme would cost more or less per month than NWSA? (more/less) [ ]

18d Would you choose a private scheme if you knew it would cost 50% more, twice as much as NWSA?(Y/N) 50% more [ ] 2x [ ]

18e If you were connected to a scheme that supplied water every day, would you expect to pay the same as now, 50% more twice as much for a unit of water?

Same [ ] 50% more [ ] 2 x [ ]

18f Would you want to be connected to a water supply if it could be used for anything except drinking and cooking? (Y/N) [ ]

We would like to produce information about saving water, health and cleanliness.

The following questions help us to know whether to use radio, TV or newspapers and how to make information relavent to families.

19a How many people live in this dwelling? [ ]

	TV	Radio
19b Do you have the following?		

	Best Time	Yemeni	Foreign	Which
19c Which TV station do you watch and when do you prefer to watch?				
19d Which Radio station do you listen to and when do you prefer to listen?				
19e Which Newspaper do you prefer?				

Since the Gulf War, how many of your house have travelled abroad for health, work, tourism or other reasons?

	No. of People	No of Trips	Countries	Purpose
20a				
20b Is any member of your house overseas now?				
20c Do you own land in the village (yes/no/refused)				
20d How many gonia do you bring from the village per yr?				
20e How many gonia do you use of flour and wheat per month?				

How many men, women or children are responsible for:	Water Collection	Washing Clothes	Cleaning House	Washing Up	Cooking	Bathing	Livestock	Garden
22a (Enter ...m, ...w, ...ch)								
22b Compared with now, was more time spent in the crisis								
22c Compared with now, was less time spent in the crisis								
22d Spent same amount of time in the crisis								
22e Compared with now, was more water used in the crisis								
22f Compared with now, was less water used in the crisis								
22g Used same amount of water in the crisis								
22h If there was less water available in the future, for which tasks would you reduce water use?								

22i Compared with the crisis, do you now use the same/more/less water?

22j If you use more water now, during the crisis did you: collect more/ Use less water than you do now, or both?

	Household Members (**Men Only Respondents**)	Total Number	Can Read	Finished Primary	Finished Middle	Finished Secondary	Finished College	Have Employment	What is it?	2ndary Employ
23a	How many men									
23b	How many women									
23c	How many children									

24 Household Members (**Women Only Respondents**) Continue overleaf if required	Male/ Female	Age	Read?	Finished Primary	Finished Middle	Finished Secondary	Finished College	Employ-ment	2ndary Employ

Consumer Survey - Taiz - Questionnaire

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1a	رقم الأستبيان	1d	رقم المنطقة	1g	التاريخ
1b	رقم القطاع	1e	اسم المنطقة	1h	العداد
	رقم البيت		مراجعة مدير البحث		مراجعة العداد

2a	عدد الطوابق المسكونة من نفس الأسرة	2d	نوعية السكن
2b	علاقة المجيب بصاحب السكن		شقة
2c	عدد السكان في البيت		بيت مستقل
			بيت مستقل +حديقة
			بناء مؤقت

	موارد المياة	دبة	قوارير	مجانا مسجد/سبيل	وايت	المشروع	مشروع خاص	(اخرى(حدد)
3a	أي المياة تستخدم ؟							
	ضع دائرة حول الوحدة	5/10/20	1/2	3/5/10/20	كبير/صغير			
3b	كم تستخدم ؟	دبة/اليوم	قاورة/اليوم	دبة/اليوم	بابور/شهر	ريال/شهر	ريال/شهر	
3c	كم أستخدمت في أزمة المياة ؟	دبة/اليوم	قاورة/اليوم	دبة/اليوم	بابور/شهر	ريال/شهر	ريال/شهر	
3d	أذا كان مختلفا الأن, ما هو الذي تغير؟ **(لا تعطي أجابات)** ((ادخل: معتمد, الجودة, السعر(رخيص),سهولة الحصول, تصاريح أخرى(حدد))							
3e	كم تدفع ؟	ريال/دبة	ريال/قارورة		ريال/بابور	ريال/شهر	ريال/شهر	
3f	كم دفعت خلال الأزمة ؟	ريال/دبة	ريال/قارورة		ريال/بابور	ريال/شهر	ريال/شهر	
3g	كم السعر الذى تدفع في الشتاء ؟	ريال/دبة	ريال/قارورة		ريال/بابور	ريال/شهر	ريال/شهر	
3h	كم السعر الذى تدفع في الصيف ؟	ريال/دبة	ريال/قارورة		ريال/بابور	ريال/شهر	ريال/شهر	

4a كم لتر تستخدم في اليوم الواحد؟

4b هل تعطي أو تبيع الماء للأخرين؟ نعم/لا

4c أذا كان كذالك ,كم خلال الشهر ؟

4d كم يدفعوا في الشهر الواحد ؟

4e كل كم في العادة تحصل علي المياة من أي من هذة المصادر؟ (كل يوم-١ كل أسبوع-٧ كل شهر=30)

5a أي المصادر تفضل ؟ **(بالترتيب)**

5b لماذا؟ **(لا تعطي أجابات)**
المعتمدة, الجودة, السعر(رخيص)- ,سهولة الحصول, تصاريح أخرى

5c ما هو الأكثر أعتمادا لديك؟ **(بالترتيب)**

موارد المياه

6a أي المصادر تستخدم للآتي :

	دبة	قوارير	مجانا مسجد/سبيل	وايت	المشروع	مشروع خاص	(اخرى(حدد)	(بالترتيب) الأهمية	الكمية
للشرب									
للطبخ									
للأستحمام									
للغسيل									
تنظيف البيت									
للحمام									
(مواشي (أذكر اذا كان يستخدم الماء الجاري)									
الحديقة									
اخرى (حدد)									

6b لأي المهام تغلي الماء؟ و من اي المصادر هي؟(صل المهام مع المصدر في الجدول الأعلى وأكتب *)

6c ما هو أهم أستخدام للمياة؟ (بترتيب الأهمية في العمود المخصص للأهمية) (بالترتيب)

6d ما هو النشاط الذي تستخدم فية أغلبية المياة؟ (بترتيب الأستهلاك في العمود المخصص للكمية) (بالترتيب)

6e هل الجودة كافية للاستخدام ؟ نعم/لا							
7a كم تستغرق في حصول المياه؟ (دقيقية)							

	هيلوكس	سيارة	تاكسي	بابور	دبل(صالون)
7b هل تمتلك سيارة؟					
7c هل تحضر الماء بها؟					

كم من الحيوانات تسقيها؟	غنم	ماعز	بقر	دجاج
7d الأن؟				
7e خلال أزمة المياة؟				

تخزين المياة

	الخزان	خزان ارضي	اوعية	اخرى (حدد)	لا يخزن
8a كم تستطيع أن تخزن المياة فيها؟	م٣	م٣	لتر		
8b لكم يوم يدوم الماء المخزن؟					
8c هل تجمع ماء المطر؟ نعم/لا					

	الحمام مع السيفون	الحمام بدون السيفون	المغسلة	الغسالة	السخان	دوش	بانيو
9a هل لديك أي من الأتي ؟ نعم /لا (أسأل كم مرحاض ومغسلة لديه)							
9b هل تشترك بهاؤلاء مع الأخرين ؟ نعم /لا							
9c كم لديك غرفة للتنظيف باستثناء الحمام .لكن بتضمين المطبخ؟							

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9d ما هي الأنظمة التي تستخدمه للتخلص من المجاري؟

لايعرف	بيارة	بلاليع	مجاري	اخرى (حدد)

9e لو كانت بيارة فكل كم تفرغها ؟

10 علي أي من الأتي تقوم باصرف أكثر في الشهر؟ (بالترتيب)

الأيجار	الكهرباء	الماء	الملابس	التعليم	القات	الطعام	المواصلات	الصحة

11 ما هي المشاكل الناتجة عن نقص المياة في بيتك؟ (لا تعطي أجابات)

لا شيء	الصحة	الراحة	النظافة	اخرى (حدد)

12 أذا كان هناك ماء أقل في المستقبل ,ما هو التأثير علي أسرتك؟ (لا تعطي أجابات)

لا شيء	الصحة	الراحة	النظافة	اخرى (حدد)

13 أذا توفر الماء في بيتك اكثر فما هي المنفعة التي سوف تحصل عليها؟ (لا تعطي أجابات)

لا شيء	الصحة	الراحة	النظافة	اخرى (حدد)

14a هل تعاني أسرتك من أي من المشاكل الصحية في الوقت الحالي ؟ نعم/لا

14b ما هو المسبب؟ (لا تعطي أجابات)

لا أعرف	الماء	اخرى (حدد)

15 هل تأثر قلة الماء علي الوضع الصحي لأسرتك؟ نعم/لا — أذا نعم ,سالب او موجب؟

	شبكة الأنابيب	المشروع	المشروع الخاص
16a	كم مضى علي حصولك علي الماء؟		
16b	كل كم يوم تاتي المياة الأن ؟		
16c	كم من الناس يستفيد من هذة التوصيلة ؟		
16d	كم تكلفة التوصيلات ؟		
16e	هل لديك عداد ؟ لا\نعم		
16f	كل كم تأتي الفاتورة؟ ١-شهريا, ٣-كل٣ اشهر		

للذين لم يوصلوا بالمشروع الحكومي فقط

عدم وجود خط رئيسي	غالي	مالك البيت لم يدفع	جودة سيئة	غير معتمد	تأتي نادرا	اخرى (حدد)

17a أذا لم يكون موصل بالمشروع الحكومي لماذا؟ (لا تعطي أجابات)

17b لو سنحت لك الفرصة للتوصيل بالشبكة ,فهل ستقوم بذالك ؟ نعم/لا

17c أذا لا, لماذا؟ (لا تعطي أجابات)

17d هل تمتلك أو تستاجر البيت؟

17e كم تعتقد أنه يكلف لتوصيل شبكة المشروع الحكومي ؟

18a لو سنحت لك الفرصة بالأشتراك باشروع الحكومي أو المشروع الخاص, أي منهما سوف تختار؟ (خاص / حكومي)

18b لماذا ؟ (أدخل :معتمدة ,الجودة ,السعر ,(رخيص),تصاريح أخرى حدد (لا تُعطى أجابات)

18c هل تعتقد أن المشروع الخاص سوف يكلف أكثر أو أقل شهريا عن المشروع الحكومي؟

	المثل	اكثر 50%	ضعف
18d هل سوف تشترك في المشروع الخاص أذا علمت أنه سوف يكلف ألمثل , ٥٠٪ أكثر أو الضعف المشروع الحكومي؟			
18e لو كنت متصل بمشروع يمول الماء يوميا ,فهل تقبل أن تدفع للوحدة ما تدفعه الأن, ٥٠٪ أكثر أو الضعف؟			

18f هل سوف تشترك بمشروع الدعم الخاص لو كان للأستخدام في كل شيء عدا الطبخ و الشرب؟ نعم/لا

نود أن نقدم معلومات عن الحفاظ علي الماء ,الصحة ,النظافة
الأسئلة التالية سوف تساعدنا في معرفة أذا كان من الأفضل أستخدام الراديو ,الصحافة ,أو التلفزيون كيف يمكن أن نجعل المعلومات مفيدة للعائلة,

19a كم شخص يعيش في هذا المنزل؟

19b هل لديك الأتي: (تلفزيون / راديو)

	أفضل وقت	يمني	أجنبي	أي قناة
19c أي قناة تلفزيونية تشاهد ؟و متي تفضل ان تشاهد؟				
19d أي قناة راديو تستمع أليها؟ ومتي تفضل ان تستمع؟				
19e أي الصحف تفضل؟				

	عدد الأشخاص	عدد الرحلات	البلدان	السبب
20a منذ حرب الخليج كم عدد أفرد أسرتك الذين سافروا للعلاج ,للعمل ,أو السياحة,للدراسة أو سبب اخرى				
20b هل يوجد أحد من أفراد أسرتك في الخارج؟				

20c هل تمتلك أرض بالقرية؟ نعم/لا

20d كم جوالة محاصيل تحضر من القرية في سنة؟

20e كم كيس من القمح و الدقيق تستخدم في الشهر ؟

	جمع المياة	غسل الملابس	تنظيف البيت	غسل الصحون	استحمام	المواشي	الحديقة
22a كم رجل , أنثي , أو طفل مسؤولون عن المهام التالي؟ ر,ن,ط							
22b مقارنة مع الوضع الحالي ,علي أي الأشياء صرفت وقت أكثر, اقل او المثل خلال الأزمة ؟ (ادخل: اكثر, اقل او المثل)							
22c مقارنة مع الوضع الحالي , في اي المهام التالي أستخدمت ماء أكثر, اقل او المثل في الأزمة؟ (ادخل: اكثر, اقل او المثل)							
22d أذا كان الماء أقل وجودا في المستقبل, في أي المهام التالي سوف تستخدم الماء اقل؟							

22e مقارنة مع الوضع في الازمة, هل تستخدم الماء اكثر, اقل او المثل الآن ؟

22f اذا تستخدم الماء اكثر الآن , خلال الازمة جمعت الماء اكثر او استخدمت اقل او الاثنين ؟

Men Respondents Only

كم :	العدد	يقرأ	خلص ابتدائي	خلص اعدادي	تخرج ثنوي	تخرج جامعة	وظيفة	ما هي؟	وظيفة أخرى	
كم رجل في البيت ؟										23a
كم مرأة في البيت ؟										23b
كم طفل في البيت ؟										23c

Women Respondents Only

24

أفراد الأسرة (الأناث فقط يجيبون) (أكمل خلف الصفحة)

أعضاء الأسرة	ذكر/انثة	العمر	يقرأ	خلص ابتدائي	خلص اعدادي	تخرج ثنوي	تخرج جامعة	وظيفة

Appendix B

Urban Domestic Water Use Survey – Sampling and Analysis

Sampling

Three stages of sampling were used. Firstly, population-based blocks of the city were selected, then sample points were areally selected within those blocks, and lastly a cluster comprising the nearest eight houses around the sample point was selected.

Population-Based Block Selection

The random selection of houses to be included in the survey could have been done by a single stage areally-related method but would have biased the sample towards less densely populated, wealthier areas. It was therefore decided to base the first stage of sampling on population density. Census data of Dec 1994 were obtained for the city of Ta'iz, including maps defining the areas used for the census. One number was assigned to each 100 houses (masaakin) in the block, which resulted in nearly 500 numbers being allocated. The groups of 100 houses were selected for the next stage of the sampling by using random numbers and the blocks in which these hundreds were located noted. The random selection ensured that more populous blocks had more sampling points and the less populous fewer.

Sample Point Selection Within Blocks

Because the boundaries used by the 1994 census defined small and reasonably homogeneous blocks in terms of population density the second stage of sampling was by areal methods. Location points were chosen by random selection of co-ordinates, within the blocks.

Cluster Sampling at Location Points

Location of sampling points in the field was facilitated by the census maps and a GPS. Time and resources constraints made it unfeasible to individually locate over one thousand houses and cluster sampling was used. During the pre-test, sampling included five houses per cluster and 72 people were interviewed. In the main survey eight to ten houses were included per cluster at 125 location points. The cluster comprised a sample of the houses immediately adjacent to the location points. In the main survey a total of 1028 houses were visited and 1250 interviews carried out, (since in two houses per cluster interviews were conducted with a male and female respondent). Those houses to be included were identified and field team leaders were shown the location point which was also identified by spray paint. Missing out houses was not permitted unless no suitable interviewee could be found after two visits.

There was rarely a need to find an alternative house due to absence of interviewees. Sketch maps of the houses to be included were prepared during the first visit and used by the team members on subsequent visits. Effects due to clustering were analysed.

NWSA Coverage

In order to check that the sample would proportionately represent the areas covered or not covered by the public utility (NWSA) water supply network, a check was kept of the number of houses with and without NWSA connections as the survey progressed. NWSA coverage was, according to NWSA in 1997 about 75%. Maps of the locations of water mains were obtained from the CES office to identify areas of coverage. The maps were rather out of date, however. Initial indications suggested about 90% of the selected sample points were located in areas served by NWSA, and 90% of the houses included in the survey were, in fact, connected to NWSA. There is also a discrepancy between NWSA estimates of sewerage coverage (48%) and those recorded in this survey (68.5%). Reasons for the difference in water supply and sewerage coverage estimates between those of the NWSA and this survey are discussed in section 4.5.1. It is statistically unlikely that the difference is due to unrepresentative sampling.

Interviewees

Interviewees had to be old enough to answer the questions and not so old that they were 'out of touch' with the issues addressed in the questionnaire. The decision regarding whether the interviewee was suitable was made by the enumerator. After the practice of the pre-test the enumerators appeared to be able to make this decision more easily. In order to investigate the difference between male and female responses, it was decided to interview a male and female respondent at two houses in every location. Men conducted the male interviews and women the female. Despite this plan, at 138 houses a woman was the only adult at home at the time of the visit and was willing to be interviewed by a man. It was therefore possible to increase the proportion of female respondents and carry out further gender analysis.

Surveys

The pre-test was conducted during late July 1997 and facilitated testing of the questionnaire, the enumerators and the survey method. Immediately prior to the pre-test a training day was held for the enumerators. The questionnaire was revised in the light of the pre-test and the main survey was conducted during August and the first half of September 1997. It was preceded by another training day in which the revised version of the questionnaire was discussed and practised. A survey of actual expenditure on the items included in the expenditure ranking question of the questionnaire was conducted after the main survey was complete. One household at each location included in the main survey was visited during December 1997. Without continued monitoring, the estimate of expenditure on each item can only be regarded as rather crude although expenditure ranking and estimated actual expenditure agreed sufficiently to warrant using the expenditure estimates in establishing broad income categories as described below.

Analysis

'Income' assessment - 'I found God in Yemen'...

was a quotation heard from several Yemenis interviewed during the course of the survey. It was apparently the salient finding of a previous study of incomes and expenditure carried out in Yemen. Although it has not been possible to trace the reference, the study apparently found that household expenditure exceeded income. When asked how this was possible householders replied '^al allah' meaning 'its upon God', that is, month after month He miraculously covers the deficit.' This observation highlights the problem of assessing income. For instance, of the 1250 interviews carried out in this survey, not a single household acknowledged having a second income. The reality of moonlighting is apparent to anyone who has mixed with the inhabitants for even a short time. Due to a fear of taxation assessment, or other reasons, householders only record their 'official'(usually morning) job. In order to analyse the survey data on the basis of income a way of determining the elusive income was needed. The first step towards establishing income brackets incorporated a basic wealth assessment (based on possessions) and an estimate of income from job titles.

Wealth Assessment

Along the same vein as the Arabic proverb 'wealth cannot hide itself' possessions, vehicles, property holdings and trips abroad, were recorded as wealth indicators. In the absence of more exact information on the value of the possessions and properties owned by the respondents included in the survey, and in an attempt to produce an indication of their relative wealth, various means of deducing prices were used.

Consumer Items

Prices of various consumer items were obtained from dealers. The prices obtained were for new purchases of medium quality, most popular models. Relatively little price variation was noted. Items comprised washing machines, water heaters, water storage tanks, TV, and satellite dishes.

Vehicle prices were also obtained from dealers. Although there is a large range in price depending on age and to a lesser extent exact model, current prices of 10 year old average quality mid-range models were used. This seems to correspond with the average age of vehicles on the road in Ta'iz, which is also the approximately the height of the pre-Gulf War boom when remittances and vehicle purchase peaked. Although this valuation method is rather crude, it is still considered useful in calculating a household wealth parameter because the major differences between households are the presence or absence of a vehicle and, after that, the type of vehicle, particularly 4WD vehicles.

Property

The survey questionnaire distinguished the property types of apartments, detached houses, villas and temporary housing. It became apparent from interviewer entries that the distinction between apartments and detached houses was different from that intended when the questionnaire was designed. Detached houses in Ta'iz typically comprise between 2 and 4 floors. The ground floor is usually for commercial purposes (hence the difference in value in land cost throughout most of the city depending on whether the property is on a main road or not). An extended family often owns the whole building and sub-families may rent apartments within it or they may live in the apartment rent-free because it is owned by a near relative.

The expenditure survey indicated that rents in most of the city are approximately 500YR/month less than those quoted by estate agents, although their estimates were more accurate in the expensive areas. A reason for the difference could be that people interviewed in the expenditure survey had been living in their houses for some time without rents being increased whilst the estate agents were giving rents for new tenants. In estimating household expenditure for the main survey sample, rents were calculated from those given for the 125 households included in the expenditure survey, rather than using those from the estate agents, and were applied on a pro rata basis to the whole sample of 1250 dependent on the size of property and its location.

The often emotional response to the question of land ownership, and, in some instances, refusal to answer (taken as acknowledgement of ownership), suggests the significance of this parameter. Ownership of agricultural land was found to correlate with expenditure and has been included as a variable in calculating the income factor of the households. Very roughly, a value of 4MYR (31,000$) was assigned, based on non-irrigated land prices of 3000YR (23$) /qasaba and a mean landholding of 3 hectares indicated by estate agents. The latter figure seems rather high. Handley (1996a;16) indicates typical holdings of a little over 1ha. Although absentee landlords tend to have larger holdings, it is unlikely they would be very much larger than the mean. Conversely, landowners may purposely underestimate holdings for tax reasons, whereas estate agents may have a more accurate picture. Whatever the mean size of holding, the price per hectare used was slightly below the mean, and the main differences in household wealth are at the more basic level of whether they own land or not.

The household wealth calculated from the above methods is less than the actual total wealth of the households for the following two main reasons: only a few consumer durables were included, and no business assets belonging to members of the household were included.

Trips Overseas:

196 households reported family members having travelled overseas since the Gulf War and did not record the current job as being 'mugtarib' (emmigrant worker). Travel overseas was costed according to distance travelled and purpose and then multiplied by the number of trips and the number of members of the household travelling. Trips for work (resulting in income) were distinguished from study, medical or tourist purposes (resulting in expenditure). Again the fundamental difference was between those who travelled overseas and those who did not, although a rudimentary costing of the trips was also made.

Income Estimates:

Nearly all the households interviewed reported jobs falling into the descriptions given below. For most of these jobs it is possible to estimate approximate incomes. Broad estimates were obtained by carrying out a small survey (sample 50) of government employees in education and military and also of employees with Hayel Said company. A few shayxs were interviewed regarding likely salaries of tribal members for the less common occupations.

Army and police ranks receive less basic salary than this, but it is supplemented by backhanders etc. Similarly officer salaries can be as high as indicated when income 'supplements' are taken into account and the higher figure has been assumed. Although the earning potential of building contractors and money changers is high, their incomes are reduced at the moment due to the depressed market. The lower figure for doctor's incomes is the basic government salary and may be multiplied many times by private practice. The term trader may refer to the owner of the largest business or be a euphemism for the boy selling a few wares out of a wheelbarrow. Shayx incomes similarly vary greatly, generally depending on whether they serve their community or sponge from it. For doctors, traders and shayxs a range of incomes was used depending on their wealth indicators.

Table B1: Salaries of occupations encountered in the survey. (For US dollar conversion divide by 130).

Job Title	Salary '000 YR/month	Job Title	Salary '000 YR/month
Most Frequently Encountered Jobs		Guard	5-10
Labourer	5-10	Nurse	5-10
Employee(govt & private)	8-15	Supervisor	10-15
Trader	5-50+*	Secretary	5-10
Clerk	10-15	Emigrant Worker	50+
Teacher	10-15		
Shopkeeper	5-10	**Rarely Encountered Jobs**	
Engineer	10-15	Surveyor	10-15
Army	10-15*	Lawyer	50+
Police	10-15*	Mechanic	20-30
Driver	10-12	Seller	20-30
		Shayx	0-50+*
Less Frequently Encountered Jobs		Carpenter	20-30
Doctor	15-50+*	Chef	10-15
Accountant	15-20	Journalist	20-25
Axdaam	0-5	Farmer	5-10
Officer (police/army)	10-50+*	Moneychanger	0-50+*
Building Contractor	0-50+*	Judge	50+
Butcher	20-30	Tailor	30-50
Chemist	50+	Blacksmith	15-20
Electrician	15-20	Headmaster	10-15
Company Director	50+	Baker	15-20
Deputy Director	30-50	Welder	15-20

* See comments below

Although the assumptions involved in determining wealth and basic income are in some cases subjective and approximate and may not meet the agreement of all readers, their accuracy is considered adequate for their purpose here of determining broad income brackets.

Regression Analysis, Income Factor and Income Bracket

As a second step towards establishing income brackets, a group of 125 households (one at each location) was interviewed to determine expenditure on major items in the monthly family budget. A correlation was then carried out between total four-monthly expenditure vs. income and wealth determined on the basis of the assumptions described in the preceding section. [It was considered reasonable to include wealth indicators in the determination of the income factor because they were either a) obtained via previous income or inheritance, or b) in the case of more durable items they require current income for operation, maintenance or replacement. The most important justification for including the wealth indicators in deriving income factors was the positive correlation obtained between the indicators and expenditure.]

The four month period was chosen arbitrarily and, initially, monthly expenditure and income were accordingly multiplied by four whilst current values of major capital items, such as property, vehicles, foreign trips and major household items were divided by various factors. These factors depend on the life expectancy of the item so as to give the amount they would depreciate in four months or, in the case of property, the time taken to inherit them (assuming 25 years per generation) or a similar time to pay off a loan to purchase them or to accumulate the wealth to purchase them outright. The four-monthly cost of foreign trips was related to trip frequency. The sum of the four-monthly income/wealth parameters was termed an 'income factor'.

Initially, demographic data of numbers of women and children was included in the income factor (as an effective four-monthly cost per individual). Although a best fit of R=0.533 was obtained when demographic data were included, the causative effect of these data on expenditure but not on income precluded its use in establishing the income factor, so this 'demographic cost' was excluded from the income factor. Although rent directly contributes to expenditure and is strongly correlated in the sample of 125, income is considered to be more strongly causative of rent rather than vice versa and rent was therefore included.

Table B2: Multipliers in Regression Equation.

Item	Multiplier / Divider	Error Margin +/-
Land Ownership	/100	20
House Ownership	/100	20
Washing Machine	/15*	
Television	/15*	
Car	/60	5
Overseas Trips since Gulf War	/10	2
Rent	x 4months	0.5
Salary	x 6months	1

* Best fit values not used, see below

The initial 'four-monthly' values of the different items proved to be quite close to the values required for giving a best-fit in the rudimentary regression analysis of expenditure against income factor, although some needed adjustment and an error margin which still permitted the fit was established. The values of the multiplying and dividing factors which gave a best fit, and their error margins are given in Table B2. The best fit obtained (R=0.35, income factor= 2.77 x expenditure + 133000, t ratio=4.1) reflects the quality of the responses and the relevance of a 'one-off' expenditure survey, however, for the purpose of establishing coarse income brackets, the methodology is considered adequate.

A 'life cycle' aspect of inheritance was not apparent in the expenditure patterns (that is, there was no correlation between ownership, or value, of inherited items and age of head of household. Apart from washing machines and TVs, the derivation of the multipliers arose directly from the regression analysis. A cross-confirmation that the wealth assessment methodology is reasonable is indicated in that the best fit regression was obtained using approximately the same time period (viz. four months). Estimated salaries had to be increased by 50% just to cover expenditure on the items included in the expenditure survey. This confirms a multiplier of 6 months rather than 4 months in the regression and suggests that real total incomes including moonlighting are 50% more than respondents are prepared to admit.

Other wealth indicators included in the survey (radio, satellite dish, water heater) showed little to no correlation with expenditure and were not used in constructing the income brackets.

Fourthly, and finally, on the basis of the above methodology, income factors were calculated for the whole sample in order to place them in 'income' brackets. Seven income brackets were constructed. The income brackets are intended as a coarse classification considered commensurate with the quality of the data used.

Income factors varied from 0 to 1,900,000 in a markedly skewed distribution (Table B3).

Table B3. Household income brackets.

Bracket	Income Factor Range	Sample (No of Households)
1	0-100,000	149
2	100,000-200,000	442
3	200,000-300,000	215
4	300,000-400,000	80
5	400,000-500,000	52
6	500,000-600,000	40
7	>600,000	50

Analysis Methods

Data sub-sets were prepared for different types of analysis (Table B4).

Table B4: Data sub-sets.

Data	Sample	Analysis
All data	1250	Source File
All unpaired data plus paired data, male (uneven locations) female (even locations)	1028	Main Analysis Income Analysis
As above, but with some records removed to ensure equal weighting for cluster effect analysis	1000	Cluster Effect Analysis
All Unpaired data, divided into male and female respondents	668m 138f	Gender Analysis a)
Paired data, divided into male and female respondents	222m 222f	Gender Analysis b)

The main analysis comprised determining the mean, standard deviation and standard error at the 5% level for each quantitative variable in the questionnaire and frequency percentages for categorical variables. Statistical significance is defined at the 5% level. Statistical parameters were based on n=number of respondents as in most instances a few respondents either refused to answer the question or did not know the answer. The income analysis comprised comparing the means for each income bracket.

Analysis was carried out to determine the extent of the cluster effect (due to the clustered sampling) by comparing the standard error when the cluster effect is taken into account and when it is not using the Csample and Analysis parts of the Epi-info (version 6) WHO statistical software. Although many sampled clusters of houses comprise a large variety of housing and incomes, cluster effects were noted for many parameters. In particular strongly income related variables showed marked differences between different locations. The wealthy areas along the southern edge of the city were the most obviously different from other areas.

Many of the variables did not show a normal distribution but were skewed, so tests for significance involved using the following non-parametric methods. Gender analysis comprised examining if male and female respondents answered significantly differently. Unpaired data were analysed using Student's t test at the 5% level (analysis a), and paired data using Wilcoxon signed-rank test (Swinscow, 1983;58), (analysis b). The comparison of male and female responses yielding categorical variables was carried out using the standard error of difference between percentage responses. Gender comparisons mentioned in the following sections are only given where differences were statistically significant at 5% or less or for percentage differences where the difference was greater than one standard error (Swinscow,1983;28-30).

Appendix C Newspaper Articles

June 12th, 1995

Taiz Governor Resigns, unless ...

Taiz Governor Abdul-Rahman Mohammed Ali Othman, wrote to Prime Minister Abdulaziz Abdulghani resigning from his post. Reason: "I am unable to fulfill my obligations based on the oath I had made when I took office."

The Governor complained of meager and falling allocations. Taiz city with almost one million residents, suffers from shortages of vital needs including water.

Al-Ayyam, Aden, 7/6/1995
Independent.
Headlines:
1) Visiting Saudi Arabia Will Contribute to Stability in the Region and Resumption of Special Neighborly Relations.
2) Leakage of Final Exams Leads to Delay in Holding Exams in Aden and their Cancellation in Lahej.
3) Taiz Governor Resigns.

No Foreseeable End to the Water Shortage in Taiz
Al-Shoura (Opposition paper) April 17

The Sheikhs and notables of Dhi-Sifal district of Taiz lead by Sheikh Sadiq Ameen Abu-Ras the Minister of Agriculture refused to allow drilling of more water wells at their area to supply Taiz. According to an agreement in 1972 The Water Authority in Taiz is allowed to take 8 million liters of water per-day from Dhi-Sifal area but it is taking now more the 18 million liter per-day.

Dhi-Sifal district citizens argue that the water resources are already exhausted and that they are afraid that the area may dry up soon.

Al-Thawra (Official Government Paper)

14 October (Official - Aden): 21-6-95
Headlines:
1) Bajammal Holds Discussions With Ministries of Economic Cooperation and Foreign Affairs in Germany
2) The Minister of Electricity and Water says: "The President Has Given the Final Instructions That Resolve The Water Supply Project Problem In Taiz
3) The Minister of Finance Says: "80% of the ...

Al-Wahdah, Sanaa, 7/6/95
(Official)
Headlines:
1) Bajammal Goes to Germany Soon.
2) The Vice Minister Of Interior, "The Security Have Been Pursuing Johans Since 1991. He Was Apprehended Alone ."
3) Deputy of Civil Aviation Authority Says that the Airbus Deal Was Concluded Without the Authority's Knowledge. He Says Reforming the Two Airlines (YEMENIA and ALYEMEN) Can Only Come by Merging them.
4) Governor of Taiz Says, "The World Bank Will Cancel the $30 Million Credit Soon, If the Dhi Sufal Water Well Drilling Is Not Implemented.

AL-AYYAM: Aden: 30-8-95
(Independent)
Main Headlines:
1) Abdul-rahman Al-Jifry Denies Requesting Postponement of his Trial in Order to Send Defense Lawyers.
2) Large Fire Ball in Al-Mukalla But Fire Fighting Equipment Not Prepared for the Job.
3) Danger Threatens Aden Airport Because of Abundance of Too Many Army Vehicles Using the Runway.
4) Taiz Water problem on its Way to a Solution

Water Situation in Taiz City Getting Desperate

YT 21/8/95 Front Page

The attitude of the Government of Yemen towards the plight of the people of Taiz cannot be described other than utter neglect, disrespect and totally irresponsible. The people of Taiz city - some one million of them - have been suffering from water shortage for more than one year now. But there has been no response, other than lip service and various promises

A loan from the World Bank had been made available to drill new water wells in Dhi Sufal area. But the authorities have been "unable" or rather unwilling to implement the project, citing tribal differences regarding the area where the wells were to be drilled. Then, the Governor of Taiz, Mr. Abdul-Rahman Mohammed Ali Othman, recently took the initiative and drilled several wells inside the city itself. But the government refused to release a meager YR 55 million it had promised and allocated in the budget to finance the pumps.

"The way I see it, the rulers are trying to punish the people of Taiz. I don't why, but the people of Taiz city are made to suffer on purpose," explained Sheikh Abdul-Rahman Noman, Member of the Parliament representing Constituency No. 63 in Taiz.

Dr. Abdul-Aleem Al-Qubati, a respected physician who is involved in many charity efforts, has a similar opinion. "I cannot understand why such a pressing issue is left on the backburner. The money is there. The need is there. Somehow the political will is not there," he said.

By: Abdul-Qader Mughalles,
Taiz Bureau Chief,
Yemen Times.

AL-TAJAMMU'U: Aden 21-8-95 (Yemeni Unionist Congregation)

Yemen Times 21/8

Main Headlines:

1) The Dollar Falls... But Prices Are Unshaken
2) In Taiz: A Water Shortage and Typhoid
3) Al-Zindani (Former Member of Presidential Council) Still Gives Orders

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6/5/96 YT

Taiz Is in for Happy Surprises

"I will not visit you until you have completed the water project for the people to drink." That was President Ali Abdullah Saleh responding to the invitation of the Governor of Taiz, Mr. Ahmed Abdullah Al-Hajri. The President was making a point. He wanted to emphasize the urgency and need getting on with the city water project. The President's pressure paid off.

The National Water and Sanitation Authority had set up an emergency team, headed by Mr. Abbas Al-Mutawakkil, under the direct supervision of Dr. Mohammed Al-Saeedi, the newly-appointed General Manager. The mission was also given some cash on hand to get on with the job. "The team has been working even through the eid holidays, and we have nearly completed half the work," Al-Saeedi said.

Governor Al-Hajri visits the site of the project every other day. "Three of the new water wells have been hooked on to the distribution network, and we shall be able to double the quantity of water to be pumped to the city by mid-May," the governor said.

In other words, President Ali Abdullah Saleh will be spending the next anniversary of May 22 (Yemen's Unification Day) in Taiz.

In an exclusive interview with the governor, to be published by Yemen Times next week, Mr. Al-Hajri also indicated that there will be other goods awaiting the President and the people of Taiz.

The President will also inaugurate the flood control drainage system in Taiz. This has always been a major problem as the rain-water floods and torrents have menaced the people and property. The Aden-based General Corporation for Building and Construction executed this project. The President will further inaugurate the Taiz ring-road. "Other projects which are being vigorously pursued are the German-financed Vocational and Technical Institute of Taiz, as well as the electric grid link-up between Taiz and Aden," the Governor indicated. The latter two projects will probably be completed for inauguration during the September/October Revolution celebrations.

The Governor of Taiz has been able to cut through the bureaucratic hurdles and speed up implementation of long-dormant projects. Ali Naji Al-Ra'awi, Chief Editor of the Taiz-based daily Al-Gumhurriyah newspaper commented on the governor saying, "He does a lot of leg-work. He is always on the move, inspecting projects and meeting with the people."

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region." YT 9/9/96 HWA and closed down one system of Yemen," he said.

World Bank Provides $10 m. to Taiz Water Project

The International Development Association, the soft-loan arm of the World Bank, approved last week an SDR 71 million) (US$ 10.238 million) credit to finance the Taiz Water Project. The loan is on standard IDA terms with a maturity of 40 years, and a grace of ten years.

The 400,000 inhabitants of Taiz have been suffering from water shortages over the last two years. Piped water to less than half the residents is pumped only once every month.

"Actually the water comes along with the bill," stated on resident.

The IDA credit, along with a government contribution of US$ 847,000, will help mitigate the immediate water shortage by doubling supply in 1997. New sources to meet project demand to the year 2000 will also be identified and tapped.

Taiz Governor Ahmed Al-Hajri, and Dr. Mohammed Al-Saeedi, Chairman of the National Water and Sanitation Authority, have worked hard to execute this project.

ISLAH Forces a Re-Shuffling of

A Free z .
market or economy. [illegible] expensive and inefficient a Free Zone cannot attract any industry.

James Leonard - Williams,
Aden.

President Saleh Enlists Service of Public Figures in Construction of Dams in Land Reclamation Drive

الجمهورية اليمنية
الرئيس

الأخ/رئيس مجلس الوزراء المحترم

يكلف الاخ/عبد الرحمن احمد نعمان عضو مجلس النواب بمتابعة تنفيذ مشروع انشاء سد(باب اللازق)منطقة بني عمر -الشمايتين(م/تعز) مع مشروع مياه مدينة تعز بحيث يتم التنسيق مع الجهات ذات العلاقة.//

الفريق/
علي عبدالله صالح
رئيس الجمهورية

General Ali Abdullah Saleh, President of the Republic, is pushing forward with a land reclamation drive. Towards that end, he is pursuing many policies. One such policy is to build more dams all over the country.

To succeed in this effort, he is by-passing the government machinery, which has proven its inefficiency, and has asked public figures and locally influential individuals to take charge.

One such instance involves the construction of the Zallaq Dam in the southern periphery of Hugarriah in Taiz Governorate.

The individual assigned to oversee the implementation of this project is Sheikh Abdul-Rahman Noman, Member of Parliament. Sheikh Noman comes from an illustrious and well-known family which commands the respect of the people in the region.

"We are not really thinking of dams in the sense of large modern structures. We are looking into medium-size projects which use local material," explained Sheikh Noman.

Other dam projects following the same format include two dams in Ibb, and two more in Lahej.

Land reclamation is seen as a solution to the rising food gap in the country, as well as a source of productive employment for the jobless hordes of people. President Saleh has given specific instructions to the Ministry of Agriculture on this matter.

In the same way, dam construction is seen as providing an answer to more than one problem. While they will help reclaim new land, dams are also expected to help in resolving the increasingly acute problem of water supply in the country.

YT 1/3/96

رئيس مجلس الإدارة
محمد عبد الرحمن المجاهد

الجمهورية

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علي ناجي الرعوي

Al-Gumhuryah

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