ANDHRA PRADESH RURAL LIVELIHOODS PROGRAMME WATER AUDIT

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2003

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Foreword

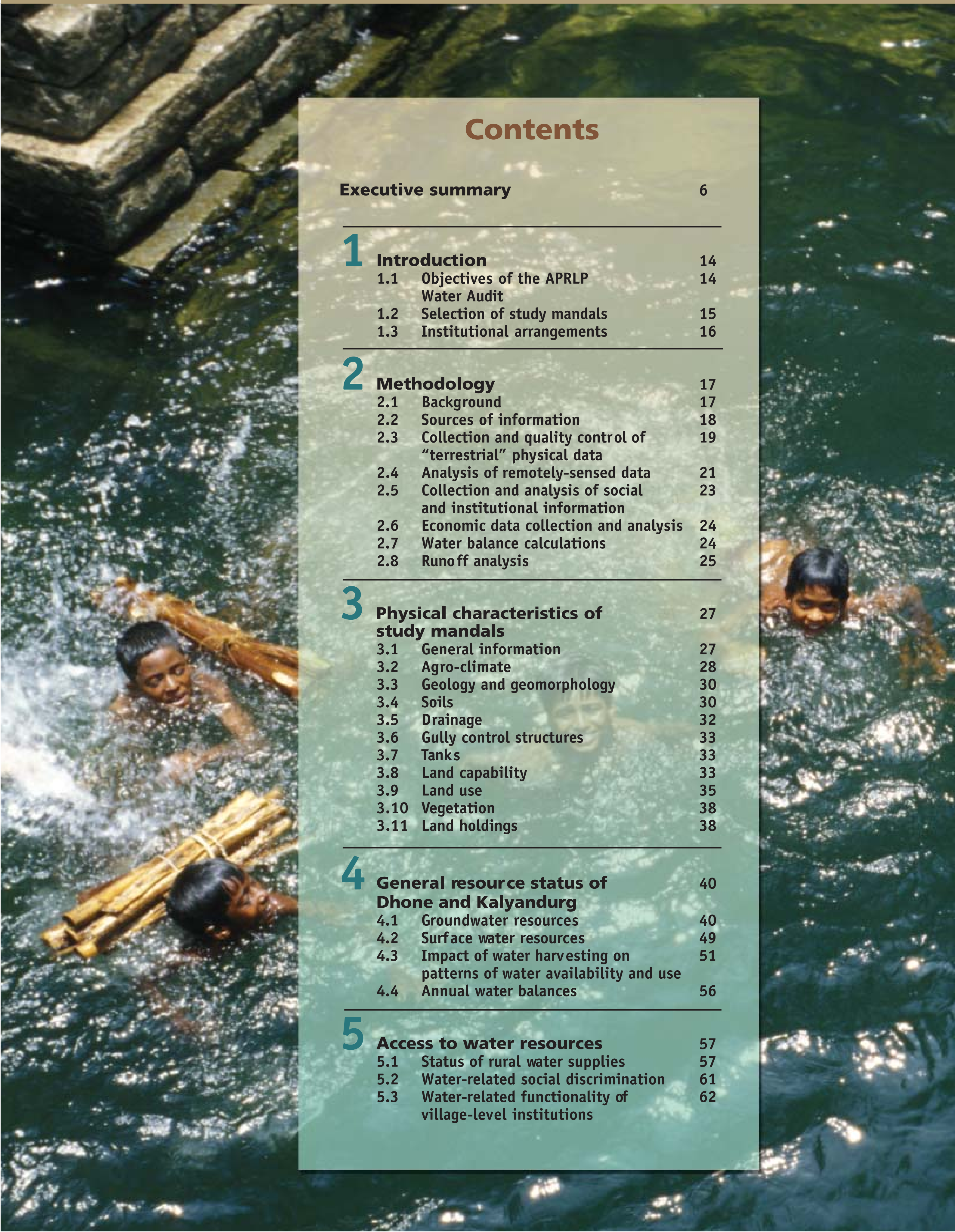
During the last 25 years, Andhra Pradesh has been at the forefront of watershed development and other innovative programmes aimed at tackling the challenges of poverty alleviation and environmental sustainability. The DFID-supported Andhra Pradesh Rural Livelihoods Programme (APRLP) is providing the Andhra Pradesh Department of Rural Development with another excellent opportunity to develop and assess novel approaches to helping rural communities and households overcome the complex constraints and impediments that impact on all aspects of their livelihoods. The APRLP is also providing an opportunity to identify and build upon the successful components of existing programmes and, where relevant, to rethink and modify those approaches to development that have been less successful or that have resulted in unintended consequences.

The APRLP Water Audit working in partnership with relevant line departments has shown that ongoing water-related policies and programmes have and are producing a range of benefits. However, the Water Audit has also identified situations in which current programmes run the risk of being victims of their own success (e.g. in cases in which intensive treatment of drainage lines is reducing tank inflows and the overall utility of traditional tank systems).

The Water Audit has highlighted the need for greater accuracy in official statistics held by different line departments. As these statistics underpin decision-making at all levels, increased effort is also required to make water-related information accessible to those who need it.

Finally, the APRLP Water Audit makes recommendations for policies and interventions that take a long-term approach to developing and managing water resources. These recommendations include practical suggestions for ways in which Andhra Pradesh could introduce and pilot integrated water resource management systems that have the aims of protecting drinking water supplies, promoting equitable access to water for productive uses and enhancing the efficiency and productivity of water use at all scales. Given that demand and competition for water resources in Andhra Pradesh is almost certainly going to intensify in coming years, the contribution of the APRLP Water Audit to ongoing debates and policy formulation is welcomed.

Shri S Ray
Special Chief Secretary,
Panchayati Raj and Rural Development,
Government of Andhra Pradesh



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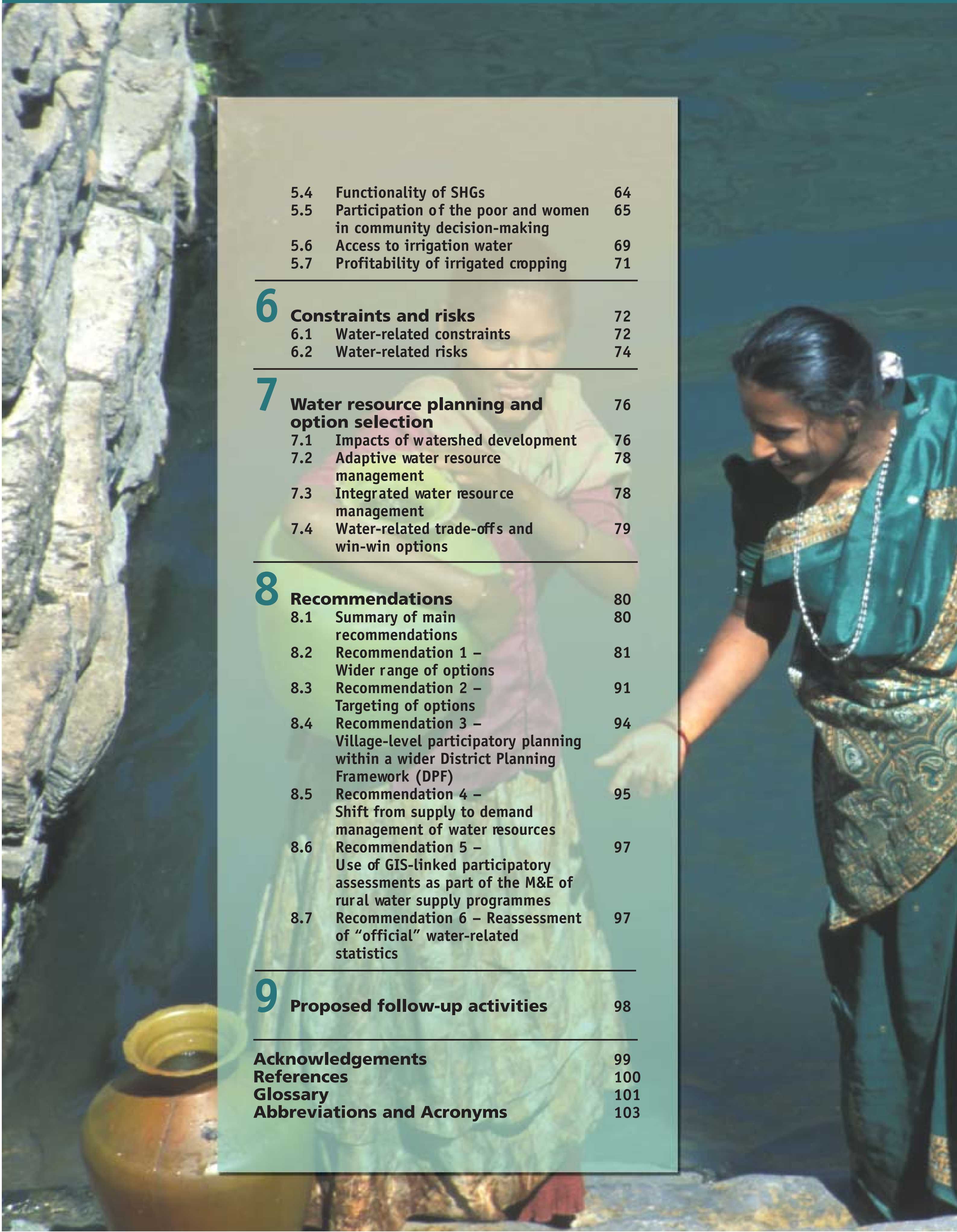

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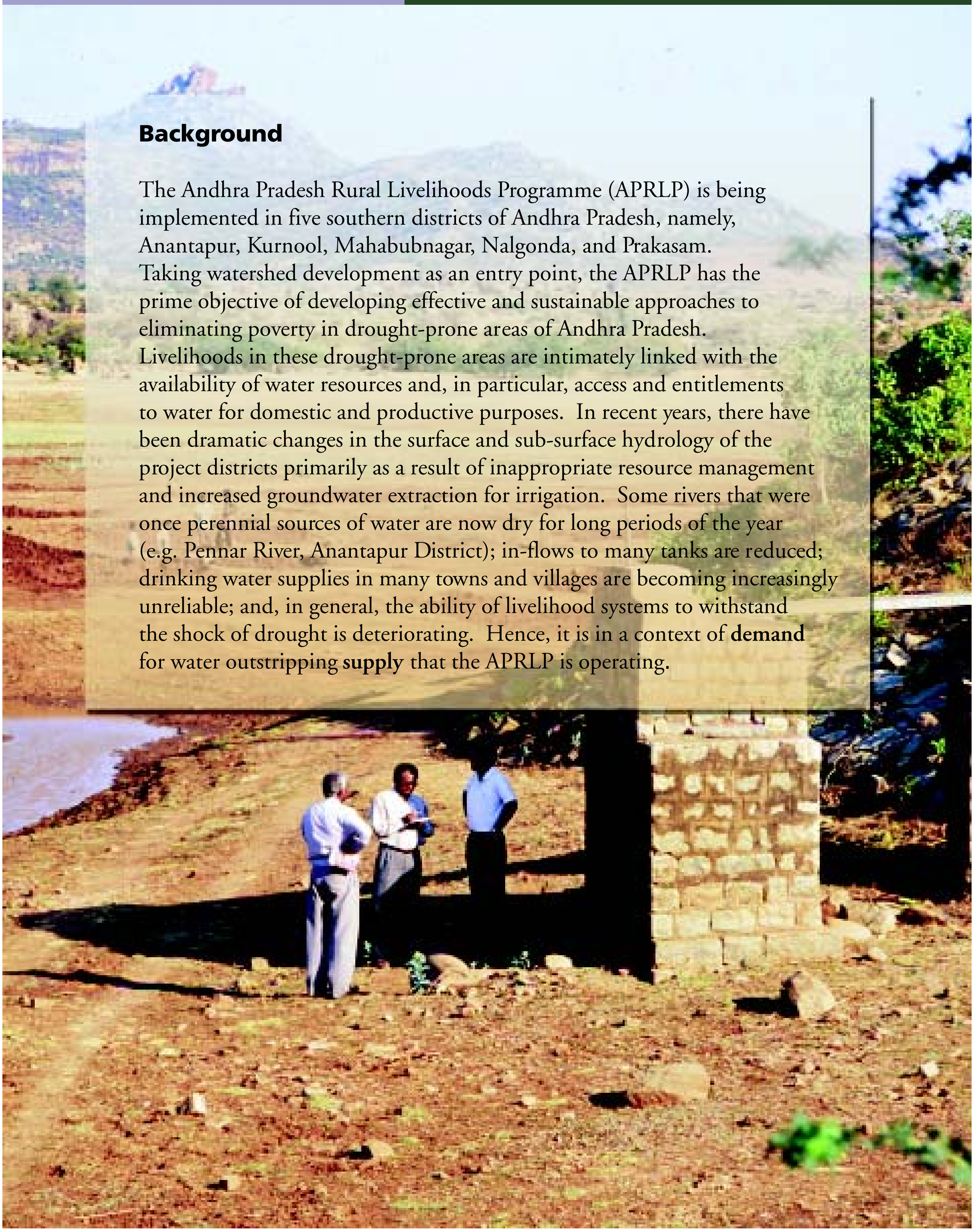
Executive summary

Background

The Andhra Pradesh Rural Livelihoods Programme (APRLP) is being implemented in five southern districts of Andhra Pradesh, namely, Anantapur, Kurnool, Mahabubnagar, Nalgonda, and Prakasam. Taking watershed development as an entry point, the APRLP has the prime objective of developing effective and sustainable approaches to eliminating poverty in drought-prone areas of Andhra Pradesh. Livelihoods in these drought-prone areas are intimately linked with the availability of water resources and, in particular, access and entitlements to water for domestic and productive purposes. In recent years, there have been dramatic changes in the surface and sub-surface hydrology of the project districts primarily as a result of inappropriate resource management and increased groundwater extraction for irrigation. Some rivers that were once perennial sources of water are now dry for long periods of the year (e.g. Pennar River, Anantapur District); in-flows to many tanks are reduced; drinking water supplies in many towns and villages are becoming increasingly unreliable; and, in general, the ability of livelihood systems to withstand the shock of drought is deteriorating. Hence, it is in a context of **demand** for water outstripping **supply** that the APRLP is operating.



APRLP Water Audit

The primary aims of the APRLP Water Audit were to: 1) Assess the current status of water resources in two selected mandals (i.e. sub-districts); 2) Evaluate water-related demand trends in these mandals; 3) Study patterns of water-related access and entitlements of, in particular, poorer social groups; 4) Consider gender and social exclusion issues surrounding access and entitlements to water for both domestic and productive purposes; 5) Assess the functionality of water-related policies and institutions at the village, district and state levels; 6) Identify improved resource management practices and policies; and, 7) Provide a practical framework for more productive, sustainable and/or equitable use of water resources. This report summarises the main findings and recommendations of the Water Audit.

General Approach

The approach adopted by the APRLP Water Audit built on experiences gained during a water audit that was carried out as part of the Karnataka Watershed Development Project (KAWAD). Similar to the KAWAD study, the APRLP Water Audit used as its starting point the fact that, in India, large amounts of physical, institutional and socio-economic data have been and are being collected routinely in rural areas. Unfortunately, these secondary data are not always easily accessible and their quality is usually quite variable. A major feature of the study was the consolidation of data from a wide range of sources onto a GIS database following groundtruthing, gap filling and quality control. Analysis focused on using water balance techniques to assess current patterns of water availability and use as well as current and future demands for water. Information on access and entitlements to water, the functionality of village-level institutions and village-level views on domestic water supplies were elicited using a participatory assessment technique modified to meet water auditing information requirements. Albeit with specialist support from a number of organisations and individuals, the bulk of the Audit's work was carried out by relevant government line departments and by the NGOs already working in the Audit mandals.

Innovative methodologies

Although it was not a research project, the APRLP Water Audit developed and refined a number of methodologies some of which were first used during the KAWAD Water Audit. These included: 1) water-related participatory assessments that produce outputs suitable for GIS analysis; 2) water auditing that combines terrestrial and remotely-sensed data; 3) a simple Excel-based modeling technique for assessing the impact of water harvesting structures on downstream water resource availability; 4) decision trees that use social, and institutional information along with physical information for targeting project interventions and activities; and 5) a simple GIS-based participatory assessment methodology for M&E of rural water supplies.

Characteristics of the "audit" mandals

The APRLP Water Audit was carried out in two representative mandals, namely Dhone and Kalyandurg. These mandals are located in Kurnool and Anantapur Districts respectively. The total area of the two mandals is just under 1,000 km and the total population is approximately 200,000. The climate of both mandals is semi-arid with potential evaporation exceeding rainfall in all but a few months in any year. Mean annual rainfall in Dhone and Kalyandurg is 560 and 525 mm respectively. However, there is considerable inter- and intra-annual rainfall variability and droughts and years of relatively high rainfall are common. As a rule of thumb, out of every ten years, five are drought years, two of which are severe and one of which is catastrophic. At the time of writing this report, both mandals were experiencing a catastrophic drought which was impacting severely on agricultural production and, in many villages, on domestic water supplies. Kalyandurg is located in an area with predominantly red soils (alfisols) that are underlain by crystalline basement geologies (e.g. granites and gneisses). Dhone is also located in an area with predominantly red soils with some areas underlain by crystalline basement and others by sedimentary geologies (e.g. shales and limestone).

Land Use

The main land use in both mandals is rainfed arable cropping. In general, a single rainfed crop is grown each year and around 80% of the rainfed arable area is under groundnuts. Crops grown are a mix of cash and subsistence crops, with most farmers growing some of each, often in the same field (e.g. the groundnut and red gram intercropping that is popular in many areas). Although official statistics suggest much lower figures, compelling evidence (based on remote sensing and survey data collected by the Andhra Pradesh Groundwater Department) points to Dhone and Kalyandurg having around 8% and 12% of net land area under irrigation respectively. Or, put more succinctly, all the indications are that the actual net irrigated area is 4-5 times higher than the official figures.

In the last 10-15 years, there has been a dramatic increase in groundwater-based irrigation. Even in the command areas of tanks, most farmers have shifted from using tank releases for irrigation to using pumped groundwater. In most cases, the tank sluices have been blocked, thereby converting the tanks into percolation tanks. Access to irrigation enables farmers to grow more than one crop regardless of rainfall conditions. This said, frequent power cuts and, in some areas, rapidly increasing competition for groundwater are putting limits on the total area under irrigation. Good returns are possible where irrigation is feasible and access to irrigable land is an important determinant of the level and security of livelihoods amongst the rural population.

Around 20% of Dhone is under forest, much of which is highly degraded, whereas less than 5% of Kalyandurg is under forest. Although precise statistics are not available, indications are that, with the exception of poor quality land, common lands in both mandals have been heavily encroached.

Masonry check dam

Profits per hectare from irrigated agriculture are, on average, twice that from rainfed farming: the lowest profit from an irrigated crop is often higher than the highest profit from a rain fed crop. Cultivation of some crops, however, is not economic, and farmers earn income largely because they do not have to buy the inputs they require. Although the large kharif areas under rainfed groundnut are justified by the high relative profits, areas under other crops do not generally correlate with the net returns per hectare. Crops with high returns (e.g. mulberry, onions, vegetables) are grown on comparatively smaller areas because of local factors such as access to market, high cultivation costs, production risks and lack of local storage and processing facilities. Food crops (e.g. jowar), on the other hand, are grown on larger areas than might be expected, given their relative profitability. This can be explained by the decision-making of poorer farmers that is geared towards maintaining household food security.

Investment in borewells

Failed borewell investments as a result of groundwater depletion have become an important cause of indebtedness and poverty. Growing inequity in access to groundwater is also fueling a process of social differentiation which impacts directly on the livelihoods of some groups and contributes to the consolidation of power relations within communities.

Tanks and other water bodies

Although there are few natural open water bodies, there are 94 tanks in the two mandals some of which date back several hundred years. Many tanks have been abandoned or are in a state of disrepair with broken bunds and silted beds which are now cropped. The majority of the tanks that are still functioning, have been converted to percolation tanks such that irrigation in command areas relies on groundwater instead of surface water releases from the tank. Inflows to many tanks have declined in recent years as a result of increased water harvesting and groundwater extraction in the tank catchment areas. In many cases, this has had a severe impact on the utility, biodiversity and cultural value of the tanks. In extreme cases, reduced tank inflows have adversely affected the reliability of domestic water supplies. Such severe negative impacts occur when tanks are an important source of recharge for the aquifers used for urban supply and when rainfall is below average.

Villagers collecting water from an agricultural well as a result of failure of domestic wells, Dhone

General Resource Status of Project Watersheds

Rainfall

Although a widely-held view is that average annual rainfall has declined in dry areas of south-western Andhra Pradesh, this view is not supported by analysis of rainfall records. There is, however, an indication that there might be small seasonal shifts and a small increase in rainfall variability.

Groundwater

In both Dhone and Kalyandurg, there has been a dramatic increase in groundwater extraction for irrigation during the last 10 - 15 years. As a result, groundwater levels have fallen and, in Kalyandurg in particular, shallow wells have failed as deep borewells have been constructed and as extraction from deeper aquifers has become the norm. Although the number and density of wells in Kalyandurg and Dhone are similar, levels of groundwater extraction are around 30% higher in Kalyandurg as compared to Dhone. This difference helps to explain why 30% of the wells in Kalyandurg are completely defunct or fail routinely. The figure for well failure in Dhone is around 8%. Well surveys by the district-level Andhra Pradesh Groundwater Department showed that the actual number of wells in each mandal is nearly double the official record. This finding has major implications for estimates of the stage of groundwater development that are based on well statistics (e.g. the GEC-97 Methodology).

Net groundwater extraction for irrigation, domestic and livestock use for Kalyandurg and Dhone was estimated at 11.0% and 8.4% of mean annual rainfall respectively. As the Andhra Pradesh Groundwater Department's estimate of groundwater recharge in this area is approximately 10% of annual rainfall, this suggests that current levels of extraction in Kalyandurg are not sustainable. Analysis of villagewise groundwater extraction showed large differences between villages in both mandals. These can be attributed in part to more favourable hydro-geological conditions in some villages and in part to variations in the historical pattern of development of both ground and surface water resources. This finding illustrates the fact that there is neither equitable access to irrigation between villages nor between households within villages.

Data from the automatic ground water level recorder installed in Kalyandurg as part of the National Hydrology Project do not correlate well with the findings of the Andhra Pradesh Groundwater Department's survey in this mandal. This can be explained by the fact that the recorder is sited in an area with a relatively low level of groundwater extraction. Also the actual location of this recorder (as with many others) was chosen primarily on the basis of security. The broader implication is that automatic water-level recorder information should be used with extreme caution when assessing regional impacts of, say, watershed development on groundwater status.

Fluoride levels in groundwater in excess of permissible limits were found in many drinking water sources in both mandals. The Bureau of Indian Standards set a maximum permissible fluoride concentration in domestic water of 1.0 ppm. However, concentrations of up to 1.5 ppm are considered to be acceptable in the absence of an alternative safer source. Although a reasonable level of awareness of fluoride problems exists at the village and district levels, a laxness was noted in the way in which fluoride permissible limits are being used by departments responsible for drinking water supplies. A consequence is that action is not taken even when fluoride concentrations are well in excess of 1.5 ppm. A subsequent, more detailed fluoride survey that was carried out by the WHiRL Project in some villages in Kalyandurg indicated that fluoride concentrations in domestic water sources are being under-reported in official statistics. This study also showed an average increase in fluoride concentrations of around 30% in domestic water sources during the 2002/2003 drought.

The overall conclusion of the "groundwater" component of the Audit is that the scope for developing additional groundwater resources in both mandals is limited and, in much of Kalyandurg, groundwater is already severely over-exploited. This conclusion does not agree with a recent statewide groundwater survey carried out by the Andhra Pradesh Groundwater Department. This difference of opinion can be explained by the fact that the statewide survey used "official" figures for irrigated area and well numbers that appear to hugely underestimate the situation on the ground.

Surface Runoff

Data from gauging stations operated by the Central Water Commission indicate that annual surface runoff at the large watershed scale in Anantapur and Kurnool is somewhat lower than is often reported or than accepted wisdom would suggest. Although there is large inter-annual variation, average annual runoff as a percentage of rainfall is in the range 1% to 8% for the Chinnahagari, Pennar, Hundri, Chitravati and Vadavathi rivers. Although runoff for individual or sequences of rainfall events is often higher, as is runoff at the plot and field scale, this finding indicates that, in the absence of inter-basin transfers, the scope for augmenting water resources in these mandals by damming, diverting or pumping water from local rivers is quite limited. The low values of runoff are not surprising given the physical characteristics of the region and the large number of tanks, check dams and nala bunds that existed before the APRLP started watershed development work in these districts.

Status of domestic water supplies

Participatory assessments were made of the status of the 225 and 438 domestic water points (hand pumps and public taps) in Dhone and Kalyandurg respectively. The following factors were considered when classifying each water point as being satisfactory or as having a problem: functionality (i.e. no technical problems), distance to water point (i.e. less than 1.6 km), crowding (i.e. less than 250 people using the water point), adequacy of supply (i.e. 40 lpcd available 365 days/year), peak summer availability (i.e. similar time and effort needed to collect water in peak summer), accessibility (i.e. no social exclusion), and water quality (i.e. acceptable from users' viewpoint). These factors and permissible limits are similar to those used by the Rajiv Gandhi National Drinking Water Mission. The rather startling finding was that 51% and 24% of domestic water points in Kalyandurg and Dhone respectively were classified, by the users, as having a problem. In addition to showing the wide variety of problems faced by domestic water users, these figures compare starkly with official statistics which suggest that, at any one time, there are few problem water points in these mandals.

Participation of the poor and women in meetings

Assessment of the participation of the poor in village-level meetings showed that, in Kalyandurg, the poor were much more likely to attend meetings and influence decisions affecting them than was the case in Dhone. The high level of empowerment of the poor reflects well on the work of an NGO, namely the Rural Development Trust, which has been working in this mandal for more than 25 years. Less encouraging was the fact that the participation of women in meetings appears to be weak in both mandals. This finding implies that a lot of effort will be required if women are to be become, under APRLP and similar programmes, effective "agents of change".

Self-Help Groups

Participatory assessment of the water-related functionality of self-help groups showed that, while they have been successful at empowering members and in thrift and credit activities, they have little influence on or interest in water-related decision making.

Performance of Gram Panchayats

Participatory assessment of the water-related performance of panchayats showed that there is considerable variability in their effectiveness. Interestingly, an inverse relationship between panchayat effectiveness and community action was observed in that community action was more prevalent wherever panchayats were weak and/or ineffective.

Social discrimination

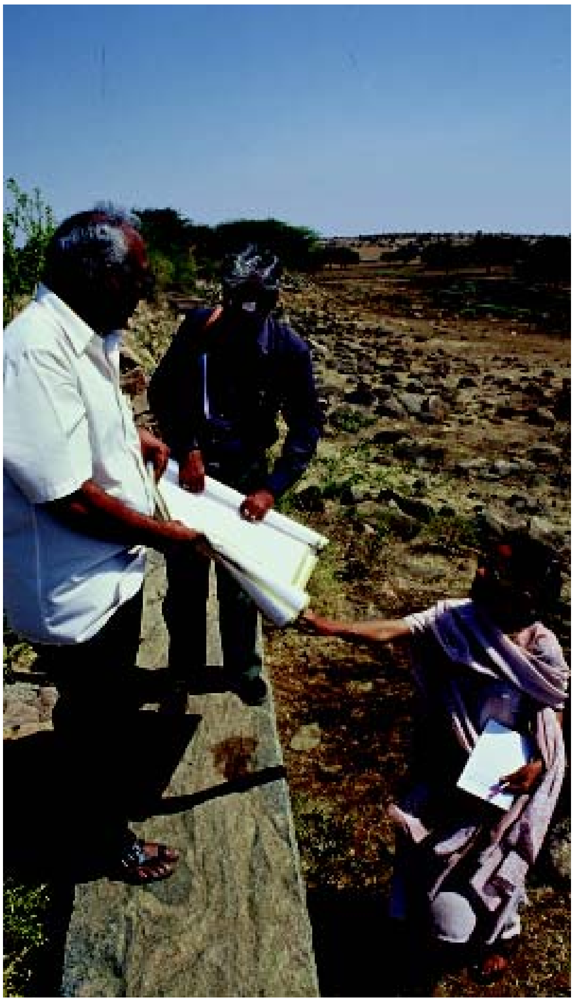
Water-related social exclusion is a deeply-ingrained fact of life in many villages in these mandals. Although the government has installed separate water points for different social groups in an attempt to minimise this problem, discrimination persists, especially when water points go dry during peak summer months. The discrimination identified in participatory assessments falls into two main categories. Firstly, prohibition on Scheduled Castes and Scheduled Tribes directly accessing water from open wells and, secondly, forced preference of 'upper' castes at water points meant for 'lower' castes.

Information from the participatory assessments also showed that, in many villages, a large amount of additional effort is required to collect even reduced amounts of water during peak summer. The additional effort and associated drudgery, in the form of longer queuing times and greater distances walked, has a disproportionate impact on the lives of women and children as in most households they take primary responsibility for fetching and carrying water from water points.

Challenges and constraints

As a sustainable livelihoods project, the APRLP is attempting to develop and promote policies and practices that meet the sometimes conflicting challenges of improving productivity, sustainability and equity. Key challenges include identifying and promoting resource management practices and policies such that:

- **There is an overall increase in production in project watersheds and a concurrent improvement in the livelihood assets of poorer social groupings;**
- **Resource extraction and use do not lower the future availability of resource endowments (e.g. as a result of deteriorating water quality, increased groundwater extraction in the areas in which over-exploitation is already taking place, upstream development of resources at the expense of downstream users or *vice versa*);**
- **Access, entitlements and patterns of resource extraction meet basic needs for drinking water as well as providing opportunities for land-based and non-land-based income generation;**
- **Vulnerability of the poor is diminished; in particular, their vulnerability to external shocks to their livelihoods, due to the environment (e.g. droughts and floods) and due to social and political change.**



Surveying Battuvani Palli tank, Kalyandurg

Raising awareness at all levels of the real nature of water-related challenges in the region needs to be given a high priority. Current watershed development publicity is often misleading in that it suggests that there are quick fixes to water-related problems in semi-arid areas (e.g. check dam construction, contour bunding and tree planting). While these activities have an important role to play, on their own they can only have a limited and mainly localised impact. More importantly, when used inappropriately, these activities can cause negative impacts that may be socially, politically and/or environmentally unacceptable. Unlike higher rainfall areas, the semi-arid areas of southern Andhra Pradesh now only have limited additional resources that can be developed. The challenge, therefore, is to make better use of existing water resources bearing in mind that the majority of changes in resource use or management involve negative trade-offs.

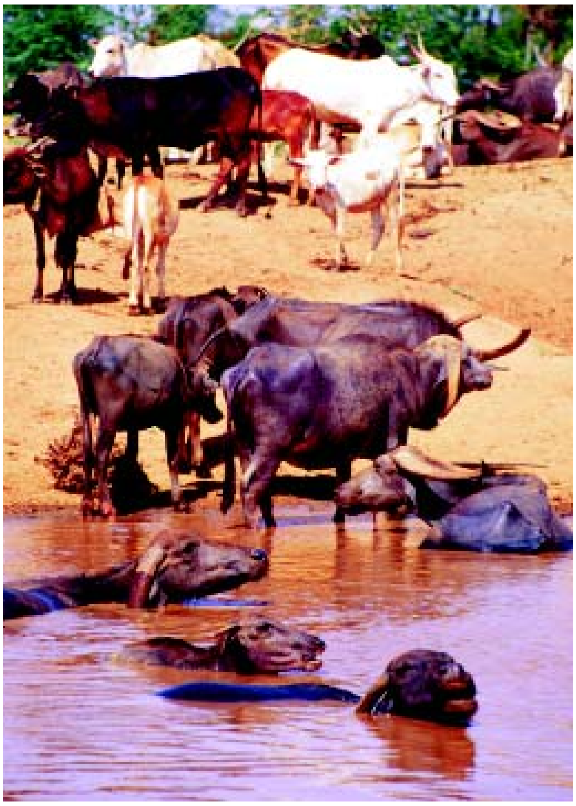
Recommendations

The main recommendations of the Water Audit are as follows:

1. Wider range of options. **Although the Audit findings suggest a rather gloomy state of affairs, one positive conclusion is that there are a large number of water management options that could be promoted by APRLP (over 40 have been identified and listed in the report). All these options have the potential to increase the water use productivity and/or to improve equitable access to water resources. The fundamental need is to consider the trade-offs associated with each option (or sequence of options) and to select options that maximise the social and economic benefits. In most cases, this means giving domestic water supplies the highest priority and then allocating water to uses that have the next highest social and economic value.**

2. Targeting of options. **In general, watershed development programmes and similar initiatives do not target activities to appropriate physical, social and institutional settings. Or put another way, such programmes tend to use a "one-size fits all" approach. An alternative approach, which is described in the report, is to use decision-trees to match interventions and activities to appropriate settings. This approach can and should use a combination of physical, social, economic and institutional data in the decision-making process. Although potentially time consuming, this approach can become simple and rapid if data are readily available (e.g. once a water audit has been completed and a GIS database created) and, preferably, once the approach is incorporated into a more general management information system.**

3. Village-level participatory planning within a wider District Planning Framework. **The aim of proposed District Planning Frameworks should be to tackle issues not covered in village-level planning (e.g. upstream-downstream equity, sustainability of domestic water supplies, protection of rare habitats, drought-proofing, pollution control etc.) and, ideally, they should be based on principles of integrated and adaptive water resource management. Ideally also, consideration should be given to adopting and adapting novel approaches to integrated water resource planning and management that are currently being pioneered in South Africa and are recommended by the Global Water Partnership and others. This recommendation may seem to many like a retrograde return to top-down master planning, however,**



Livestock around Chapari tank, Kalyandurg

it is clear from this study that water resource planning and management is needed at levels above the village if many large scale equity and sustainability challenges are to be addressed adequately.

4. Shift from supply to demand management of water resources. **The results of the study show clearly that the focus of the APRLP and similar programmes should be on resource management as opposed to resource development. This said, demand management is not going to be a panacea and its introduction has many potential unintended consequences, some of which could impact negatively on poorer social groupings. A whole range of demand management options are listed in this report. One of the most important options relates to the essential need to create the policy and legislative environment that provide incentives for more productive use of water by individual users and disincentives for practices that are wasteful or lead to environmental degradation. However, changing current attitudes and behaviour is not going to be an easy task, particularly as many recent and current state-level policies (e.g. grants for well construction, subsidised electricity for pumping irrigation water, support prices for paddy rice) have had the unintended consequence of encouraging inefficient and inequitable use of water.**

5. Use of GIS-linked rapid participatory assessments as part of the M&E of rural water supply programmes. **The Water Audit has revealed a major disparity between official statistics and the users' view of the status of domestic water supplies. One reason for this disparity is the strong emphasis of current M&E on the functioning of infrastructure and the meeting of supply norms (i.e. 40 lpcd). Many of the other problems faced by users are ignored by the M&E systems. However, these additional problems can be considered, and appropriate steps can be taken if routine M&E systemstake users' views into account. Incorporating and presenting this information using a GIS database is one way of processing and presenting the relevant information in a form that can easily be assimilated and acted upon by decision makers at all levels.**

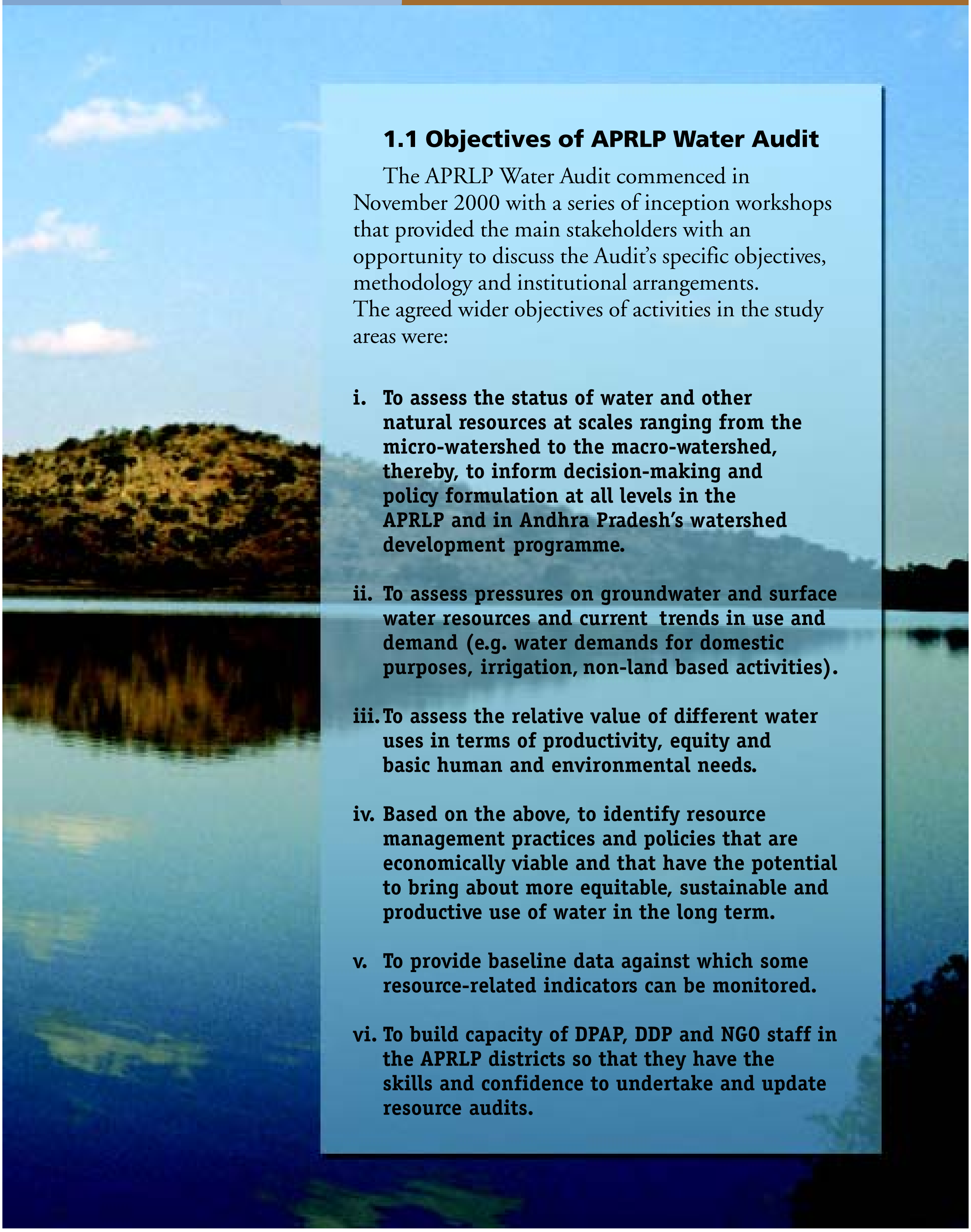
6. Reassessment of "official" water-related statistics. **Finally, survey work carried out primarily by government departments has shown huge discrepancies between "official" statistics and the reality on the ground with regard to area under irrigation, well statistics, stage of groundwater development and status of domestic water points. Hence it is recommended that further checks on relevant official statistics be carried out, possibly using procedures used by the Water Audit team. This work is needed urgently because these statistics underpin policies relating to: groundwater development, NABARD loans, power sector reform, protection of rural water supplies, river basin management and irrigation development. Findings from the Audit have also shown that certain beliefs that underpin the watershed development programmes (e.g. annual runoff is 30-40% of annual rainfall) need to be re-evaluated.**

Concluding Remarks

The Water Audit has shown that in the study areas demand for water is outstripping supply and that scope for augmentation is limited. Although the water resource situation in this area is extremely serious and arguably at crisis point for many villages, there is much that can be done. However, it cannot be stressed enough that there are no quick fixes to the complex challenges facing people in the semi-arid areas of Andhra Pradesh. Policies and practices are needed that are based on accurate information and that seek long-term solutions. Finally, it is strongly recommended that a plan be developed and implemented for the capacity building that is needed at all levels if effective integrated water resource management policies and programmes are to be developed and implemented in Andhra Pradesh.

Lifting a rainfed groundnut crop in Kalyandurg

1 Introduction



1.1 Objectives of APRLP Water Audit

The APRLP Water Audit commenced in November 2000 with a series of inception workshops that provided the main stakeholders with an opportunity to discuss the Audit's specific objectives, methodology and institutional arrangements.
The agreed wider objectives of activities in the study areas were:

i. To assess the status of water and other natural resources at scales ranging from the micro-watershed to the macro-watershed, thereby, to inform decision-making and policy formulation at all levels in the APRLP and in Andhra Pradesh's watershed development programme.

ii. To assess pressures on groundwater and surface water resources and current trends in use and demand (e.g. water demands for domestic purposes, irrigation, non-land based activities).

iii. To assess the relative value of different water uses in terms of productivity, equity and basic human and environmental needs.

iv. Based on the above, to identify resource management practices and policies that are economically viable and that have the potential to bring about more equitable, sustainable and productive use of water in the long term.

v. To provide baseline data against which some resource-related indicators can be monitored.

vi. To build capacity of DPAP, DDP and NGO staff in the APRLP districts so that they have the skills and confidence to undertake and update resource audits.

1.2 Selection of study mandals

The APRLP Water Audit was carried out in two mandals, namely, Dhone mandal in Kurnool district and Kalyandurg mandal in Anantapur district (see Figure 1). Criteria for selecting these mandals included representativeness and the potential availability of NGO support. Final selection was made from short lists provided by the DPAP and DDP Project Directors. The mandal scale (i.e. approximately 400-500 km^2) was selected because it was felt that this would provide findings that would give a good insight into issues of scale (e.g. upstream-downstream competition for water). It was decided also that this would be a good scale to work at whilst training and capacity building had a high priority and whilst new data collection procedures were being piloted.

Administrative units, rather than physical units (i.e. watersheds), were chosen as the main units for carrying out the Water Audit because much of the data are available on a villagewise basis and much resource-related management and decision-making has to take place on the basis of administrative units. However, relevant analysis was carried out using physical units whenever necessary (e.g. analysis of surface runoff).

Kocheruvu village, Dhone

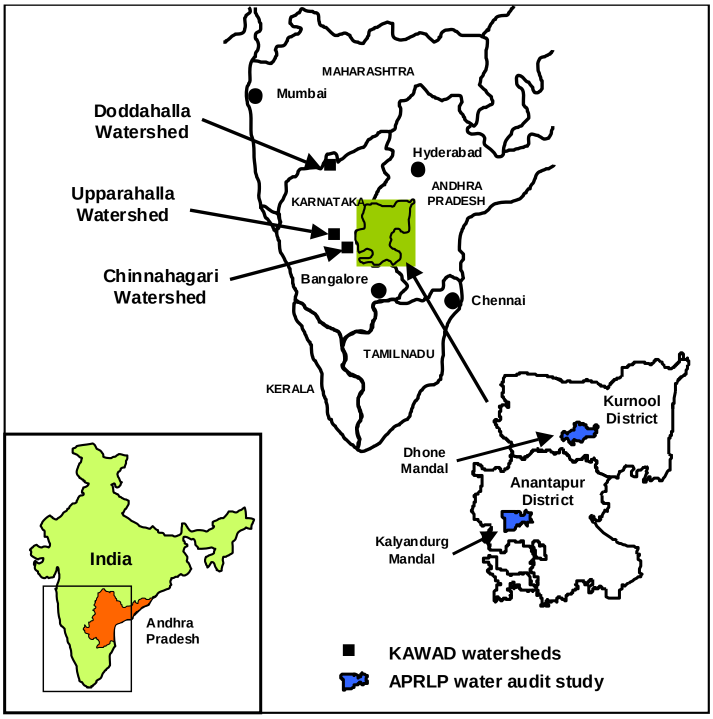


Figure 1. Location of APRLP and KAWAD Water Audit study areas

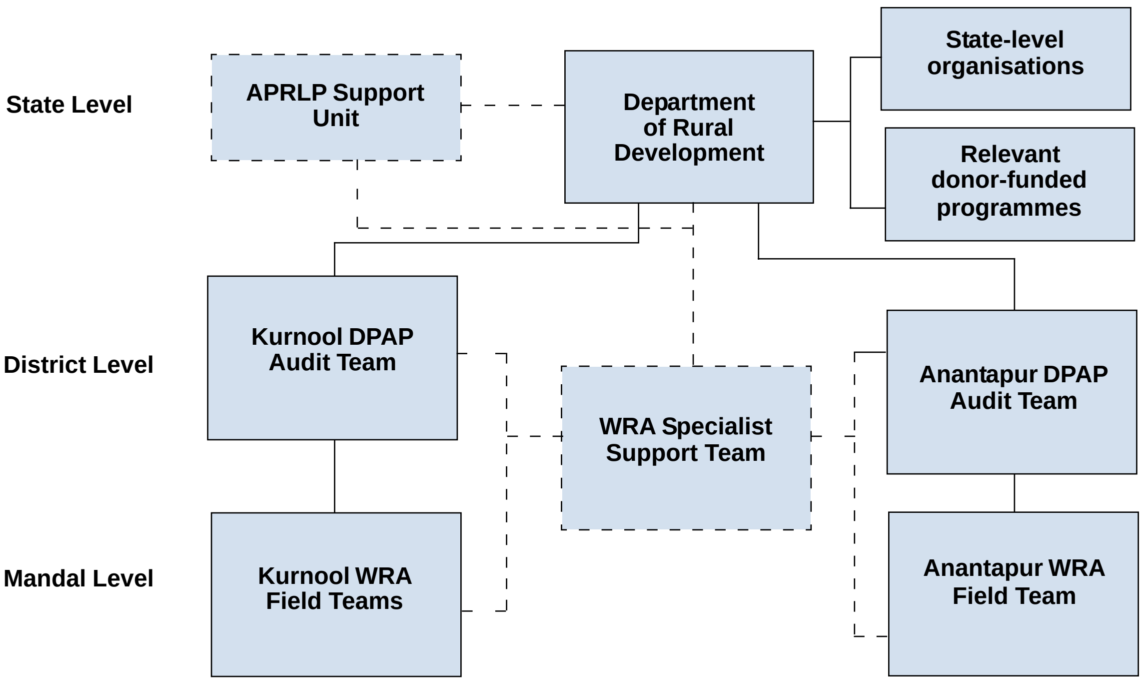
Dry season paddy cultivation in Dhone

Buffalo wallowing in urban waste water, Kalyandurg

1.3 Institutional arrangements

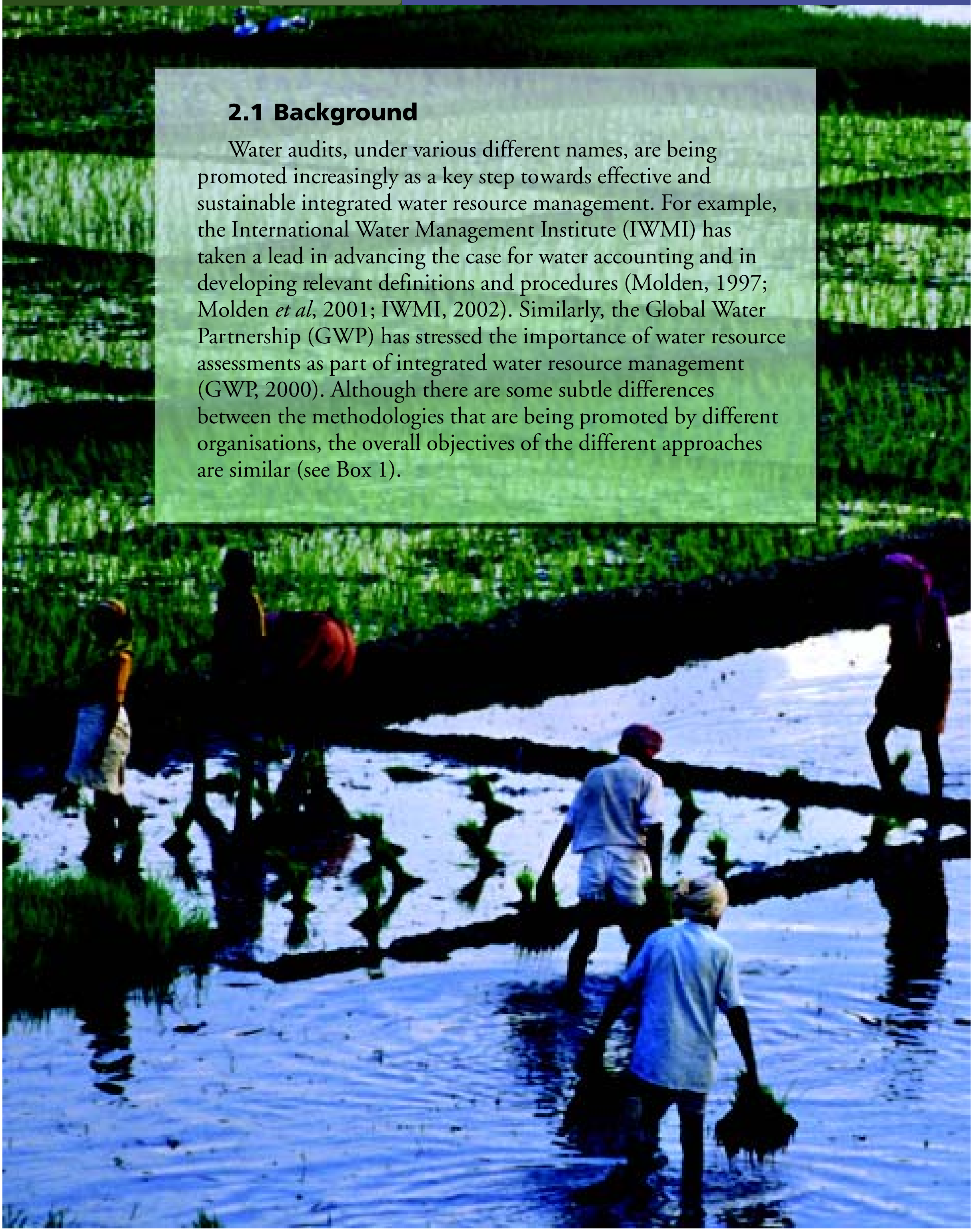
The APRLP began in the second half of 2000 with the establishment of a Project Support Unit at the state level and District Capacity-Building Centres in each of the five districts[1]. Given the APRLP's emphasis on capacity building, it was decided that the Water Audit would be implemented by GoAP line departments with support being provided by a specialist support team (see Figure 2). The logic was that active involvement in the Water Audit of, in particular, district-level staff would build their capacity so that they would be able to scale up the water auditing to other mandals and districts. However, as will be discussed, this approach did not prove to be entirely successful and the bulk of the work, particularly during the latter stages of the Audit, was carried out by the specialist support team. This team was comprised of staff from the Central Soil and Water Conservation Research and Training Institute (Bellary), staff from the Land Use Section of the National Remote Sensing Agency, Dr Snehalatha and Mr Sundar Raman (both of whom subsequently joined APRLP District Capacity-Building Centres), Dr J Seeley (University of East Anglia), Dr J Butterworth (Natural Resources Institute), Dr A J James (Environmental Economics consultant) and Dr C H Batchelor (Hydrological consultant).

Figure 2. Institutional arrangement of the APRLP Water Audit



1 Up-to-date information on the programme can be found on: www.aplivelihoods.org

2 Methodology



2.1 Background

Water audits, under various different names, are being promoted increasingly as a key step towards effective and sustainable integrated water resource management. For example, the International Water Management Institute (IWMI) has taken a lead in advancing the case for water accounting and in developing relevant definitions and procedures (Molden, 1997; Molden *et al*, 2001; IWMI, 2002). Similarly, the Global Water Partnership (GWP) has stressed the importance of water resource assessments as part of integrated water resource management (GWP, 2000). Although there are some subtle differences between the methodologies that are being promoted by different organisations, the overall objectives of the different approaches are similar (see Box 1).

Box 1. Why carry out a water audit?

Because a water audit can:

- **Identify the current status of water resources at different scales and trends in demand and use;**
- **Provide information on access and entitlements to water and the trade-offs that have resulted or will result from different patterns of water use;**
- **Provide information on social and institutional factors affecting access to water and reliability of water supplies;**
- **Help identify externalities which only become apparent when the patterns of water use are considered at the macro temporal and spatial scales;**
- **Provide information that is required for assessing efficacy of existing water-related policies;**
- **Identify opportunities for saving or making more productive and/or equitable use of water;**
- **Identify the effectiveness of current drought and flood coping strategies;**
- **Identify potential problems resulting from competing or multiple uses of water;**
- **Assess the accuracy of government statistics;**
- **Identify the extent to which decision-making is based on hydrological myths or misconceptions.**

Survey team working with a villager from Lakshmipalli, Dhone

The concept of water auditing is based on the argument that knowledge of the current status of water resources and trends in demand and use is a precondition for successful water management. Equally important, an understanding of factors affecting patterns of access and entitlement to water resources is fundamental in any projects that seek to improve and protect the livelihoods of poorer social groups. Effective water auditing implies a holistic view of the water resources situation and its interaction with societal use. This includes: 1) addressing the occurrence of surface and ground water, in space and time, and, in particular, assessing levels of sustainable use and the frequency of extreme events such as droughts and floods; 2) providing a tentative assessment of the demand trends for different uses; 3) identifying the main driving forces influencing demand and use (e.g. government policy, societal behaviour); 4) assessing the functionality and effectiveness of institutions charged with developing and managing water resources; and, 5) understanding factors that affect access and entitlements to water for both domestic and productive uses.

2.2 Sources of information

Although the Water Audit used quality-controlled secondary information wherever possible, primary data collection was carried out to fill gaps and to collect additional data. Agreement on the need for and the methods of collecting these additional data was reached during three inception workshops. Compared to many countries, relatively large quantities of hydrological, geological, agricultural, social and other information is collected routinely in India at the national and state levels by government and non-government organisations. Unfortunately, these data are not always easily accessible or utilisable for reasons that include:

- **Data are fragmented in that they are held by different organisations and, in some cases, by different departments or individuals within these organisations;**
- **Spatial and non-spatial data are stored in a wide range of formats (e.g. maps, remotely-sensed images, tables of figures, text, graphs, etc.) and media (e.g. in year books, on computer disks etc.);**
- **Spatial and temporal scales at which data have been collected are not at all consistent;**
- **Data quality is extremely variable.**

Box 2. APRLP Water Audit design philosophy

1. **Make maximum use of secondary baseline information (e.g. soil maps, remotely-sensed data, etc.) and resource monitoring information (e.g. rainfall records, groundwater levels, agricultural statistics etc.) that has been or is being collected by government line departments and other organisations;**
2. **Adopt an approach that builds on experience gained during the KAWAD Water Audit and, in particular, include systematic collection of social and institutional data;**
3. **Use GIS software to consolidate spatial information and, where necessary, reconcile differences between administrative and physical boundaries;**
4. **Ensure maximum involvement of specialists that are either based in the APRLP districts or have long experience of working in this area;**
5. **Encourage the active involvement of GoAP line department staff.**

2.3 Collection and quality control of "terrestrial" physical data

A major feature of the APRLP Water Audit was the consolidation of spatial and non-spatial data from a wide range of sources onto geographical information system (GIS) databases (see Figure 3). Some groundtruthing and gap filling was carried out during the collection process and further quality control checks were carried out once the database was established. A major part of the quality control process was the inter-comparison of data and statistics from different sources and analysis and discussions aimed at understanding the reasons for disparities. This is arguably the key step in a water audit as it also involves assessing whether data support accepted wisdom relating to the development and management of water resources.

In Kalyandurg, line department staff were not readily available, hence field data collection was carried out primarily by field teams assembled by Mr Sundar Raman (Anantapur Water Resource Audit coordinator) or by CSWCRTI staff. Each field team consisted of an Engineering Diploma holder, a field assistant and a local villager who was preferably the village *thalarry* or *etti*. Assistant geologists of the Ground Water Department under the guidance of Mr G V Reddy (Deputy Director, Andhra Pradesh Groundwater Department) carried out the well survey. In Dhone, field data collection was carried out primarily by line department staff with CSWCRTI staff undertaking some specialist tasks. This arrangement, although potentially good for capacity building, led to many delays (see Box 3).

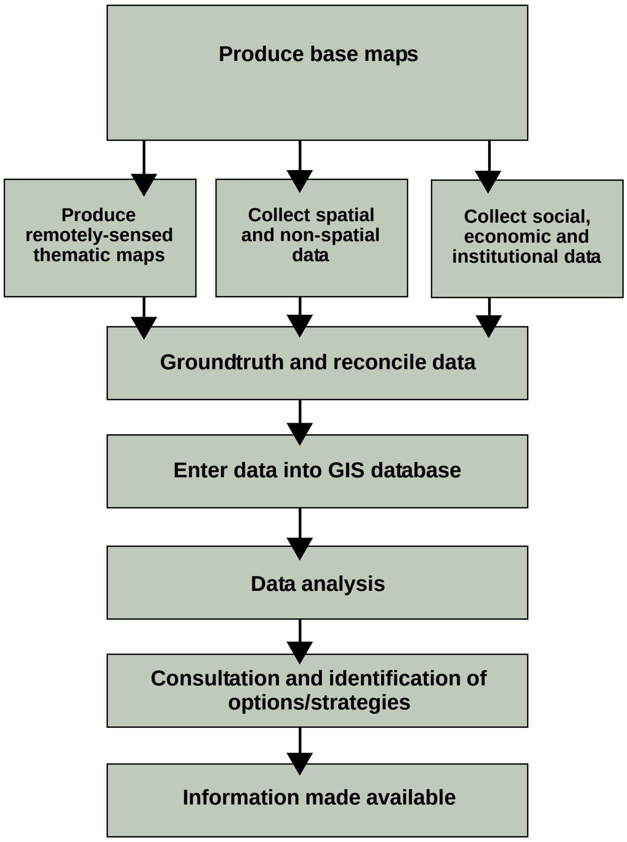


Figure 3. General procedure for collecting, quality controlling and processing information

Some cadastral maps of the villages were available in Kurnool and Anantapur whereas others had to be purchased from the Survey of India in Hyderabad. Photocopies of relevant cadastral maps were used by survey teams as base maps for marking the location of point features such as wells and check dams. At the same time, GPS handsets (Garmin 12XL, USA) were used to record the latitude and longitude of these features.

In Kalyandurg, the gully survey teams walked along each and every gully collecting data relating to the gully dimensions every 200-300m. For each survey point, the latitude and longitude were recorded, the point was marked on the relevant cadastral map and the nearest survey number was recorded on the relevant proformas. The condition of each gully such as whether it was under cultivation, levelled or flat was also recorded. All the water harvesting structures such as masonry check dams, earthen bund or rock fill dams were also surveyed and their effectiveness and condition noted. Regarding the tanks or percolation tanks, the conditions of bund, sluice, weir and feeder channel were collected during the survey along with year of construction, cost, potential command area, area irrigated during the year 1999-2000 and water spread area. It was possible to collect some of this information from the Panchayat Raj and Minor Irrigation Departments. For each revenue village the time taken was between 5 to 10 days based on the size of the village. A similar procedure was followed in Dhone.

Box 3. Lessons learnt during the information collection and groundtruthing phase

Many delays were experienced during the collection and groundtruthing of terrestrial data. Reasons (in approximate order of importance) included:

- Delays in transfer of APRLP funds to the field teams**. These funds were needed to pay for transport, DAs, fieldwork equipment etc. As the Water Audit was one of the first APRLP field activities, the modalities of getting funds from DFID to GoI to GoAP to the DRD and then right down to the field teams had not been tested previously;**

- Delays in letting the contract for processing remotely-sensed data and digitising spatial terrestrial data**. Internal problems affecting APSRAC meant the contract had to be switched to NRSA. Delays were then caused because, at that time, APARD did not have the authority to let contracts;**

- Delays caused by the workload of DPAP/DDP staff**. These staff can be particularly busy when central funds are released. It should be noted also that Water Audit activities were given a relatively low priority by some individuals and groups;**

- Availability and accessibility of secondary data. **In some district-level departments complete sets of maps, reports, non-spatial data are readily available but not in others;**

- Perception that the Audit requires only primary data to be collected. **Convincing some team members that the aim of the Audit was to groundtruth and use secondary data wherever feasible was not successful;**

- Recruitment of a person to work in Anantapur and to take responsibility for the Audit**. The recruitment of Mr Sundar Raman delayed work in Anantapur. Further delays were then caused by Mr Sundar Raman being allocated regular DDP tasks;**

- Delays in the purchase of 2 PCs and GPS equipment. **This problem was also linked to teething problems related to the transfer of APRLP funds.**

Although this list may give a rather negative impression, the positive message is that decisions and actions taken at all levels meant that ways were found around all the problems listed. A lot of experience was gained that will help any follow-up audits and, possibly, the implementation of other APRLP activities at the district and mandal levels. This said, it is recommended that data collection and groundtruthing in any further audits is either carried out by line department staff who are relieved from other duties until the work is finished or contracted out to the private sector.

For the well surveys, staff of the Andhra Pradesh Groundwater Department (APGWD) with the help of villagers visited all the wells in the village area and collected data that included: type of well, use of well, dimensions of well, year of construction, area irrigated, pump capacity and discharge of well, reliability of well, latitude and longitude and survey number. Water samples were collected from each well and sent to the CSWCRTI or APGWD laboratories in Kurnool in the cases of Kalyandurg and Dhone respectively. Follow-up water sampling and fluoride analysis were carried out in four villages in Kalyandurg by staff involved in the WHiRL Project.

In the main, cropping statistics were collected from the Mandal Revenue officer. Details of land holdings were collected from the National Informatics Centre. Rainfall data were collected from the Andhra Pradesh Groundwater Department and Chief Planning Officers in Kurnool and Anantapur.

2.4 Analysis of remotely-sensed data

Cloud-free satellite data of February-March 2001 of Indian Remote Sensing Satellite (IRS)-1C/1D (PAN and LISS-III) were used as the main source of remotely-sensed data. Once analysed, these data were reconciled with the relevant terrestrial spatial data. Final mapping was done on 1:50,000 scale. Cadastral maps at the 1:8,000 scale were digitised and mosaics of these were created to extract the village, cadastral and mandal maps. Well locations, drainages patterns, check dams, gullies and embankments were also digitised from cadastral maps which had been annotated by the field teams. Watersheds, sub-watersheds, mini-watersheds and micro-watersheds were delineated and digitised using the Survey of India topographical maps.

The land use/land cover themes were prepared using the following data analysis procedures. Onscreen interpretation (based on tone/colour, texture, pattern, shape, size, location, shadow, association) of satellite image and its digitisation was performed using Erdas Imagine Software. Before interpretation and analysis of the satellite imagery, the satellite image was rectified and resampled using a 1st order polynomial transformation model and a bilinear interpolation algorithm respectively. To perform the same, the ground control points were taken from topographical maps and used with relevant GPS data sets to achieve sub-meter RMS accuracy. For better interpretation, high resolution capability of PAN data and multi-spectral advantage of LISS-III data were fused using Brovey Transformation Model and Bilinear Interpolation resampling algorithm to generate the merged image. This merged image was used for interpretation/ analysis. The steps taken are presented schematically in Figure 4.

Village meeting in Battuvani palli, Kalyandurg

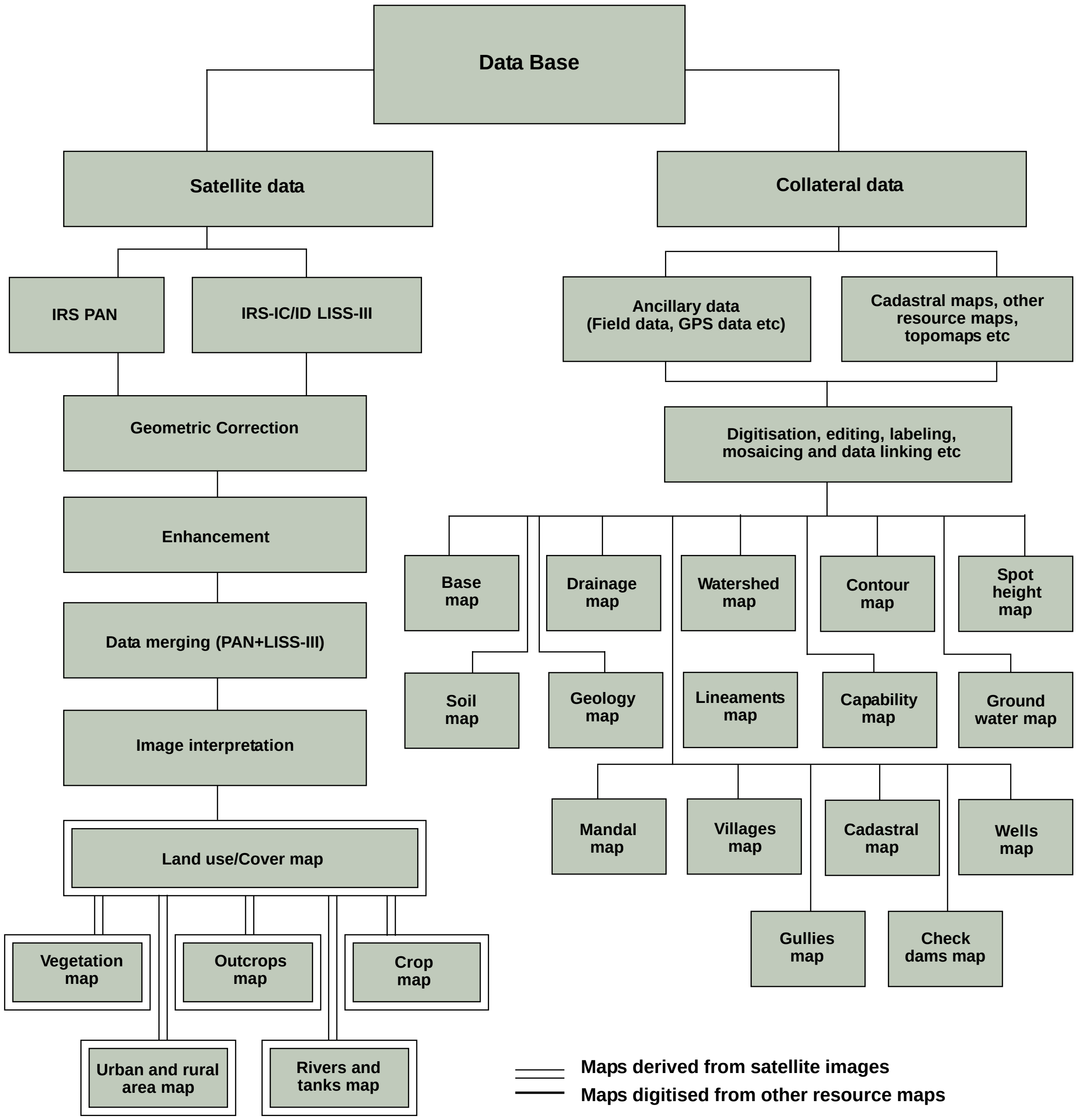


Figure 4. Procedure for processing and reconciling spatial data

Watersheds were delineated using the delineation procedure adopted by All India Soil and Land Use Survey (AIS & LUS) and National Remote Sensing Agency (NRSA) for the project on wastelands mapping of India. The coding used an 8-stage hierarchical approach starting from water resource region (average size 550 lakh ha.), basin (95 lakh ha.), catchment (30 lakh ha.), sub-catchment (7 lakh ha.), watershed (1 lakh ha.), sub-watershed (0.15 lakh ha.), mini-watershed (0.05 lakh ha.), micro-watershed (0.005 lakh ha.). The delineation of different boundaries was carried out by considering factors such as river morphology, drainage and slope/elevation.

Eight digit alphanumeric symbolic codes were allocated for all polygons by adopting an alphanumeric system as per the Natural Resource Information System (NRIS) guidelines.

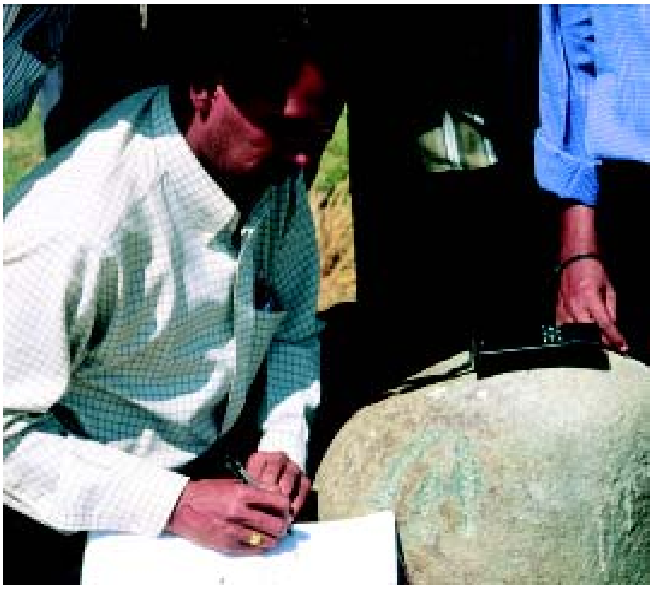
The field data and GPS collected data were linked to the respective spatial database of Record of Right (ROR) and relevant field data. To link non-spatial data to the spatial database, the primary database key (linking code) for wells, check dams, gullies and embankments was defined with respect to mandal villages. After defining the primary key, the non-spatial database was linked using GIS database relational utility.

Box 4. Lessons learnt using GPS handsets

GPS handsets were used by field teams as one of the methods for determining the location of features such as check dams and wells. Unfortunately, the data collected proved to be inadequate for most Audit purposes. Primarily, this was because the system's "antispoofing" system was operative during the Water Audit. Consequently, the accuracy of the GPS handset readings was of the order of ± 10-20 m. Shortage of handsets also resulted in the Kalyandurg team using GPS handsets produced by different manufacturers. This introduced additional uncertainty in the measurements. It is recommended in future that audits use differential GPS to improve the accuracy of measurements and equipment of the same specification purchased from only one manufacturer.

2.5 Collection and analysis of social and institutional information

Quantified Participatory Assessment (QPA) was used as the main method of collecting water-related social and institutional information. This method collects qualitative information using conventional rapid-rural appraisal tools (e.g. transect walks and focus group discussions) and uses descriptive ordinal scoring to convert this information into numbers. In both mandals, following pre-testing and training, a field team comprising both men and women spent one day in each village. After a community-leaders' meeting in the morning, the field team of 6-12 people split up and undertook group work.
In the smaller groups, villagers undertook tasks that included drawing a detailed social map (marking all poor and non-poor households, and water points in the habitation); assessing the functionality of all SHGs in the village; filling in a



Using GPS equipment to mark the location of village boundary stone, Dhone

questionnaire on household water use; and, confirming the accuracy or otherwise of the information provided by the community leaders. At the end of the day, the entire team presented the findings at a Gram Sabha, where the purpose of the assessment was re-iterated and the collected information was verified.

Reasons for choosing this form of participatory assessment included:

- Large sample size: **All 100 habitations of Dhone and Kalyandurg mandals had to be covered in a short space of time (i.e. 3 months) at an acceptable cost. A low cost was required because it was envisaged that assessment would be repeated as part of the APRLP's M&E programme.**
- Both qualitative and quantitative information were required.
- GIS-compatible information was needed**: The qualitative and quantitative information collected were to be combined in the GIS database with the more "technical" information that was being collected by other people and groups involved in the Water Audit.**

Following the fieldwork, numerical information was entered either into Excel spreadsheets or into an Access database and supporting qualitative information was recorded in a village report. Considerable discussion then went into developing different formats for presenting the data as part of GIS layouts and incorporating it in the development of decision-making tools such as decisions trees.

2.6 Economic data collection and analysis

Proformas were developed for collecting data on the profitability of both rainfed and irrigated crops and a sample of farmers was interviewed in each mandal. The resulting data were then used to undertake both financial and economic analysis of different crops and cropping systems. Additional supporting information was collected on the relative profitability of non-landbased activities, the role of livestock, proximity to markets and drought coping strategies.

Simple economic analysis was also carried out on the ability of farmers to service loans on borehole investments and the levels of risk that, in particular, small and marginal farmers have been taking when developing new wells.

Box 5. Lessons learnt during fieldwork

It would have been better if the gully survey, well survey and other "technical" fieldwork had been carried out in conjunction with the QPA surveys. This would have improved the participation and awareness at the village level and generated higher-quality information. Although this had been the original plan, logistical problems and delays in the transfer of funds resulted in a fragmented approach being taken. However it is strongly recommended that a combined coordinated approach be used in any further audits.

2.7 Water balance calculations

Water balance calculations were used to assess the status of water resource availability, with particular attention being given to evaluating the impacts of land use change, groundwater extraction and water harvesting structures on temporal and spatial patterns of water resource availability and use. The initial step in performing the water balances was to specify the spatial and temporal boundaries of the domain of interest. For example, individual tank systems bounded by the catchment and command area were considered to be a domain bounded in time by a particular growing season. Conservation of mass requires that, for the domain over the time period of interest, inflows are equal to outflows, plus any change of storage within the domain. Although many components of the water balance were difficult to estimate, establishing water balances was possible using data that were readily available. Results were cross-checked with the often qualitative observations and experiences of specialists and local people working and living in the areas of interest. Cross-checks were also made by comparing results with the results from research studies that had been carried out in the region (e.g. the Chinnatekur Watershed Study [Rama Mohan Rao et al, 1995]).

Separate water balance calculations were made for: groundwater extraction for irrigation, domestic and livestock uses; actual evaporation from irrigated, rainfed arable, wasteland and forested areas; and, groundwater recharge.
In the case of groundwater recharge the GEC 97 methodology and the methodology described in Box 6 were used.

As a caveat, it must be stated that there are uncertainties in the absolute values presented in this report and it can be anticipated that these uncertainties will be reduced as more reliable data become available. However, as the same methodologies were used when working with each domain type (e.g. annual water balance of a village area), relative differences can be used with a reasonable level of confidence.

Silt excavation from Chapari tank, Kalyandurg

Box 6. Estimation of annual average recharge

Recharge estimates were made using the simple water balance equation:

$$R = Q_p + Q_a + R_d + E_t + B_f - \Delta s$$

Where: R was annual groundwater recharge, Q_p was groundwater pumped from wells, Q_a was aquifer throughflow, R_d was recharge to deep aquifers, E_t was groundwater extraction by deep-rooting vegetation, B_f was the baseflow contribution to streams and Δs was change in aquifer storage.

For the domains over which recharge estimates were made, it was assumed that Q_a was very small. This assumption was based on a knowledge of aquifer characteristics and levels of groundwater depletion. R_d was also assumed to be negligible because extraction is already taking place from the deep aquifers in these domains. E_t and B_f were assumed to be negligible because of low groundwater levels. Δs was also assumed to be small because the tendency during recent years has been for farmers to pump wells until they fail. Hence, recharge was estimated as being equivalent to groundwater extraction for irrigation which, in turn, was estimated using areas under different crops and information gathered locally on actual irrigation application rates for these different crops. In each watershed, drainage was estimated to be 20%, 20% and 10% of water applied during the kharif, rabi and summer seasons, respectively.

2.8 Runoff analysis

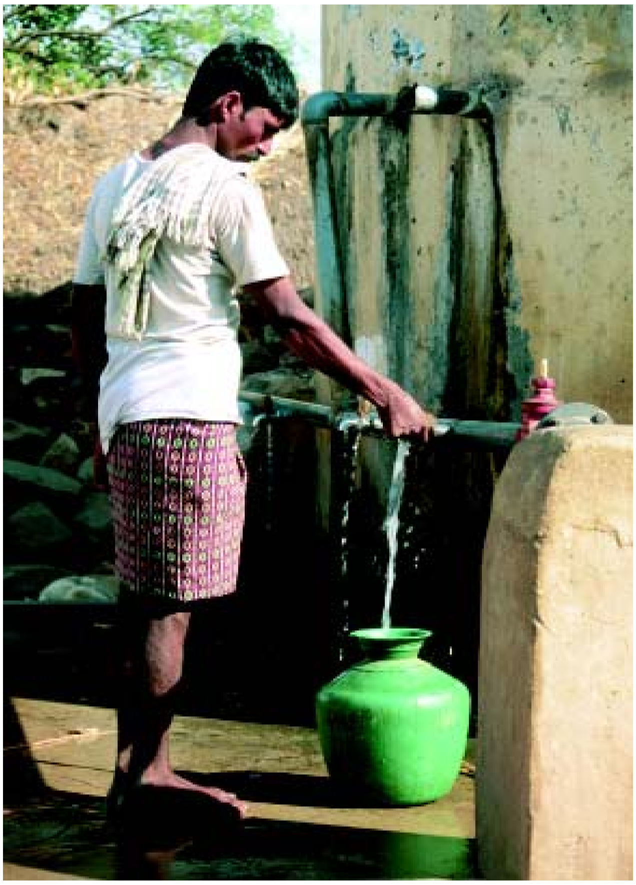
River flow data were collected from the Central Water Commission and other official government sources for seven river basins that drain the south-eastern parts of Andhra Pradesh and neighbouring Karnataka. These data were consolidated into continuous monthly and annual river flow records of 9 to 27 years duration (see Table 1). Contiguous monthly rainfall data were also collated for rainfall stations within the study catchments. Stations with long periods of missing data were excluded from the analysis. Records with only a few months of missing data were patched using data from the nearest adjacent station. A total of 15 stations were used. Areal rainfall values were determined from the individual rainfall records using the Thiessen method.

Table 1. Details of hydrological stations used in runoff analysis

Gauging Station Code	River/ Site name	River Basin	Start of record	End of record	Catchment area (km²)
12A	Chinnahagari at Amkundi Bridge	Krishna	Jun-80	May-98	2206
11A	Vadavathi at Bhupasamudram	Krishna	Dec-78	May-98	15326
95	Hundri at Lakshmipuram	Krishna	Jun-89	May-98	3592
8N	Pennar at Nagalamadike	Pennar	Jun-78	May-98	4814
41	Pennar at Tadapatri	Pennar	Jun-71	May-98	12558
2N	Chitravathi at Singavaram/ Ellanuru	Pennar	Jun-80	May-95	6301
93	Kunderu at Alladapalle	Pennar	Jun-85	May-98	8736

The impact of intensive water harvesting along drainage lines on tank inflows was estimated using a simple "bucket-type" water balance model. The main aim of this model being to assess the affects of the additional storage created by new water harvesting structures and the relationship between runoff attenuation and different patterns of rainfall. During the Water Audit, runoff analysis was carried out using data from five representative tank catchment areas in southern Andhra Pradesh and north-eastern Karnataka. Runoff estimates were made using a version of the SCS method that has been modified for Indian conditions (see Box 7). The main findings of this analysis were cross-checked against the perceptions and knowledge of villagers and NGO staff living and working near to the five tank systems that were studied in detail. Subsequent to the Water Audit the model was refined by the WHiRL Project and an Excel-based version was developed based on a daily time step. This model was then used to analyse the affects of water harvesting on patterns and availability of runoff in the catchment areas of an additional six tanks in Kalyandurg.

Leaking taps in Kocheruvu village, Dhone



Box 7. Runoff estimation using the SCS method

The SCS method for estimating runoff can be applied to small agricultural catchments. Although it was developed originally using data obtained in the US, the method has been modified to suit Indian conditions (e.g. Singh et al., 1990). The equation governing the relations between rainfall and runoff used in the study reported here was:

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

Where,

- Q = actual runoff (mm)
- P = run-off generating rainfall (mm)
- S = maximum potential rainfall retention (mm)
- I_a = Initial abstraction (0.1S and 0.2S for black and red soils respectively)

The maximum potential rainfall retention was calculated by the equation:

$$S = (25400 / CN) - 254$$

Where,

CN is the curve number taken from Singh et al (1990). (CN falls in the range 1-100. When CN = 100 all the rain runs off and S = 0 and P = Q).

Runoff generating rainfall was calculated using the following equation:

$$P = 0.7R - 21.2$$

Where,

R = daily rainfall (mm).

3 Physical characteristics of of study mandals

3.1 General information

Table 2 provides general facts and figures relating to the two study mandals

General information	Dhone	Kalyandurg
Longitude	77^{0} 39’ - 78^{0} 02’ E	77^{0} 05’ - 77^{0} 22’ E
Latitude	15^{0} 15’ - 15^{0} 29’ N	14^{0} 18’ - 14^{0} 26’ N
Altitude (m)	360 - 650	460 - 780
Average annual rainfall (mm)	560	525
Mandal area (km^2)	487	488
No. of revenue villages	16	15
No. of hamlets	31	36
Population (2001 Census)	102,018	81,105
No. of males/females	51850/50168	41278/39827
No. of literate males/females	31916/19467	24589/16059
Child population (0-6 years)	14085	10604
District decadal pop. growth (%)	18.1	14.3

Table 2. Summary statistics

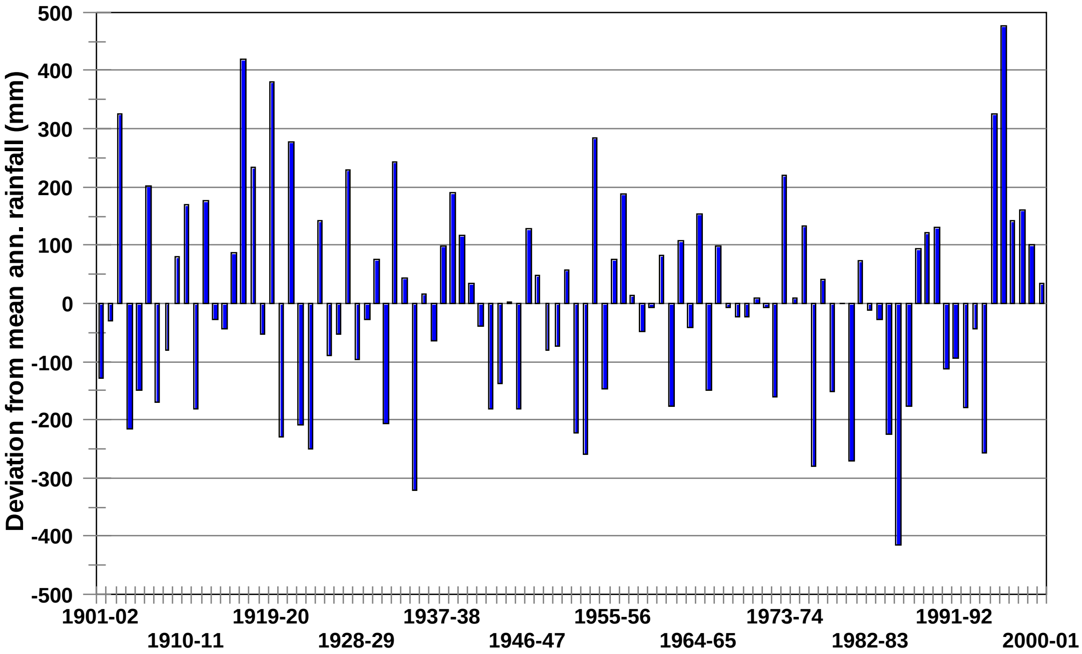


Figure 5. Anantapur deviation in annual rainfall from the long-term mean

3.2 Agro-climate

The climate prevailing in the two mandals is semi-arid to arid. Rainfed agricultural production in south-western Andhra Pradesh is far from easy as monsoon rains are often unevenly distributed and droughts are common. In fact, Anantapur has been listed as the second most drought-prone area in India in terms of rainfall (Hill, 2001). Although Kurnool has generally higher rainfall than Anantapur, Dhone ranks as the driest mandal in Kurnool district. Far from the east-coast, this part of Andhra Pradesh does not receive the full benefits of the north-east monsoon (October to December); and being cut off by the Western Ghats, the south-west monsoon (June to September) is also prevented from fully reaching the district. The south-west monsoon and north-east monsoon rainfall contribute about 57% and 27% of the total rainfall for the year, respectively (Hill, 2001). In climatic terms, the area does not have distinct kharif and rabi seasons as, rainfall permitting, cropping takes place continuously throughout these periods (except on deep black soils).

Using data from Anantapur[2], Figure 5 shows that there is considerable variation in annual rainfall around the average value. In some years during the period 1901-2001, rainfall was as much as 475 mm higher than the average and in others it was more than 400 mm below the average. Extreme inter- and intra-annual rainfall variability is also an important characteristic of the agro-climate of the study mandals. A major challenge facing farmers in this area is the adoption of farming systems that both cope with periods of low rainfall, bearing in mind the fact that meteorological drought is a natural and recurring phenomenon, and capitalise on years of above-average rainfall. The general perception is that in every ten year period, there will be five droughts of different intensities. Two of these droughts will be moderate, two will be severe and one will be catastrophic.

Although a widely-held view is that annual average rainfall has been declining in dry areas of south-western Andhra Pradesh, statistical analysis of 100 years data from 13 stations in Anantapur, revealed that, if anything, average annual rainfall has been increasing, albeit by around 25 mm, throughout the district since the mid-1970s (Hill, 2001). The only station to show a decline during recent years is Kalyandurg (Hill, 2001). Comparison of two periods (1901-51 and 1951-2001) revealed a slight decreasing trend in variability over the whole Anantapur District, with seven of the thirteen stations witnessing decreasing variability. However, decadal analysis indicated that during the most recent decades of 1991-2001 and 1981-91, nine and eleven stations, respectively, faced increasing variability (Hill, 2001).

2 Long-term rainfall data records for Dhone and Kalyandurg are not in good order. In particular, the IMD Kalyandurg rainfall records for the period 1901-1950 are clearly for another station.

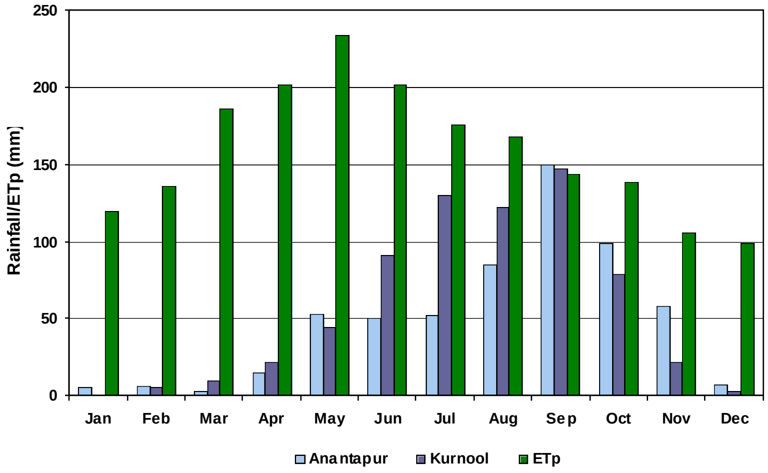


Figure 6. Mean monthly rainfall and potential evaporation (ETp) (FAO)

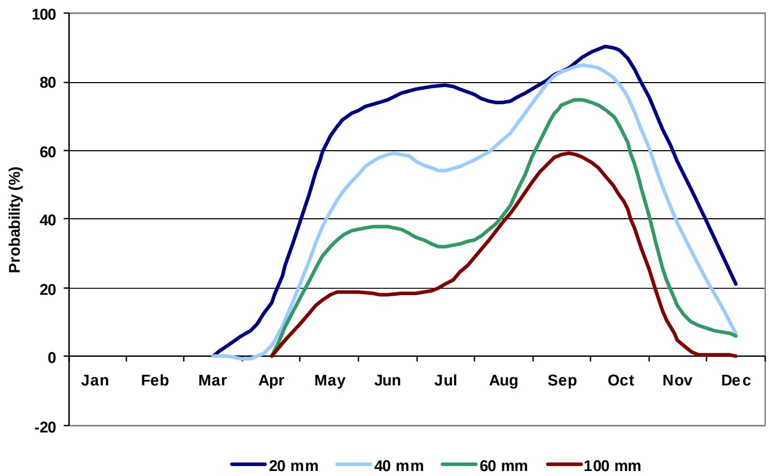


Figure 7. Probability of different monthly rainfall amounts in Anantapur (CSWCRTI)

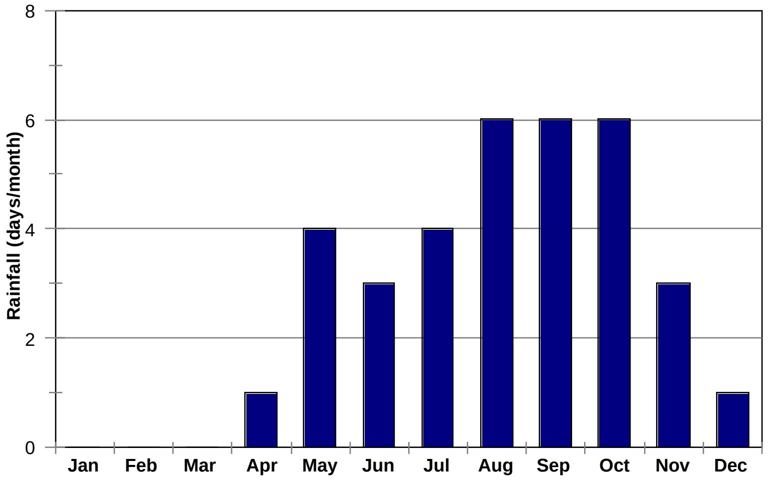


Figure 8. Mean number of rain days for Anantapur

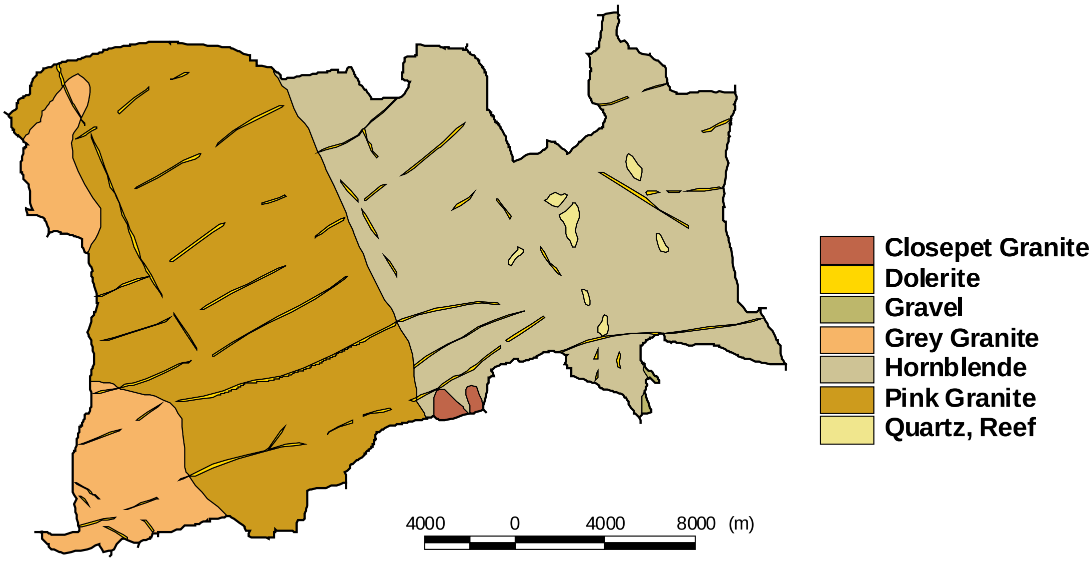
Figure 6 compares the mean monthly rainfall at Kurnool and Anantapur with potential evaporation[3]. It can be seen that Anantapur's mean monthly rainfall is below 100 mm for every month except September. This figure also gives an indication of the relatively higher rainfall at Kurnool during the early south-west monsoon and relatively higher rainfall in Anantapur during the north-east monsoon. Mean monthly rainfall is less than potential evaporation for both locations for every month except September.

Figure 7 shows the probability of monthly rainfall exceeding 20, 40, 60 or 100 mm at Anantapur. It can be seen that the highest probability of monthly rain exceeding 60 mm is during September-October. Hence, this is the period during which large volumes of runoff are most likely to be generated.

Figure 8 presents the mean number of rain days per month for Anantapur. As the number of rain days is not well correlated with the rainfall, this also indicates that rainfall events tend to be smaller during the early and late parts of the south-west and north-east monsoons respectively.

3 Potential evaporation can be defined as the rate of evaporation from an extensive surface of 8 – 15 cm tall, green grass cover of uniform height, actively growing, completely shading the ground and not short of water. The ratio between rainfall and potential evaporation provides a good indication of the aridity of an area.

Figure 9. Geology of Kalyandurg mandal



3.3 Geology and geomorphology

Kalyandurg has an undulating topography with a general slope towards north and east. The geology of the mandal (see Figure 9) is comprised of Archean rocks which consist of gneisses, schists, younger granites, quartz veins and basic dykes. The Archaen rocks have suffered a considerable degree of tectonic disturbance as a result of which the rocks have been metamorphosed and recrystallised (APGWD, 1999). The granite rocks may be separated into two distinct groups, namely, the massive and foliated types. The massive grey granites give rise to elevated features while foliated rocks are found below the plains and also occur as low dome hillocks. Dharwar rocks, occurring as a linear schist belt within the gneissic complex, form linear hills in the eastern part of the mandal. Numerous basic dykes, which are essentially dolerite in composition, traverse the older rocks and these are exposed as long narrow and generally persistent ridges. The length of the dykes varies from 0.5 to 9 km and the width from 50 to 500 m. In addition to the above, alluvium of 1-7 m thickness occurs along the course of the Pennar river and in the vicinity of minor streams and tanks.

Located on the periphery of the Cuddapah basin, Dhone has a geology that comprises both crystalline and sedimentary rocks. Granites and associated rocks with intrusive bodies like dykes and quartz veins are encountered to the north and west of the mandal and sedimentary rocks such as limestones and shales with intercalation of chert bands are found to the south and east. The areas underlain by granites are undulating with numerous rock outcrops. The areas underlain by the sedimentary rocks are hilly with a steeper terrain. Figure 10 shows Dhone's main geomorphic units.[4]

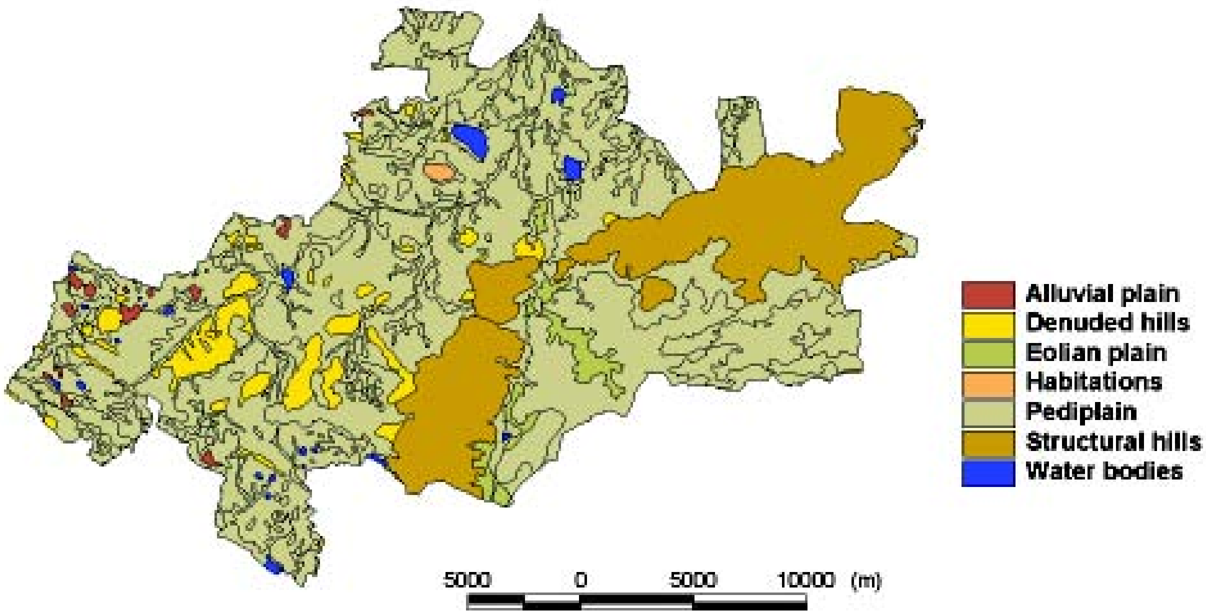
3.4 Soils

Approximately 95% of the soils in Kalyandurg are alfisols with the remaining area covered by black clayey soils (vertisols) (APGWD, 1999). The soils in Dhone are also predominantly red sandy loam soils with a depth in the range 0.3 - 1 m (APGWD, 2000). Table 3 provides information on the length of growing period for each APRLP district based on rainfall frequency analysis and soil water holding capacity. The relatively short growing period in Anantapur gives an indication of the risk involved in rainfed cropping in this district. The inherent advantages of the vertisols, in terms of soil water availability, can also be seen.

Shallow and very shallow gravelly soils occur at the base of foothills with 3-5% slope in Dhone and 4-8% slope in Kalyandurg. The gravel content of these soils ranges from 50 to 85% and is a major limitation on arable cultivation. Moderately deep soils occur in gently sloping lands and deep to very deep soils occur in valleys.

4 Despite considerable effort, obtaining a 1:50,000 groundtruthed map of Dhone proved to be impossible during the water audit. Copies of this map could not be found either in Kurnool or Hyderabad.

Figure 10. Dhone's geomorphic units



As a result of erosion, clays are transported to valleys where they form calcareous clayey soils which are at times saline. Red soils suffer from the physical limitations of crusting and compact sub soils, while black soils suffer from crusting and low infiltration rates due to high exchangeable sodium percentage (>7.0). Soil salinity is a serious problem in the case of black soils and in red soils when irrigated with saline waters.

Soil depths vary as a result of differential erosion. High levels of erosion continue to occur on many of the steeper slopes with soil losses ranging from 4 to 10 t ha^{-1} y^{-1}. Wind erosion is also common in the mandals particularly from river bed areas and groundnut fields. Both the soils are universally deficient in nitrogen.
Red and black soils are poor in phosphorus, while potassium may become a limiting factor in light soils dominated by the clay mineral kaolonite. Deficiency of zinc, sulphur and calcium is widespread in the case of red soils that are under continuous groundnut cropping. Similarly in black soils, zinc deficiency is a major limitation for crop production under intensive farming. Boron toxicity is also reported to inhibit crop growth in these mandals.

Table 3. Length of crop growing period for main soil types in the five APRLP districts (Source: ICRISAT)

District	Soil Type	First moist period (days)	Humid period (days)	Second moist period (days)	Length of growing period (days)
Anantapur	Sandy Alfisol	49	7	56	112
Kurnool	Sandy Alfisol Vertic Soil	77 77	35 35	42 42	154 154
Mahabubnagar	Vertisols Vertic Soils Sandy Alfisol	27 27 27	141 141 141	21 14 14	203 189 182
Nalgonda	Sandy Alfisol	42	112	28	196
Prakasam	Vertic Soils Orthids	71 70	91 96	18 18	180 186

Krishna river during October 2001

3.5 Drainage

The eastern part of Kalyandurg is drained by the Pennar river which flows from south to north across the mandal (see Figure 11), whilst the western part of Kalyandurg drains northwards towards the Chinnahagari river. The mandal can be divided into eleven sub-watersheds and the drainage density is 1.79 km/km^2. Dhone mandal drains into both the Krishna and the Pennar systems. This mandal can be divided into seven sub-watersheds that have streams that are ephemeral. Taking the mandal as a whole the average drainage density is 2.63 km/km^2.

Table 4. Water harvesting structures

Type	Dhone	Kalyandurg
Masonry check dams	225	132
Rockfill dams	28	19
Earthen dams	-	22
Nala bunds	-	6
Total	253	179

Chinnahagari river following heavy rains

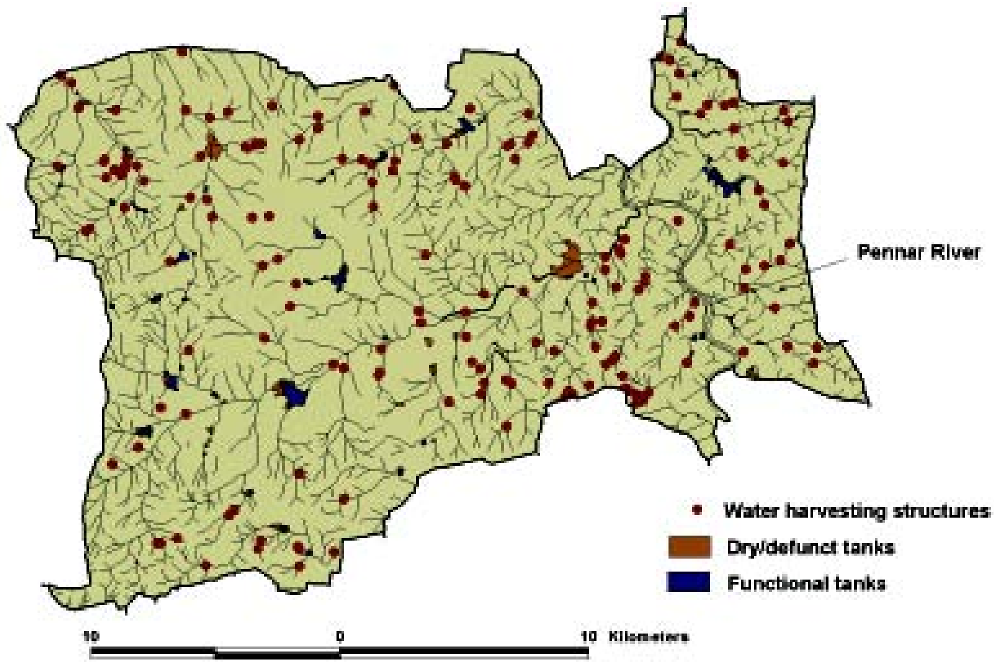


Figure 11. Kalyandurg's water harvesting structures and drainage network

3.6 Gully control structures

Figures 11 and 12 show the location of water harvesting and gully control structures that have been constructed as part of the DPAP, DDP and other government programmes. Table 4 provides more details on the type and number of structures. The totals in Table 4 can be compared with the APGWD figures of 83 check dams in Kalyandurg and 164 gully control structures in Dhone. One reason for such large discrepancies (i.e. 50% and 115%) is the fact that the official figures do not include structures that were not funded by the DPAP and DDP programmes. It should be noted that a more detailed survey of gully control structures by the WHiRL Project in four villages in Kalyandurg showed that many structures were also missed by the Water Audit surveys. If all smaller structures are included the true numbers of gully control structures may be around double the figures reported here.

Gully control structures are relatively more uniformly distributed across Kalyandurg. In Dhone, gully control structures are concentrated primarily in the red soil areas. Many gullies in other areas of Dhone that have steep slopes have been treated in recent years as part of the Neeru-Meeru programme's continuous contour trenching activities.

3.7 Tanks

The use of tanks for catching runoff is a traditional practice in the study mandals that is more prevalent in the red soil areas underlain by crystalline basement geologies. The tank surveys showed that there are 85 tanks in Kalyandurg and 18 tanks in Dhone. Official statistics show that in Kalyandurg there are 13 minor irrigation tanks having a total command area of 367 ha. Although some of Kalyandurg's tanks date back to the early 18th Century, the majority were constructed during the second half of the 19th Century or the first half of the 20th Century. The survey showed that approximately 25% of the tank bunds and weirs were in poor condition. As part of GoAP policy, all but four of the tanks are now used as percolation tanks (i.e. groundwater recharge structures) rather than sources of water for surface irrigation. Farmers in the command areas now rely on groundwater as a primary source of irrigation water and, in some cases, seepage water from the tank or water flowing through damaged sluices or weirs. In the majority of tanks, siltation has occurred and, as a consequence, dead storage and average depth have been reduced. Issues surrounding the widely-held view that inflows to tanks have decreased in recent years are discussed in Section 4.3.

3.8 Land capability

The areas of the two study mandals with different land capability classes are presented in Table 5. The soil and land characteristic associated with each capability class and sub-class can be found in Table 6.

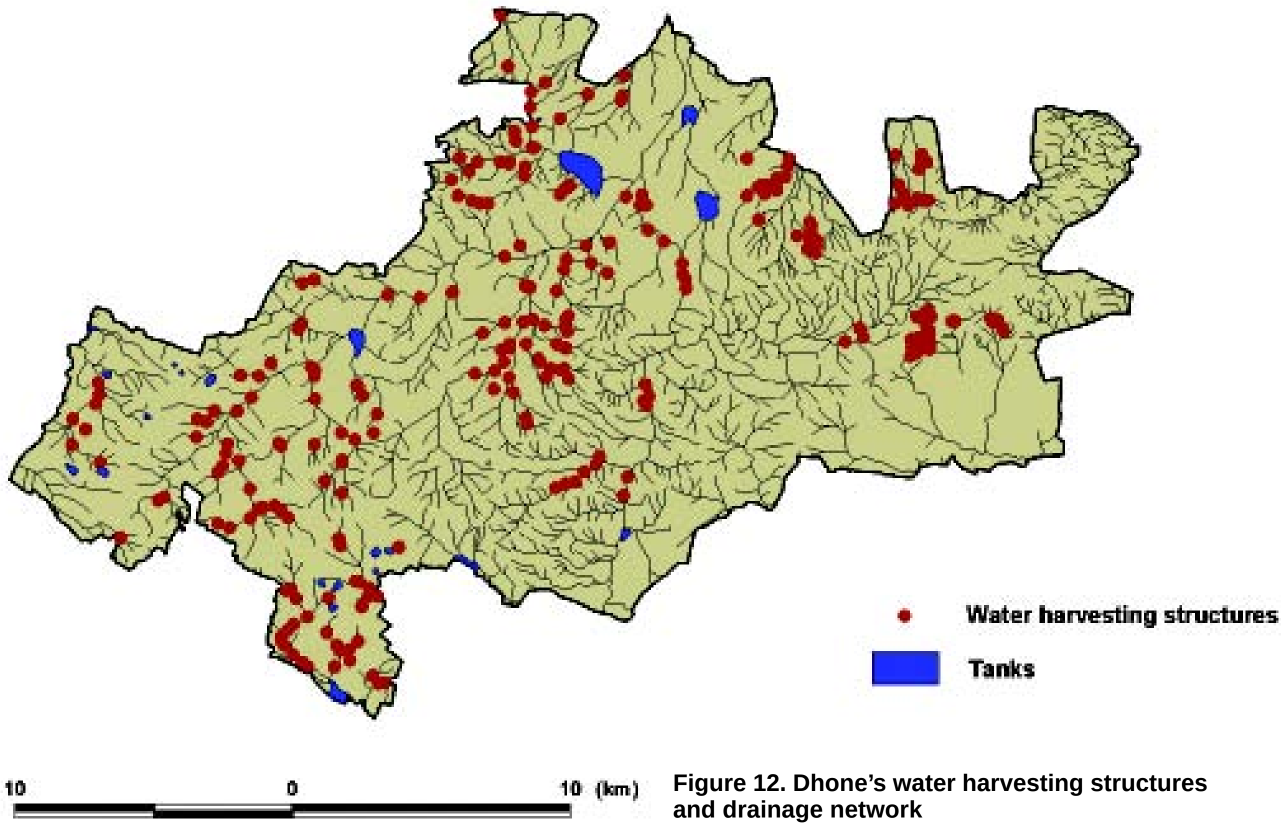


Figure 12. Dhone's water harvesting structures and drainage network

Table 6. Land capability soil and land characteristics

Land Capability class	Soil and land characteristics
IIs-IIIe	Moderately deep, well drained, good cultivable lands having erosion and soil problems due to heavy texture. Class also includes fairly good cultivable lands having erosion and soil problems. Some areas need simple soil and water conservation measures; all climatically adapted crops can be grown.
IIes-IIIes	Moderately deep, well drained, good cultivable lands associated with minor to moderate problems of erosion and heavy textures and gravelliness; need appropriate soil and water conservation measures; all climatically adapted crops can be grown.
IIs-IIIes	Moderately deep to deep, well drained, good cultivable lands with minor soil problems of heavy cracking clays; associated with moderate problems of erosion and soil problems; need simple soil and water conservation measures; all climatically adapted crops can be grown.
IIIes	Moderately deep to shallow, well drained. Good cultivable lands with problems of erosion, shallow rooting depth, gravelliness and stoniness and gentle slopes; need intensive soil and water conservation measures; all climatically adapted crops can be grown.
IIIs	Moderately shallow, well drained, moderately good cultivable lands having soil problems of shallow rooting depth, gravelliness, slightly eroded and gentle slopes; need simple soil and water conservation measures; all climatically adapted crops can be grown.
VIe-VIIes	Shallow to moderately shallow, well drained uncultivable lands with very severe limitations of erosion, shallow rooting depth, gravelliness and stoniness, steep to moderate slopes; need intensive soil and water conservation measures; suitable for forestry, pasture and silvipasture.
VIes-VIII	Shallow to very shallow, excessively drained, uncultivable rock lands having severe erosion and soil problems associated with fairly good cultivable lands with very severe limitations of erosion, shallow rooting depth, gravelliness, stoniness and steep slopes; need intensive soil and water conservation measures; suitable for quarrying, mining, as habitat for wild life, pasture and forestry.

Table 5: Areas under different land capability classes in Kalyandurg and Dhone mandals

Kalyandurg		Dhone	
Class	Area (ha)	Class	Area (ha)
IIs to IIIes	6,253	IIs to IIIe	15,245
IIIs	9,335	IIes to IIIes	5,325
IIIes	31,809	IIIes	11,708
VIe to VIIes	1,438	VIes to VIII	16,456
Total	48,835	Total	48,644

3.9 Land Use

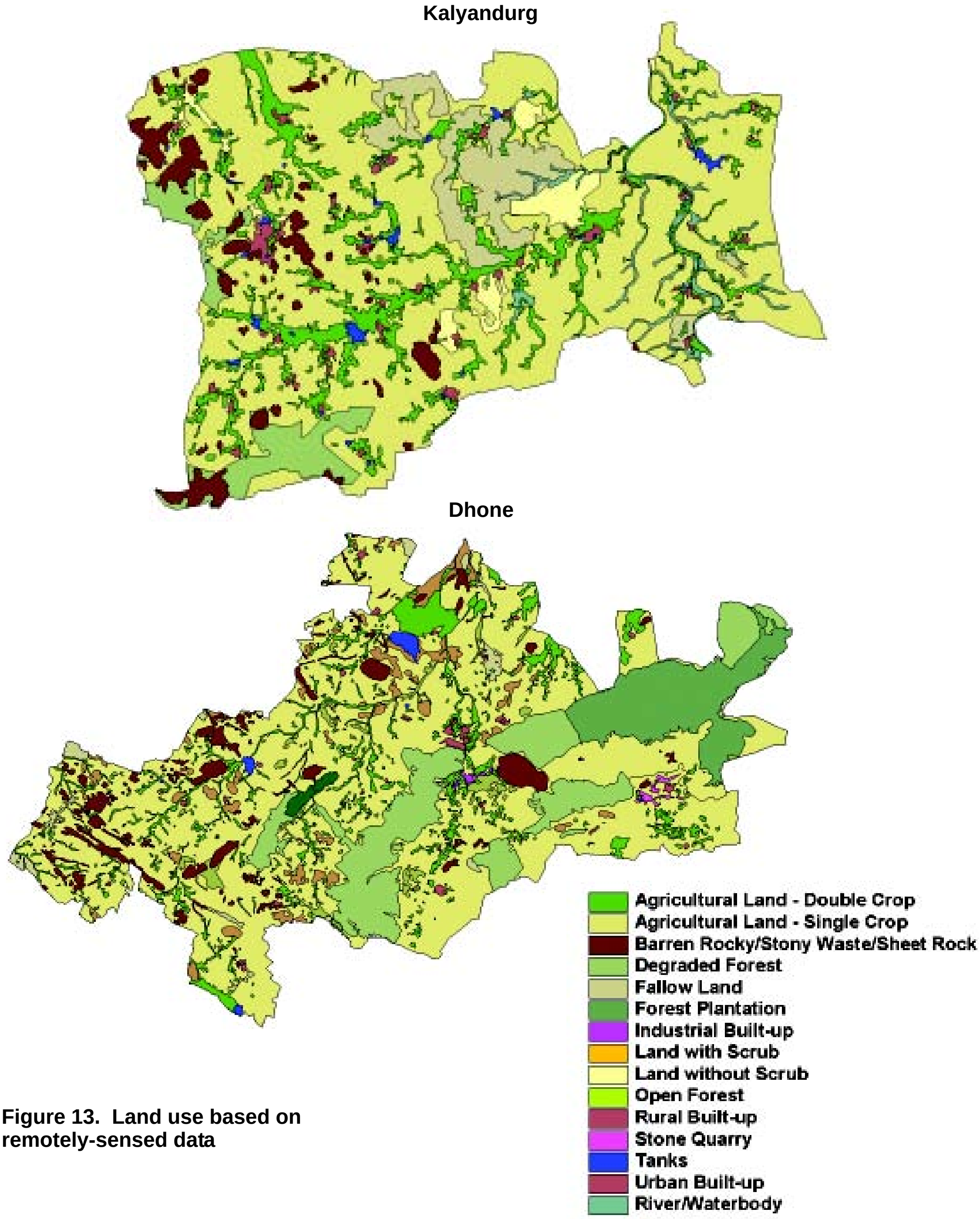


Figure 13. Land use based on remotely-sensed data

Figure 14. Main land uses percentages based on remotely-sensed data

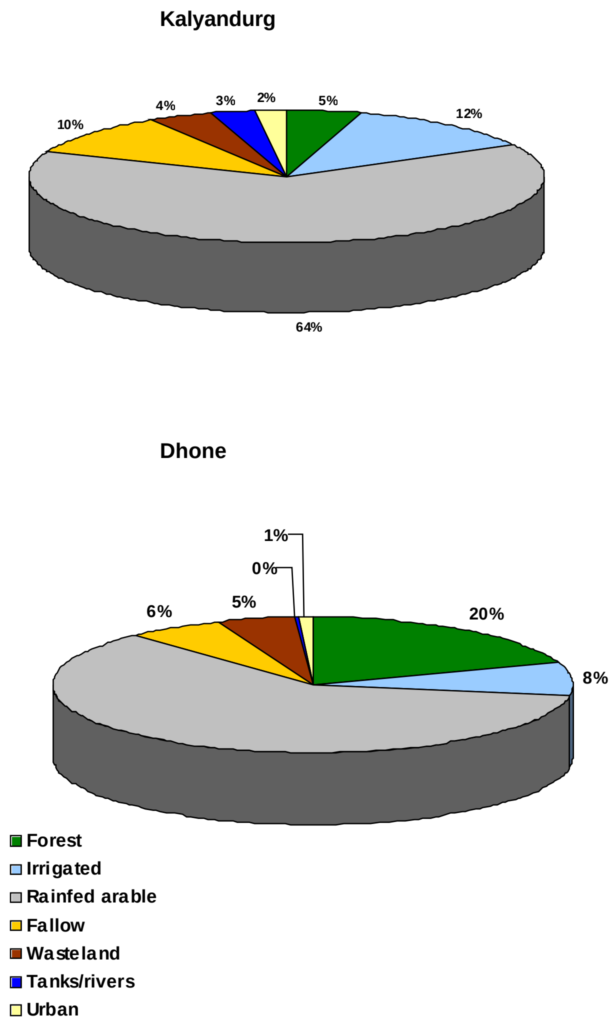
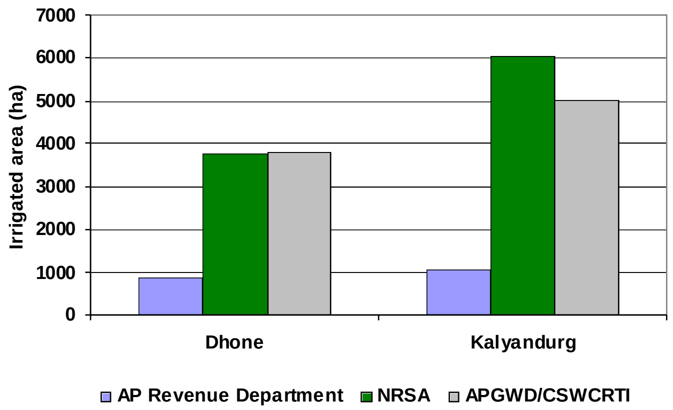


Figure 15. Comparison of irrigation statistics from different sources



Figures 13 and 14 present remotely-sensed information on current land uses in the two study mandals. There are a number of important points that relate to this information. Firstly, the main land use in both mandals is currently rainfed arable cropping. The precise area cropped and the cropping system varies from year to year in direct response to the onset of the south-west monsoon and the subsequent rainfall pattern. However, in most years, only one crop can be grown. Groundnut or a groundnut intercrop system is preferred. Secondly, within living memory, there has been a major decline in forested areas in both mandals and in the biodiversity associated with undisturbed forest. Currently, Dhone has a relatively larger area than Kalyandurg under Forest Department responsibility. In both mandals, forested areas are generally degraded and devoid of vegetation other than scrub. Also in both mandals, good quality forested land, other than land under Forest Department control, has become heavily encroached in recent years. Participatory assessments indicated that fuel wood shortages have also increased during recent years. Thirdly, substantial areas of fallow and waste land exist in both mandals.

During the last 10-15 years there has been a substantial increase in groundwater-based irrigation in both mandals. According to remotely-sensed information, 8 and 12% of the net land area of Dhone and Kalyandurg respectively was under multi-cropped irrigation during the 2000-2001 crop season. These figures were supported by independent estimates based on well survey data collected by the Andhra Pradesh Groundwater Department as part of this Water Audit. However, the "official" irrigation statistics supplied by the Mandal Records Office (i.e. the Revenue Dept) and the Departmentof Agriculture (see Figure 15) suggested that the total net irrigated area is much smaller. During discussions involving district-level specialists and line department staff, it became clear that gross under-reporting of "official" irrigation statistics is common knowledge (see Box 7a). The lack of faith in irrigation statistics at the district level did not appear to be reflected at the state level where "official" irrigation statistics are used to underpin a whole range of important policy-related decisions.

Continuous contour trenching near Dhone town

Irrigated floriculture in Erraguntla, Dhone

Box 7a. Collection of irrigation statistics

The basic source of primary data as far as number of wells, land ownership, cultivated area and irrigated area is concerned is the village record, or *Adangal*. This is maintained for every revenue village by the concerned Village Administrative Officers (VAOs) working under the Revenue Department. Data from revenue villages are aggregated to provide mandal, district and state statistics. Thus the accuracy and reliability of irrigation statistics depends entirely on the standard of work of individual VAOs not least because data checking mechanisms are basic and generally just a formality. Even conscientious VAOs tend not to put much effort into recording groundwater-based irrigation statistics and the reality is that new wells often go unrecorded and areas irrigated per well are rarely entered into the *Adangal*. One reason being that there is more compulsion for accuracy regarding land use pattern, land ownership and area under surface irrigation sources as they are directly used for collection/assessment of taxes (Janakarajan, 2000).

Salt-affected area near Lakshmipalli, Dhone

3.10 Vegetation

The region was endowed with diversified land use systems ranging from agriculture to forestry. However, in the last 50 years, community barren lands and large parts of forest areas abutting villages have been encroached upon by villagers. One consequence is that access to fuel, fodder and pasture lands has become a problem in many of the villages in the study mandals.

Table 7 summarises the results of a qualitative vegetation survey that was carried out in Dhone and Kalyandurg. Although the lists obtained were quite encouraging, the main observation of the survey was the high prevalence of *prosophis juliflora* in wasteland areas, along gullies and along roadsides. It was assumed that this was due in part to degradation and overgrazing.

3.11 Land Holdings

Cadastral information was collected and updated in digital format. In addition to providing a valuable cross-check of land use, village/mandal area and well statistics, these data provided an important source of information for analysis relating to levels of land fragmentation, economics of well construction and identification of the main beneficiaries of water harvesting and groundwater-based irrigation. Figure 16 is a composite layout of spatial and non-spatial cadastral data that is presented to give an example of the level of detail available in the cadastral database. It should be noted that this information, which is held and updated by the Revenue Department, is rarely used by development programmes. The villagewise size distribution of land holdings on *patta* land in Kalyandurg is presented in Figure 17. It can be seen that the average size of holding, size of holding distribution and number of land owners varies enormously from village to village. In both Dhone and Kalyandurg, the average size of holding is declining as a result of inheritance arrangements that involve splitting land between sons. However, extended families often farm their holdings as one unit or, at the very least, cooperatively. Consequently, the size of individual holdings is not always a reliable indicator of levels of poverty. It was found also that, in both mandals, cooperative use of groundwater (i.e. sharing of wells) was common by members of the same family.

Table 7. Tree, shrub and grass species found in Dhone and Kalyandurg

Tree species	Shrubs	Grass species
Acacia leucophloes	*Carissa carandus*	*Apluda aristata*
A. sundra	*C. spinorum*	*Cymbopogan coloratus*
A. arabica	*Cassia auriculata*	*Cynodon dactylon*
Albizia amara	*Dodonia viscose*	*Digitaria longifolia*
A. lebbek	*Caparis hispida*	*Imprata cylindrica*
Azadirachta indica	*Randia dimmatorum*	*Heteropogan contortus*
Dalbergia sissoo	*Euphoria tirucalli*	*Sehima nervosum*
Ziziphys Zylopyalis	*E. piverlia*	
Morinda tinctoria	*Jatropha carcus*	
Soymidia febrifuga		
Pterocarpus santalinus		
Wrightia tinctonia		
Delonixelata		
Hardwickia binata		
Feronia elephantum		
Gyrocarpus jacquini		

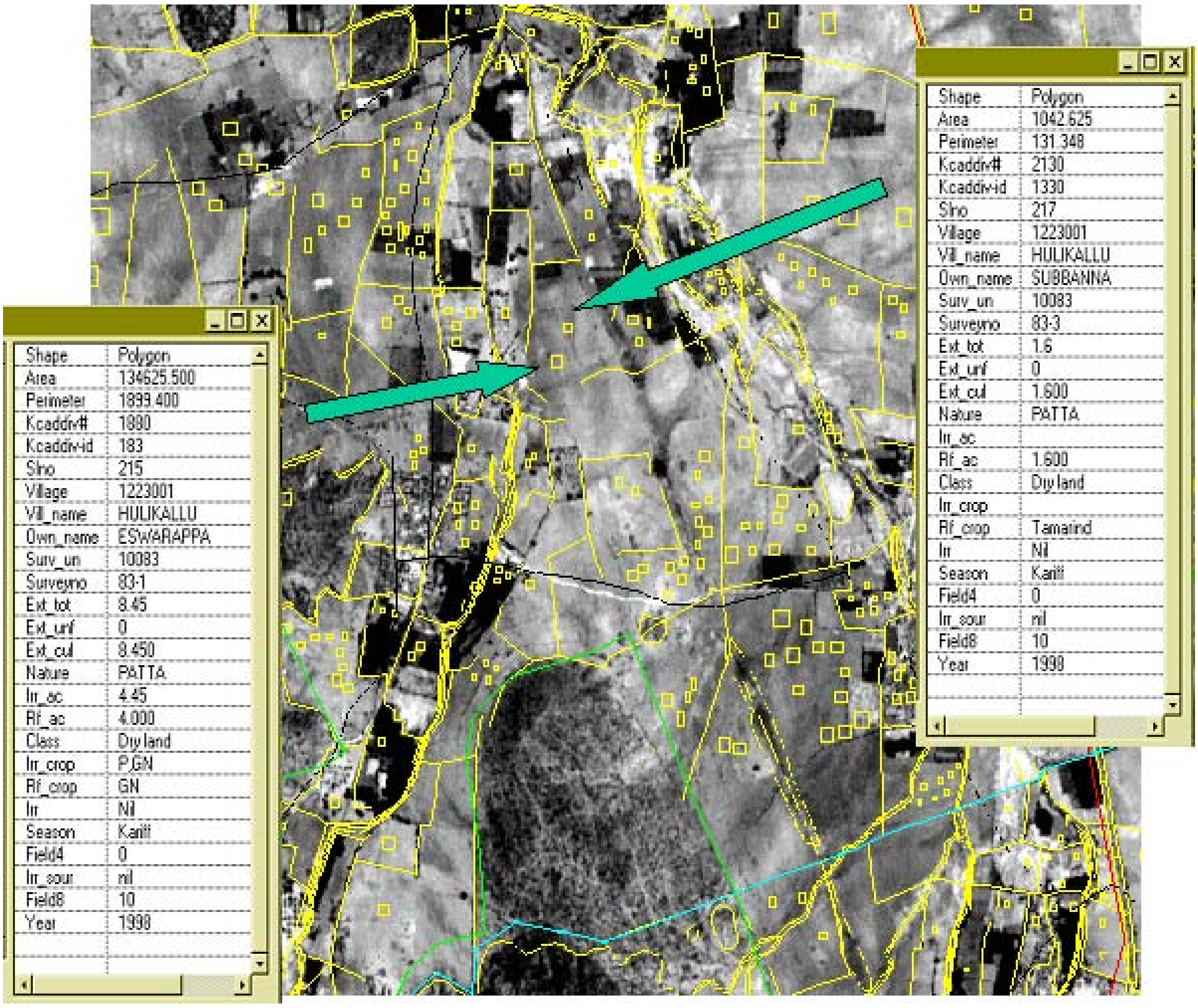


Figure 16. Example of spatial and non-spatial cadastral information accessible from GIS database

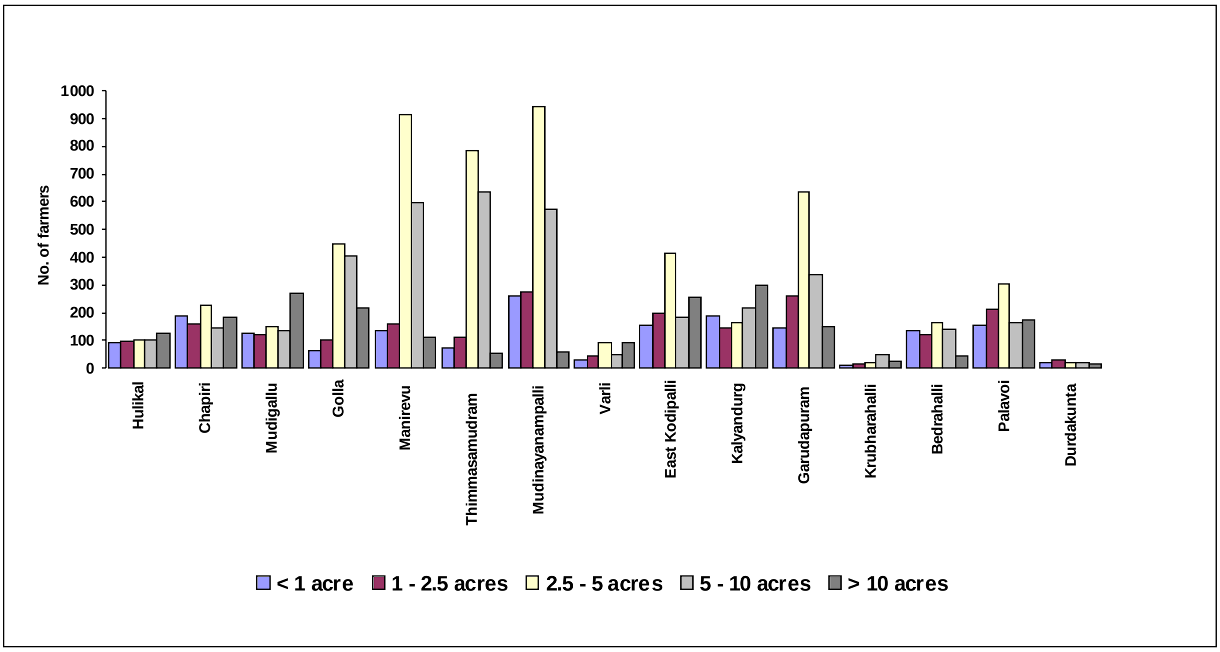


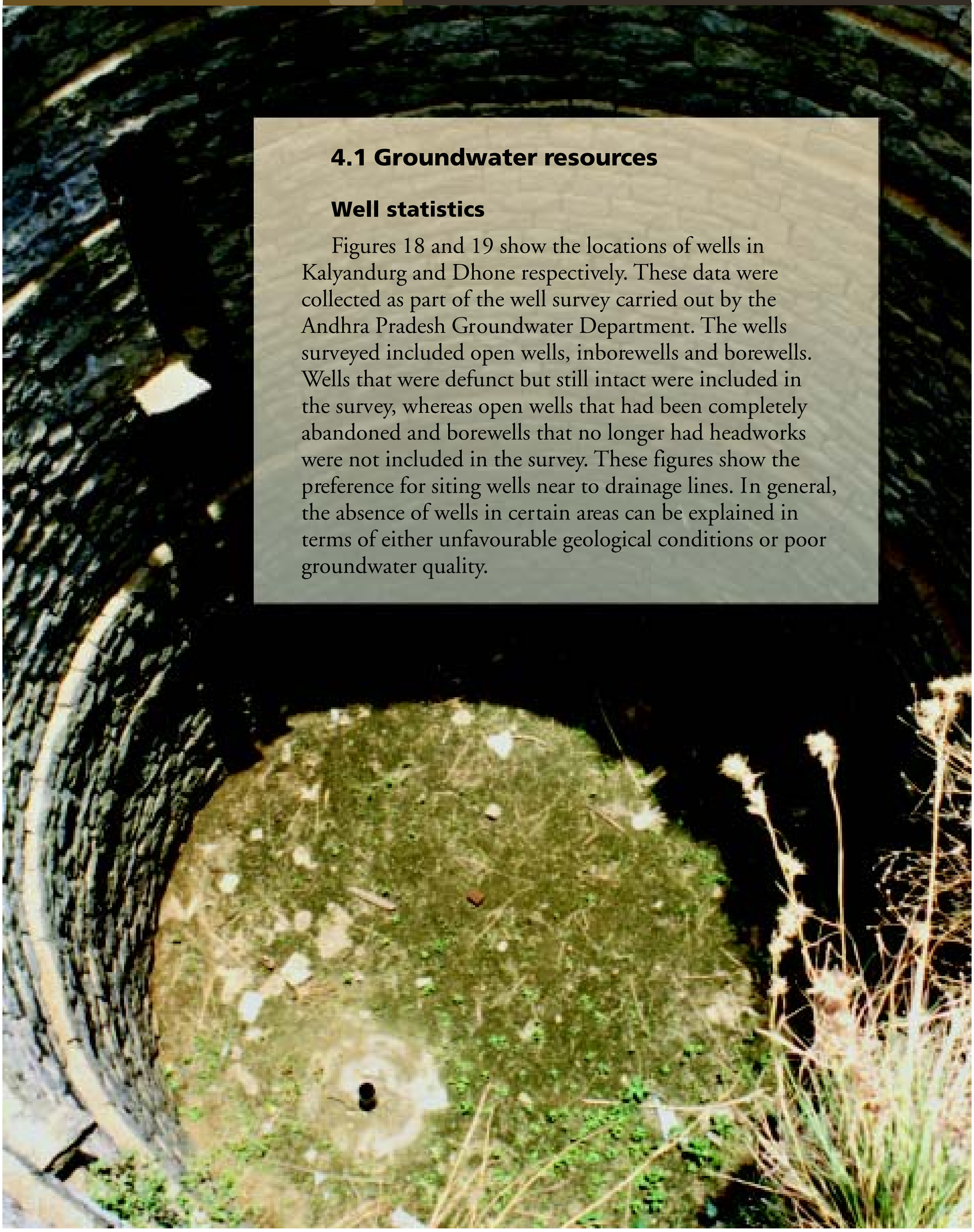
Figure 17. Villagewise land holding size distribution in Kalyandurg

4 General resource status of Dhone and Kalyandurg

4.1 Groundwater resources

Well statistics

Figures 18 and 19 show the locations of wells in Kalyandurg and Dhone respectively. These data were collected as part of the well survey carried out by the Andhra Pradesh Groundwater Department. The wells surveyed included open wells, inborewells and borewells. Wells that were defunct but still intact were included in the survey, whereas open wells that had been completely abandoned and borewells that no longer had headworks were not included in the survey. These figures show the preference for siting wells near to drainage lines. In general, the absence of wells in certain areas can be explained in terms of either unfavourable geological conditions or poor groundwater quality.



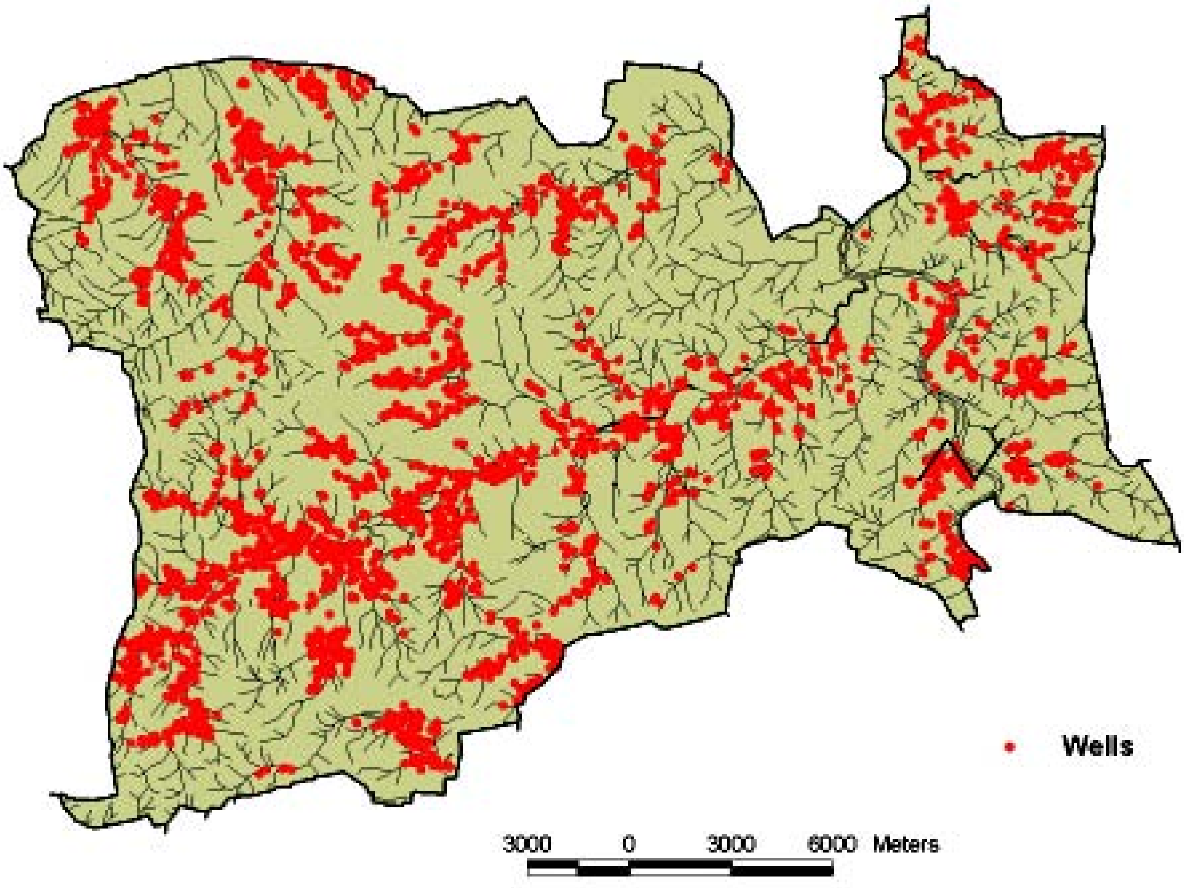


Figure 18. Location of wells in Kalyandurg

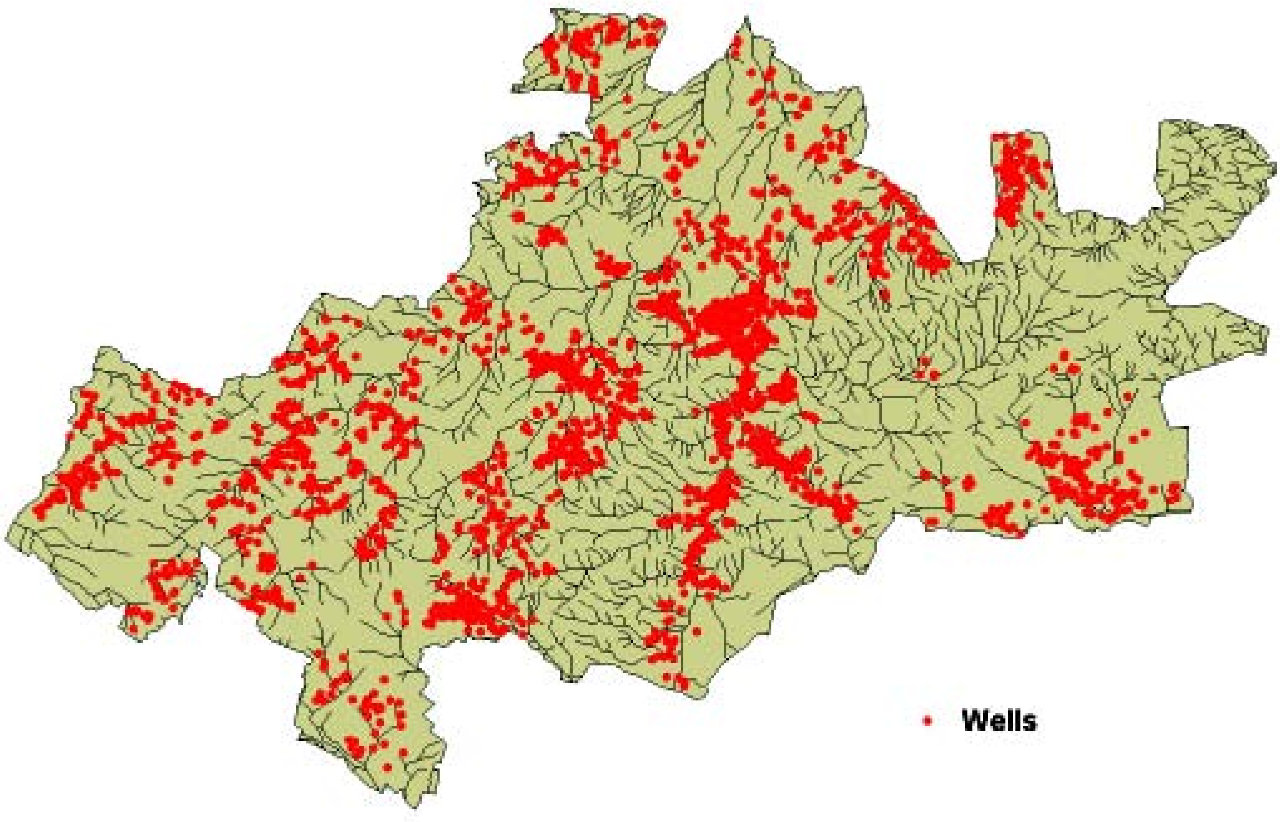
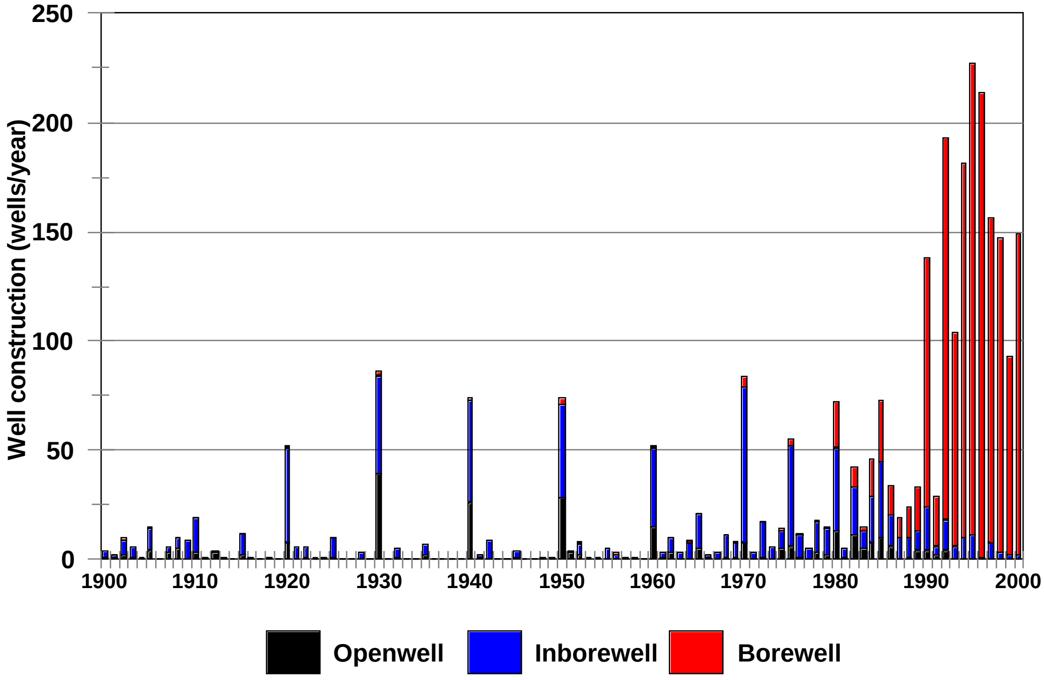
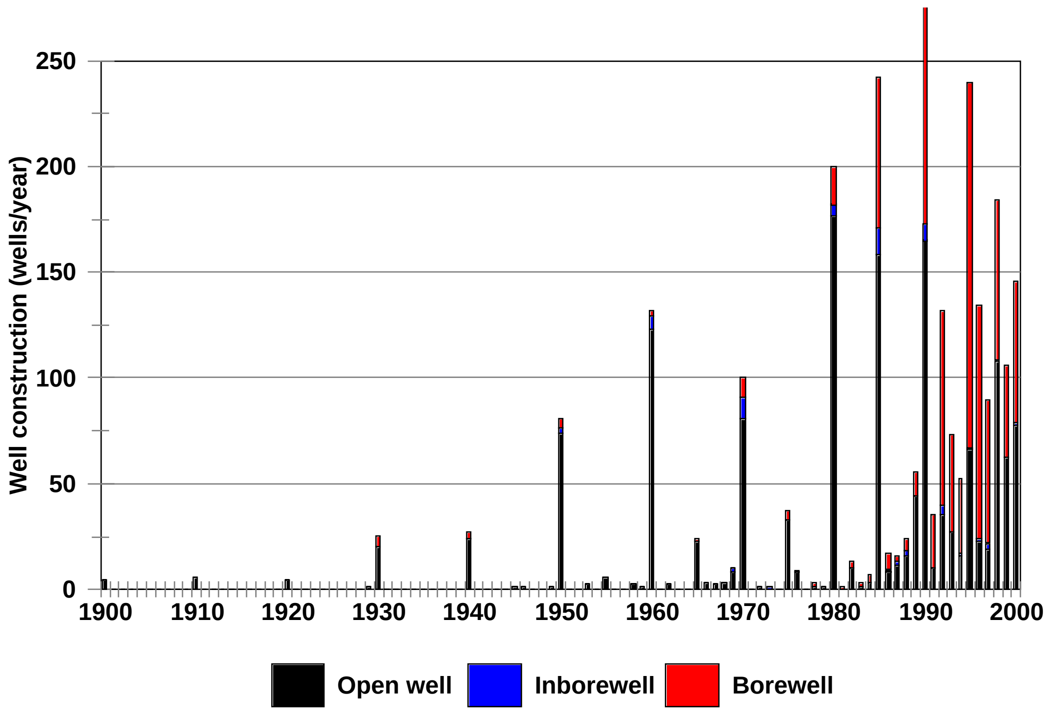


Figure 19. Location of wells in Dhone

Figure 20. Well construction timeline for Kalyandurg





Figures 20 and 21present the number of wells of different types constructed during the 20th Century in Kalyandurg and Dhone respectively. As information on date of construction of wells was elicited in part from local villagers, information for the first part of the century is presented on a decadal basis. The peaks in well construction during the first part of the century are, therefore, misleading and the reality was that the rate of well construction was more uniform during these decades. In contrast, peaks during the last 25 years were related primarily to government grants and loans that encouraged sudden spurts in well construction.

The following points relate to the history and pattern of well construction in these mandals:

- **There has been a dramatic increase in well construction and groundwater extraction during the last 15 years primarily for groundwater-based irrigation;**
- **Official statistics on well construction underestimate the current number of wells by a factor of two. This finding has major implications for estimation of groundwater draft that is based on well statistics (e.g. the GEC-97 Methodology);**
- **At the mandal level, there was reasonable agreement between water audit well statistics and statistics provided by Transco on the number of pump connections;**
- **In recent years, groundwater extraction per well has increased substantially as a result of the availability of submersible pumps and electricity;**
- **The shift in well construction from open wells to borewells, in Kalyandurg in particular, represents a shift from groundwater extraction that exploited shallow regolith aquifers to extraction from deeper bedrock aquifers.**

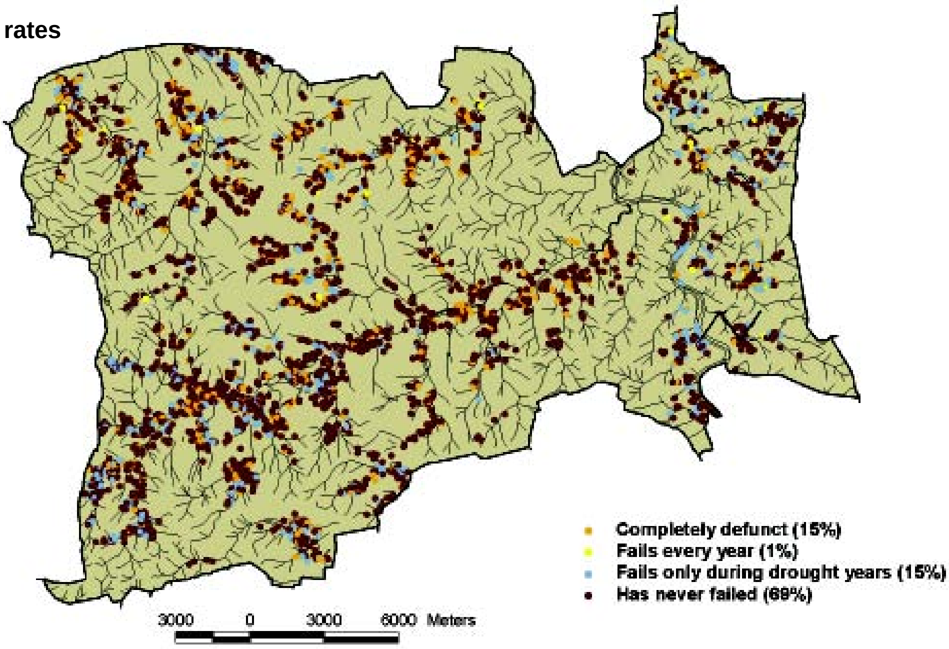
Box 8. Driving forces behind well construction

Factors that have encouraged the increase in well construction include:

- **Markedly higher and more reliable returns that farmers get from irrigated cropping as opposed to rainfed cropping;**
- **Government programmes that have provided grants or soft loans for well construction;**
- **Government policies that have led to the cost of electricity being subsidised;**
- **Improved drilling technology and competition between contractors. Both have ensured that the cost of borewell construction is relatively low;**
- **Competition for water between farmers accessing the same aquifer. This has led to competetive deepening of wells and/or construction of new borewells.**

Figure 22 presents the status of wells surveyed in Kalyandurg. It can be seen that in early 2001, 31% of the wells surveyed had either failed completely or were unreliable. The wells that were completely defunct were predominantly open wells. Similar analysis of survey data for Dhone indicated that less than 1% of wells were defunct and 7% of wells failed routinely. Although the number and density of wells in Kalyandurg and Dhone was similar, this difference in well failure was explained by the fact that levels of groundwater extraction for irrigation, domestic use and livestock were around 30% higher in Kalyandurg as compared to Dhone. In both mandals indications were that competition for water between farmers was intensifying. The prognosis is therefore for an increase in well failure in both mandals and a more marked shift from open well to borewell construction in Dhone.

Figure 22. Well failure rates in Kalyandurg

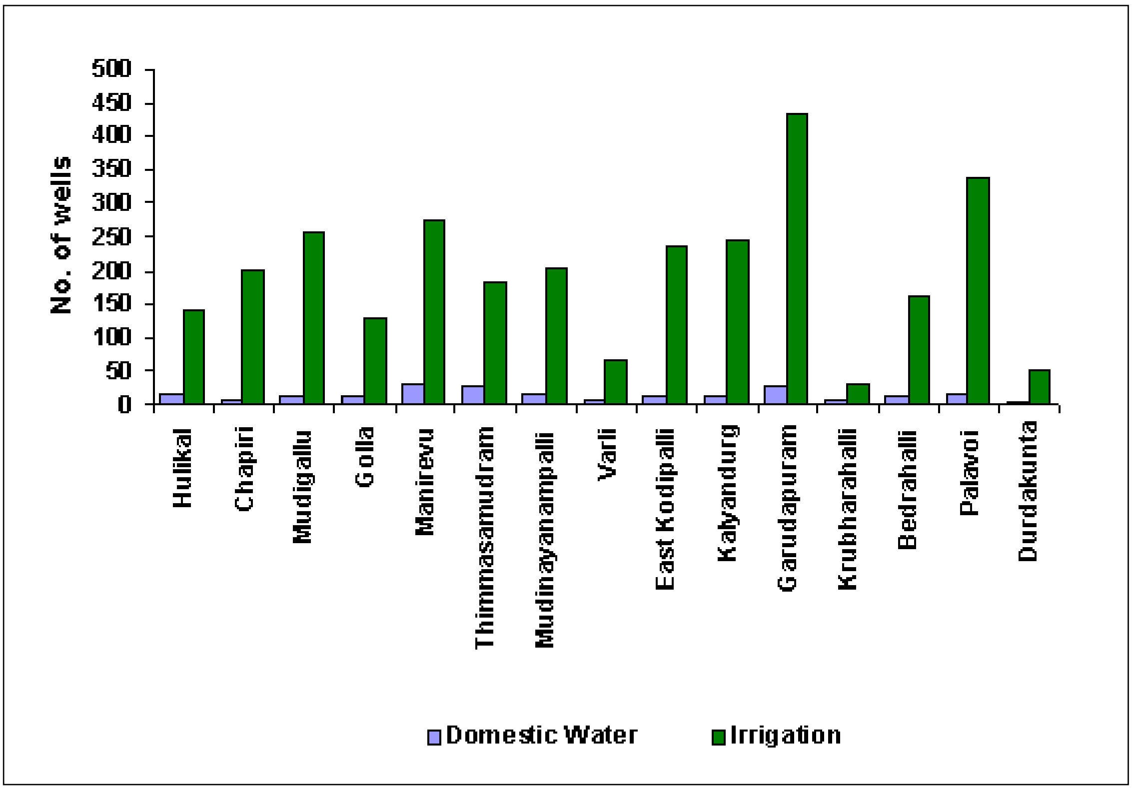


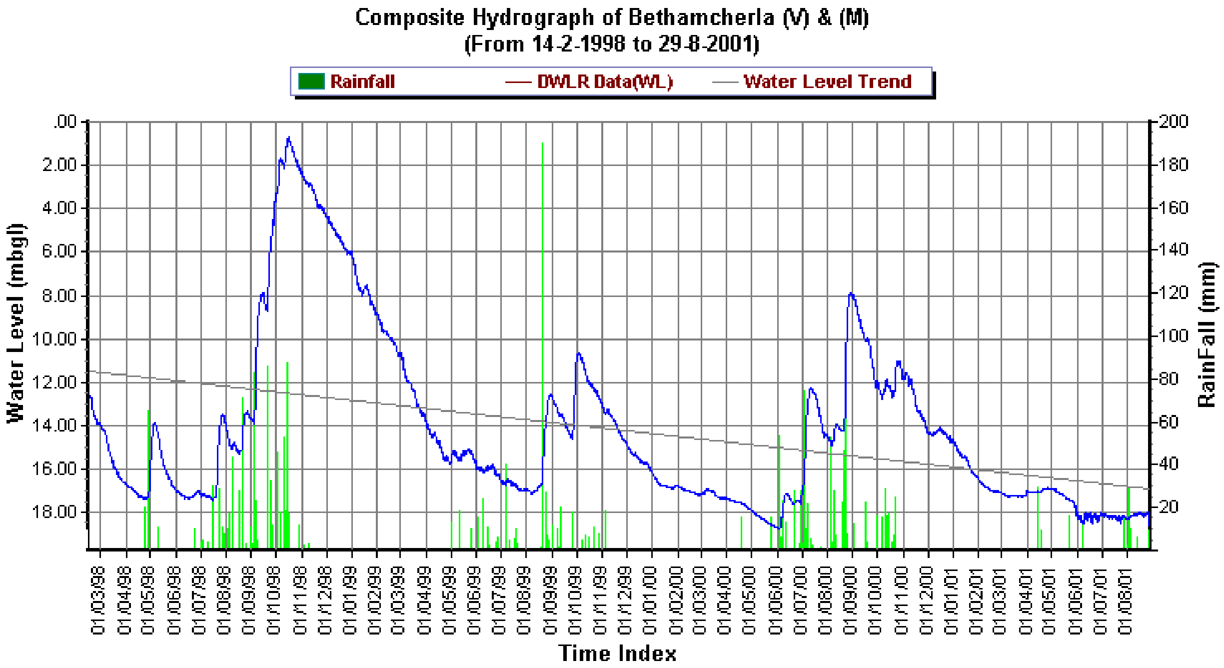
Domestic water use

Net groundwater extraction for irrigation, domestic and livestock use for Kalyandurg and Dhone was estimated at 11.0% and 8.4% of mean annual rainfall respectively. As the Andhra Pradesh Groundwater Department estimate of groundwater recharge in this area is approximately 10% of annual rainfall, this suggests that current levels of extraction in Kalyandurg are not sustainable. Analysis of villagewise groundwater extraction showed large differences between villages in both mandals. These were attributed in part to more favourable hydro-geological conditions in some villages and in part to variations in the historical pattern of development of both ground and surface water resources. This finding, coupled with the results of analysis of cadastral information, illustrates the fact that there is neither equitable access to irrigation between villages nor between households within villages.

Figure 23 gives an indication of the number of wells per revenue village in Kalyandurg that were being used as sources of water for irrigation and domestic supply. As might be expected, the number of "irrigation" wells now far exceeds the number of "domestic supply" wells. Annual groundwater extraction for domestic and livestock use was estimated at 0.6% and 0.8% of annual rainfall for Kalyandurg and Dhone respectively. If annual domestic and livestock use are considered in terms of average annual groundwater recharge, it is apparent that currently 6% and 8% of average annual recharge is being used to meet these needs in Kalyandurg and Dhone respectively. Taking a population growth rate of 2.5% and assuming that current per capita levels of water use are maintained, it can be estimated that groundwater extraction for domestic and livestock use will double in the next 30 years to 12% and 16% of average annual groundwater recharge. In many village areas, meeting this increased demand will not be possible without a commensurate reduction in groundwater use for irrigation. There is considerable variability in domestic water use with some revenue village areas (e.g. Dhone town, Kalyandurg town and Duradakunta) having current levels of use well in excess of 20% of average annual recharge.

Figure 23. Use of wells in Kalyandurg





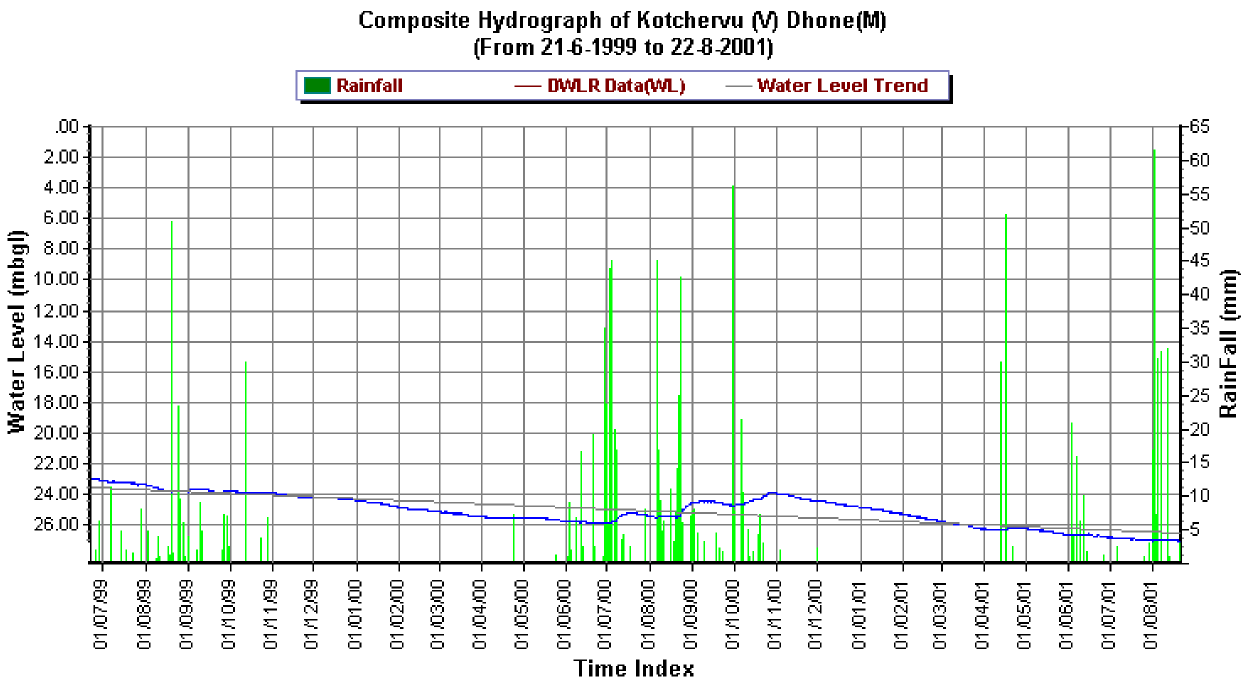
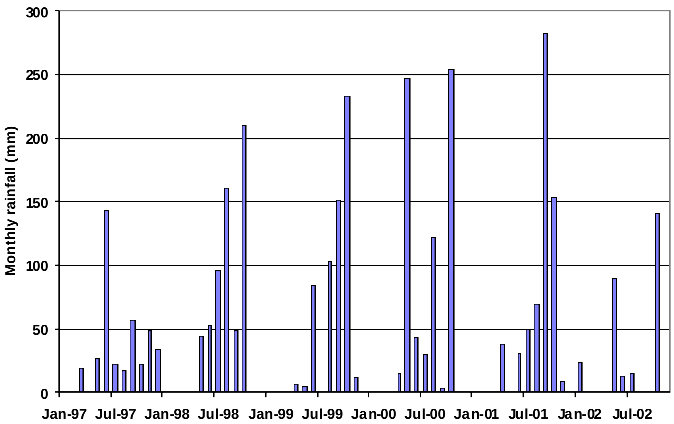


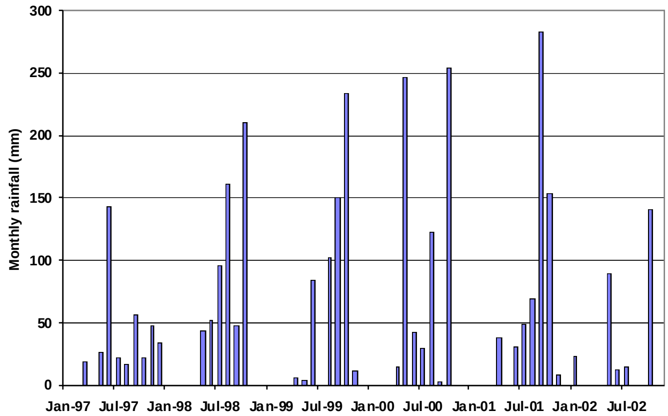
Figure 24. Automatic groundwater level data from Dhone

Groundwater levels

Figure 24 presents data from two of the three automatic groundwater level recorders installed in Dhone as part of the National Hydrology Project. Although these provide a useful insight into the dynamics of groundwater level change, the data are not easy to interpret without accurate information on levels of groundwater extraction in the immediate vicinity of the observation wells. At best, groundwater levels are a crude and unreliable indicator of the localised success (or otherwise) of watershed development programmes. Information showing: changes in access and entitlements to water, changes in time taken by women and children to fetch and carry water, changes in the number of villages requiring tankers or with water markets and changes in irrigated cropping intensity provide more compelling evidence as to whether or not programmes are successful.

Figure 25. Groundwater level data from Golla and Kalyandurg (Source: Andhra Pradesh Groundwater Department)





Data from the groundwater level recorders at Golla and Kalyandurg (see Figure 25) do not correlate well with the findings of the Groundwater Department's survey in this mandal. In the case of Golla, this can be explained by the fact that the recorder is sited in a locality with a relatively low level of groundwater extraction. Also the actual site of this recorder (as with many others) was chosen primarily on the basis of the security of the equipment. The wider implication is that water-level recorder information should be used with extreme caution when assessing regional impacts of, say, watershed development.

Small tank near Gosanapalli, Dhone

Goat drinking from a hand pump

Box 9. Electricity tariffs for irrigation wells

One-off connection charges include: a Rs.25 application fee, a Rs.100 security deposit and a development fee of Rs.1,000 per HP of the pump. Once connected, the electricity tariff is an annual charge that depends only on the rating of the pump. Pumps with ratings of up to 3 HP, 3-5 HP, 5-10 HP and more than 10 HP have annual tariffs of Rs.225, Rs.375, Rs.475 and Rs.575 respectively. Farmers with small and marginal holdings can opt for unit payment or optional tariff of Rs.0.2 per unit up to 2,500 units and Rs.0.5 for consumption in excess of 2,500 units.

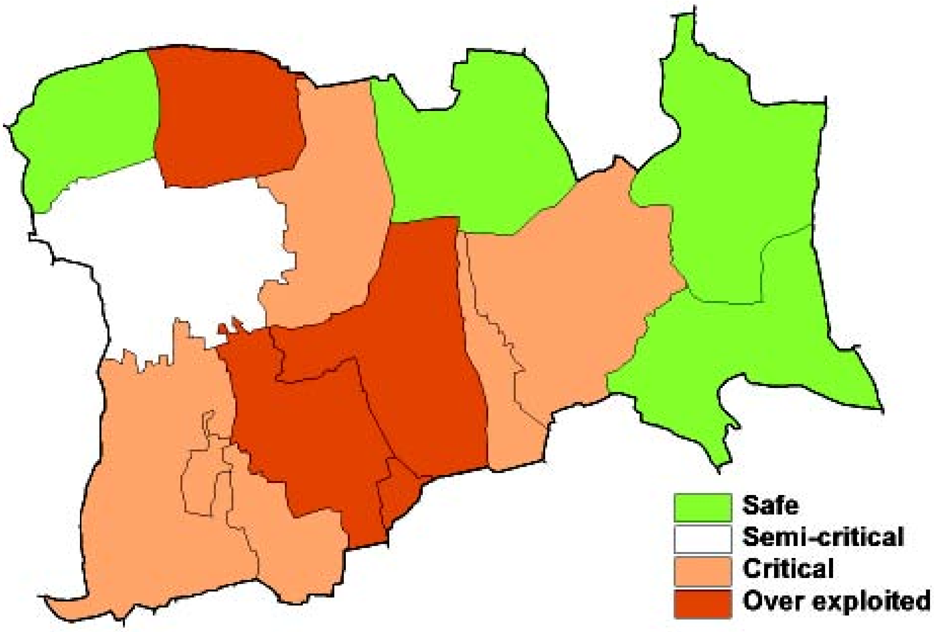


Figure 26. Stage of groundwater development in Kalyandurg

Figure 26 presents stage of groundwater development in Kalyandurg as estimated by the Andhra Pradesh Groundwater Department using data collected during the Water Audit survey. This figure shows that groundwater development has reached the "critical" or "over-exploited" stage in two thirds of the villages in this mandal. Subsequent and more detailed water-budget investigations carried out by the DFID-supported WHiRL project in four villages in Kalyandurg supported the findings presented here.

Box 10. Stage of groundwater development terminology

Safe: **A sub-unit is categorised as "safe" with potential for future groundwater development if one of the following two criteria is fulfilled: i) the stage of groundwater development is less than or equal to 70% and the water table during at least one of the two intervals (either pre-monsoon or post-monsoon) does not show a falling trend and ii) the stage of groundwater development is greater than 70% but less than or equal to 90% and the water table during both pre-monsoon and post-monsoon intervals does not show a falling trend.**

Semi-critical: **A sub-unit is categorised as "semi-critical" with caution to be executed for future groundwater development if the following criterion is fulfilled: the stage of groundwater development is greater than 70% but less than or equal to 90% and the water table during only one of the two intervals (either pre-monsoon or post-monsoon) shows a falling trend.**

Critical: **A sub-unit is categorised as "critical" with only very marginal scope for future groundwater development if one of the following criteria is fulfilled: i) the stage of groundwater development is more than 90% and the water table during only one of the two intervals (either pre-monsoon or post-monsoon) shows a falling trend and ii) the stage of groundwater development is equal to 100% and the water table during both pre-monsoon and post-monsoon intervals shows a falling trend.**

Over exploited: **A sub-unit is categorised as "over exploited" with practically no scope for any future groundwater development if the following criterion is met: the stage of groundwater development is more than 100% and the water table during both pre-monsoon and post-monsoon intervals shows a falling trend.**

Source: Andhra Pradesh Groundwater Department

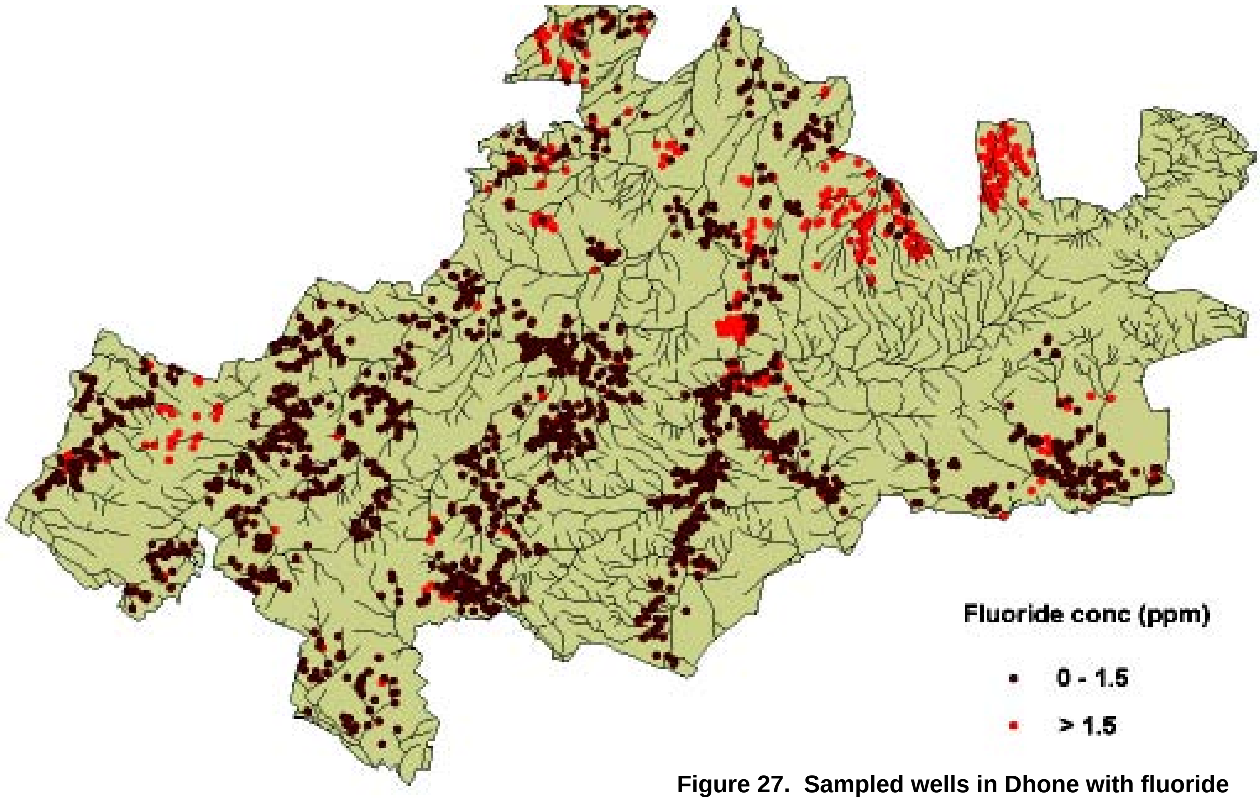


Figure 27. Sampled wells in Dhone with fluoride exceeding domestic water permissible limits

Groundwater quality

The current WHO permissible limit for the fluoride concentration of drinking water supplies is 1.5 ppm with the added recommendation that "climatic conditions, volume of water consumed and intake from other sources should be considered when setting national standards".
In 1993, the Bureau of Indian Standards set a maximum permissible fluoride concentration of 1.0 ppm, although concentrations of up to 1.5 ppm are considered to be acceptable in the absence of an alternative safer source.

Figure 27 shows the number of wells that were sampled in Dhone that have fluoride concentrations in excess of 1.5 ppm. It can be seen that 468 of the wells sampled had fluoride levels in excess of 1.5 ppm. Of these, 62 were being used solely as a source of domestic supply. Preliminary water sample analysis for Kalyandurg suggested a relatively lower prevalence of wells with fluoride in excess of 1.5 ppm as compared to Dhone. However, follow-up analysis by the WHiRL Project, indicated that high fluoride in domestic water supplies is a major issue in Kalyandurg. The routine monitoring of wells by the WHiRL Project also indicated a widespread increase in fluoride concentrations of around 30% during the 2002/2003 drought. Although a reasonable level of awareness exists at the village and district levels of the risks to human health related to high levels of fluoride ingestion, a laxness was noted in the way in which fluoride permissible limits are being used by departments responsible for drinking water supplies. A consequence being that action is not taken even when fluoride levels are well in excess of Indian permissible limits (i.e. 1.5 ppm).

Although not such a severe problem as fluoride, the common occurrence of saline groundwater in both mandals was found to be a problem in some domestic supplies and, in some areas, a major constraint on agricultural use. In Dhone, fifty of the sources of domestic supply were found to exceed the permissible limit for total dissolved solids.

Conclusion

The overall conclusion of the "groundwater" component of the Audit is that the scope for developing additional groundwater resources in both mandals is limited and, in much of Kalyandurg, groundwater is already severely over-exploited. This conclusion does not agree with a recent statewide groundwater survey carried out by the Andhra Pradesh Groundwater Department. This difference of opinion can be explained by the fact that the statewide survey based estimates of groundwater draft on "official" figures for irrigated area and well numbers that appear to hugely underestimate the situation on the ground.

4.2 Surface water resources

Runoff at the regional and large watershed scale

Analysis of gauging data from the Central Water Commission (CWC) showed that annual surface runoff, at the macro-watershed or basin scale, is somewhat lower than is often reported or than accepted wisdom would suggest (see Table 8). With the exception of one river, the Kunderu at Alladapalle, the average annual runoff values are within the range 4-35 mm which is equivalent to between 0.8 and 7.5% of rainfall. The main reason for the apparent higher runoff in the Kunderu is the fact that this river is used for inter-basin transfer of Krishna River water. The relatively low runoff values observed at most gauging stations challenge the widespread assumption that runoff in this region is always in the range 30-40% of annual rainfall. Although significant volumes of water can drain into the Bay of Bengal during periods or years with exceptionally high rainfall, in general, runoff represents a relatively small loss from the region.

The runoff figures presented in Table 8 agree with the low runoff values reported in the KAWAD Water Audit Report (Batchelor et al., 2000) for large watersheds. They are also consistent with the characteristics of the area (e.g. semi-arid climate, extensive development of water harvesting structures).

Figure 28 compares annual rainfall and runoff at the CWC Tadapatri gauging station on the Pennar River. This figure shows the considerable inter-annual variation in rainfall and surface runoff and that there have been long intervals of virtually no surface flow during this 25 year period (e.g 1990-1996).

Figure 29 compares monthly rainfall and runoff at Tadapatri. In addition to indicating levels of variability, this figure shows that on average 80% of annual runoff occurs during the three months September to November.

In conclusion, the main points from the runoff analysis using CWC data are:

- **Throughout southern Andhra Pradesh, average annual runoff values at the large watershed scale, in the absence of inter-basin transfers, are in the range 1% and 8% of average annual rainfall.**
- **Rainfall and runoff are extremely variable both within and between years. Coping with seasonality in surface water availability and droughts and floods is therefore a key issue.**
- **Although scope for further development of surface water resources along with regulation of river flows is possible in some areas, the scale of this development is much lower than suggested by some GoAP programmes.**

Check dam near Golla, Kalyandurg

Table 8. Average runoff and rainfall for study catchments

River	Average annual runoff (mm)	Average catchment rainfall (mm)	Average annual runoff (as % rainfall)
Chinnahagari at Amkundi Bridge	6	451	1.3
Vadavathi at Bhupasamudram	4	450	0.8
Hundri at Lakshmipuram	35	468	7.5
Pennar at Nagalamadike	12	573	2.0
Pennar at Tadapatri	28	551	5.0
Chitravathi at Singavaram/ Ellanuru	20	549	3.6
Kunderu at Alladapalle	133	617	21.6

Figure 28. Comparison of annual rainfall and runoff, Pennar River at Tadapatri

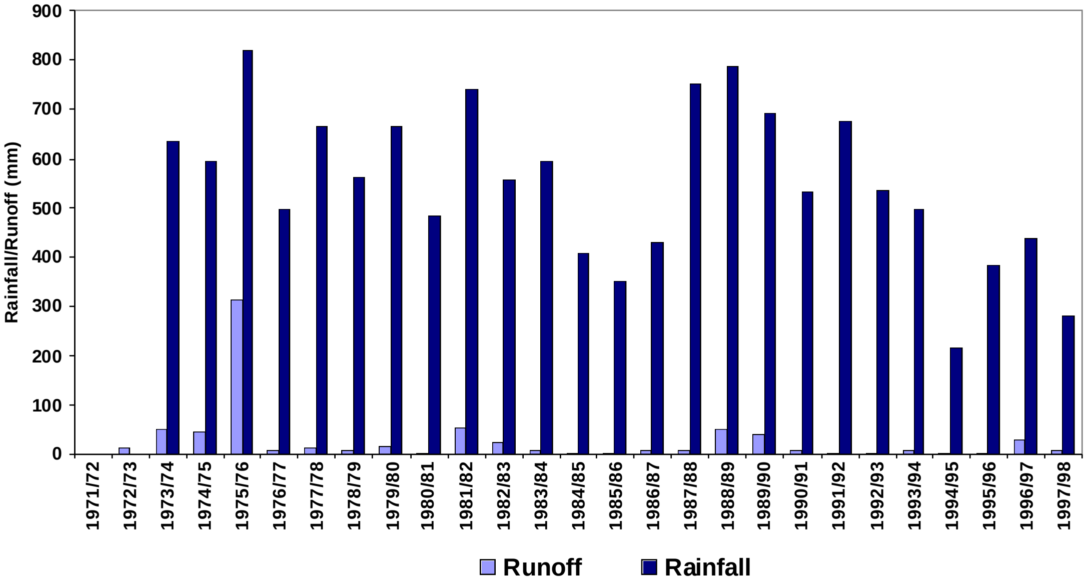
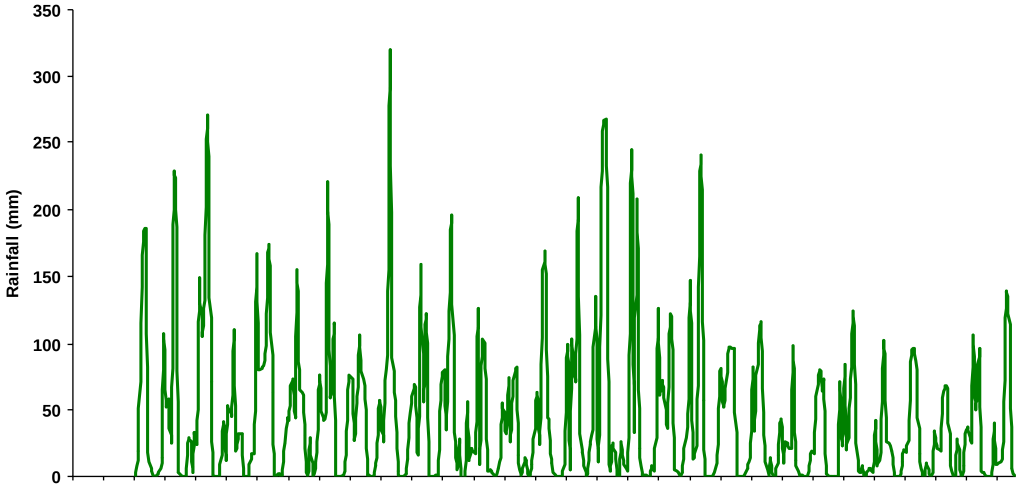
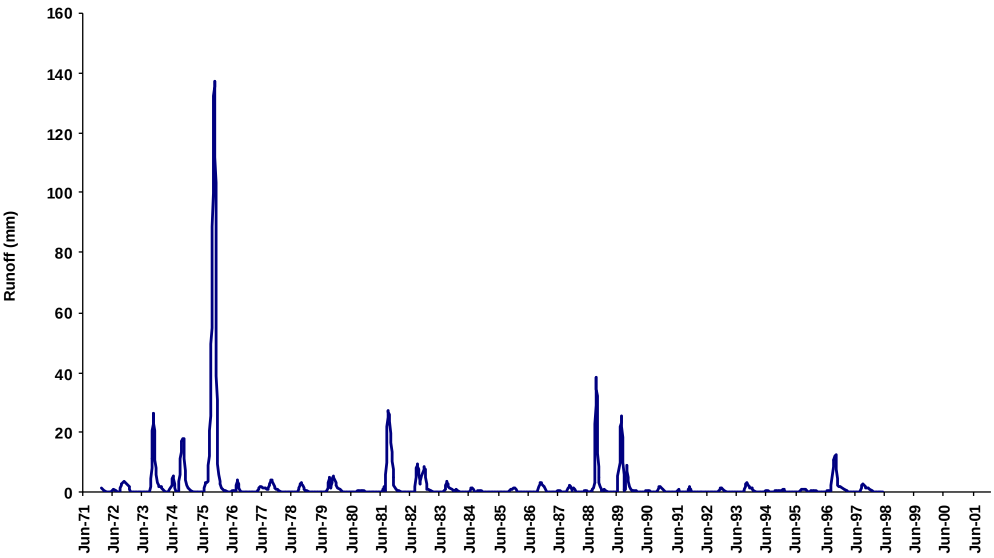


Figure 29. Comparison of monthly rainfall (a) and runoff (b), Pennar River at Tadapatri



(b)



Runoff at the micro-watershed and field scales

Micro-watershed and field-scale studies of runoff have been carried out by the CSWCRTI in Bellary and by CRIDA in Anantapur. These studies have shown that average annual runoff is typically 2% to 15% of average annual rainfall and highly dependent on such factors as: soil type, slope, land use and/or vegetative cover and presence of in-field soil and water conservation measures. Although average annual runoff figures are low, it must be emphasised that runoff resulting from individual or sequences of rainfall events will often be much higher. Runoff will also tend to be relatively high from small plots or from certain features in the landscape (e.g. rock outcrops, roads, urban areas, areas of hard pan etc.). However, it is the annual average runoff figure that provides an indication of the scope for developing additional surface water resources at any given point in a watershed.

Table 9 summarises runoff findings from micro-watershed experiments that were carried out by CSWCRTI (Bellary) at off-station locations. The information from Chinnatekur is particularly relevant because this experimental watershed is located in Kurnool District approximately 40 km from Dhone. It can be seen from these findings that mean annual runoff as a percentage of mean annual rainfall is less than 10% regardless of the nature of the land use or land surface conditions. It can also be seen that runoff is relatively lower from forested areas and from agricultural areas that have received soil and water conservation treatment.

4.3 Impact of water harvesting on patterns of water availability and use

For centuries, tanks have played an important role in maintaining rural livelihoods in the semi-arid areas of South India. Until recently, they provided a reliable source of water for irrigation and, in many cases, they helped recharge shallow aquifers that met drinking water needs during dry seasons and periods of drought. As has been well documented elsewhere, a shift towards centralised government contributed to the breakdown of traditional management systems as government departments took responsibility for decisions and tasks that had originally been the responsibility of local people and/or elites. As a result of relatively recent state government policy, most tanks in the two study mandals have been converted into percolation tanks (i.e. sluices have been blocked and surface water is no longer released for irrigation in the command area).

In recent years, people in the study mandals have observed a reduction in both inflows to many tanks and the frequency of spillage or surplusing. In discussions, the reasons that are often given for these changes are: i) A decline in rainfall and ii) Deforestation in the tank catchment area. Neither of these explanations is convincing because: i) There has not been a measurable decline in rainfall and ii) Although deforestation has taken place, this occurred before the phenomena of reduced inflows was observed and, in any case, deforestation is more likely to increase tank inflows.

Using the methodology described in Section 2.8, the impacts of water harvesting on five traditional tanks systems were assessed. Chapari and Yapadinne tanks are located in Kalyandurg and Dhone respectively, whereas Gundlur, Inchigeri and Anabur tanks are located in north-east Karnataka in areas with similar agro-climatic conditions to the study mandals. Physiographic information relating to the tanks and their catchment areas can be found in Table 10.

Table 9. Summary of runoff from two experimental micro-watersheds

Experimental watershed	Mean annual rainfall (mm)	No. of years	Runoff (% mean annual rainfall)			
			Forest Catchment	Treated agricultural Catchment	Untreated Catchment	Barren area
Chinnatekur	501	5	2	5	9	
G R Halli	569	7	-	2	-	9

Table 10. Physiographic features of the five tanks

Physiographic features	Gundlur	Anabur	Inchigeri	Yapadinne	Chapari
Altitude (m)	536-880	600-711	460-641	480-600	450-525
Rainfall (mm)	472	576	573	585	580
Soil type	Alfisol	Alfisol	Vertisol	Alfisol	Alfisol / Vertisol
Catchment area (ha)	1234	2476	527	6423	2900
Average slope (%)	0.5-2.5	1.5-3.0	1-8	0.8-4.5	0.8-3.5
Tank capacity (ham)	27	144	34	42	68
Water spread (ha)	15	85	15	42	28

Table 11 presents information on recent increases in the number of wells, irrigated area and irrigator farmers in the tank catchment areas. Table 11 also presents information on the increase in the number of water harvesting structures and the estimated impact that these have had on annual tank inflows, frequency of years in which surplusing takes place and average annual spillage. These figures show that the additional storage created along drainage lines in the tank catchment areas in recent years has led to a decline in tank inflow, spillage frequency and average spillage in almost all cases. The reason is that runoff that would otherwise have run into the tanks is captured by the water harvesting structures. Once captured, the bulk of this water either evaporates or infiltrates and recharges aquifers which are pumped as sources of water for irrigation. In these semi-arid areas, water harvested by structures only makes a small contribution to base flow which itself tends to be captured by downstream structures.

Table 11. Summary of changes in characteristics of the tank systems

	Gundlur		Anabur		Inchigeri		Yapadinne		Chapari	
	1990	2002	1987	2002	1990	2002	1987	2002	1986	2002
Wells:										
catchment	14	92	71	147	15	89	112	308	84	217
command	8	8	58	134	34	72	1	1	27	98
Irrigation:										
catchment	22	143	86	178	11	241	186	536	132	343
command	32	32	65	158	54	156	44	44	83	132
Structures: command	4	23	5	26	8	37	5	48	20	29
Irrigator farmers in catchment area	8	93	87	147	14	33	111	308	115	315
Tank inflow (ham)	61	35	138	93	40	20	285	213	70	63
Spillage frequency	9/11	7/11	5/11	1/11	6/15	2/15	14/15	12/15	1/15	1/15
Av. Spillage (ham)	25	10	4	2	9	1	187	135	7	7

The findings presented in Table 11 are entirely consistent with other studies in the region that have also reported reduced runoff as a result of water harvesting along drainage lines and within agricultural and forested areas (e.g. Rama Mohan Rao et. al. 1993 and 1995). Soil water conservation and construction of a large number of check dams along the drainage lines is clearly a major cause for reduced runoff. Groundwater extraction in the vicinity of the drainage lines and water harvesting structures is probably an additional contributory factor because the resulting groundwater depletion allows a larger volume of water to infiltrate and be stored in the aquifer. However, the relative importance of these two causes and possible interactions between the two could not be differentiated in this study.

Bearing in mind the fact that some of these tanks are more than 200 years old, Figure 30 compares potential mean annual tank inflows (i.e. the naturalised runoff that would occur if there were no structures in the tank catchment area), mean annual tank inflows approximately 15 years ago and mean annual tank inflows in 2002. It can be seen that in all cases there has been a reduction in mean annual inflows during both the period from construction up until 15 years ago and from 15 years ago up until 2002. In the case of Chapari, the biggest reduction took place during the period up until 1986 and, whereas for Gundlur, the reduction was more marked during the period 1990-2002. Table 12 summarises tank inflow information that is specific to each tank.

Figure 30. Comparison of tank inflows with no structures in catchment, and the situation 12-16 years ago and in 2002

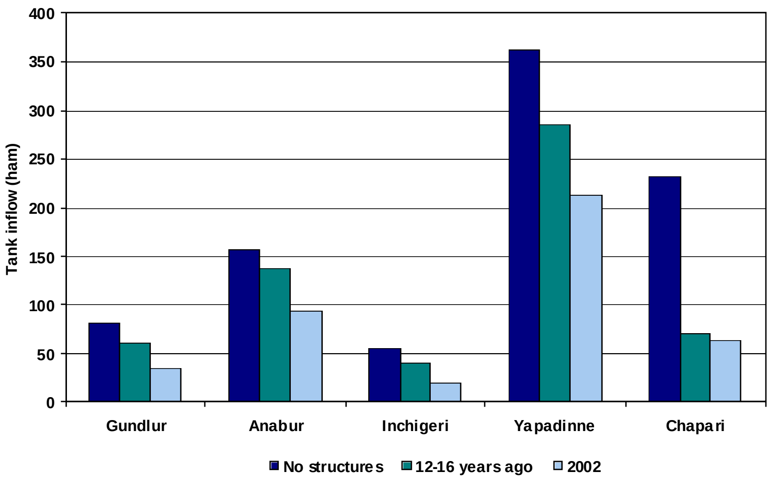


Table 12. Summary of tank inflow information specific to each

Tank	Specific characteristics relating to tank inflows
Chapari	Major decline in tank inflow occurred approximately 100 years ago when two tanks were constructed in catchment area to meet the domestic water needs of Kalyandurg town.
Yapadinne	Although there has been a large reduction in tank inflows, this is not leading to significant problems because the catchment area is very large in comparison to tank capacity .
Gundlur	Sand extraction along feeder canals and stone quarries in catchment have created additional storage in the catchment area.
Anabur	Original design of the tank relied on two feeder canals to fill the tank to full capacity. Unfortunately, one feeder canal was blocked by water harvesting structures and the other was poorly constructed and never functioned.
Inchigeri	Inchigeri has a relatively small catchment area. Runoff from this area was reduced as a result of farmers blocking feeder canals with large field bunds. These have enabled these farmers to cultivate paddy and sugar cane. Reduced inflows to the tank and the resulting reduced percolation to groundwater appears to be directly linked to the severe drinking water problems now faced by people living in Inchigeri town.

Figure 31 presents information on Gundlur tank's surface water balance components during an eleven year period. This figure gives an indication of the variability in these components. It also shows that the potential runoff, tank inflow and spillage is only loosely correlated with annual rainfall. Subsequent analysis carried out by the WHiRL project has shown that the impact of intensive water harvesting on tank inflows is most marked in percentage terms in years with low rainfall.

Figure 32 compares the increase in groundwater-based irrigation in the tank catchment areas during the last 12-16 years. It can be seen that there has been a big increase in each case with Yapadinne having the largest net expansion in irrigated area. Figure 32 also shows the portion of the increased irrigation that could have come from increased groundwater recharge that resulted from increased water harvesting in the tank catchment areas. It can be seen that all the increase in irrigation in Anabur could, in theory, be met by the increased groundwater recharge, whereas in Chapari virtually all the additional irrigation must rely on "natural" groundwater recharge.

Figure 31. Gundlur tank surface water balance components

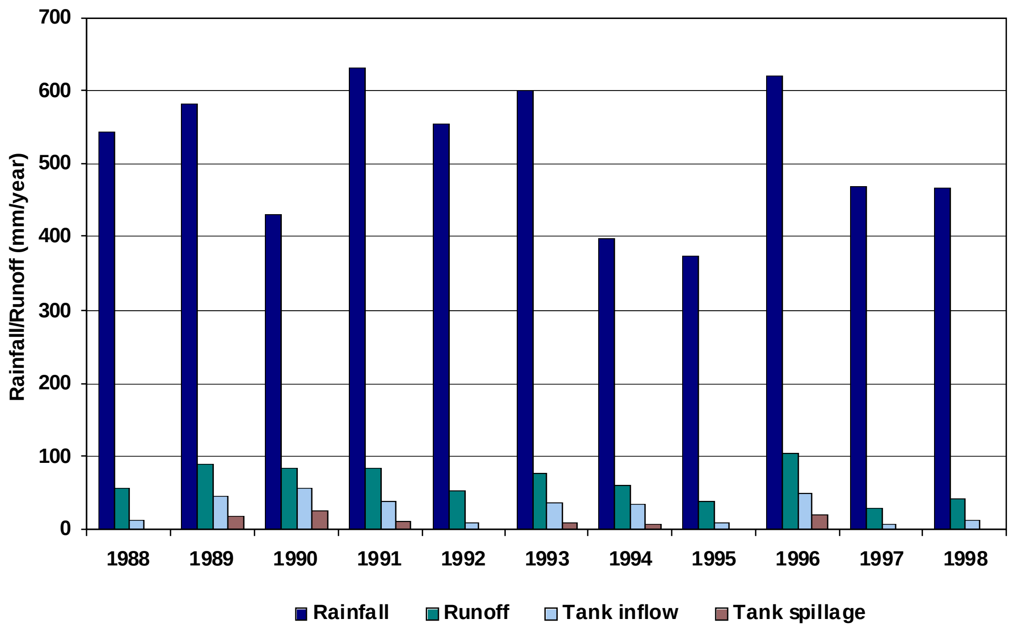
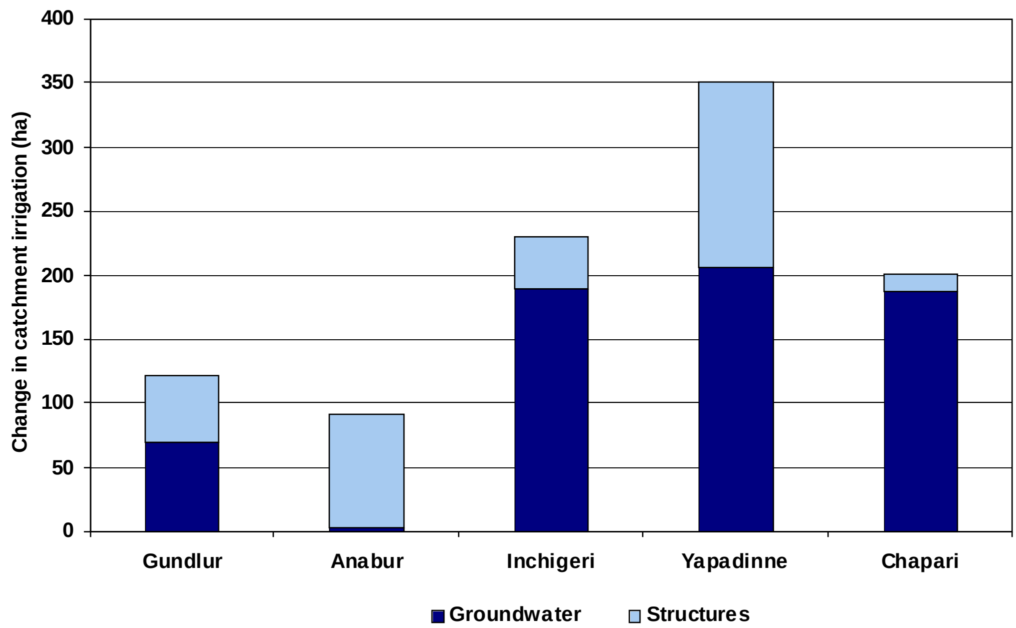


Figure 32. Possible sources of water for increased irrigation in tank catchment areas during the last 12-16 years



Increased groundwater development in the study mandals during the last 12-16 years has resulted in many hundreds of farmers having access to irrigation. Given the relatively high profitability of irrigated agriculture in this region (Batchelor *et al.,* 2000), the additional and more reliable income generated will have had a significant impact on the livelihoods of these farmers and their households. Although there is not a direct causal link between water harvesting and increased groundwater development (i.e. increased groundwater development is taking place even in areas without water harvesting activities), construction of structures and water harvesting does increase the volumes of water available in the tank catchment. Thereby, water harvesting is contributing to the dramatic changes that have taken place in recent years in terms of patterns of water availability and use.

Interestingly, reduced inflows to tanks have not led to a widespread reduction in the total area irrigated in the tank command areas because farmers that used to rely on tank releases now use groundwater as a water source. From the irrigation perspective and assuming that current levels of groundwater extraction are sustainable, changes during the last 12-16 years have been entirely positive not least because these changes have benefited poor and marginal farmers as well as relatively richer farmers. However, if the non-irrigation uses of the tanks are considered, it becomes obvious that the "irrigation" benefits have come at a social and economic cost. In the last 12-16 years the utility of many tanks has declined (Yapadinne being an exception) for activities such as washing, bathing, watering livestock and pisciculture. In some cases (e.g. Inchigeri), tanks are no longer a perennial source of recharge for wells that meet the domestic water needs of the village.

In many cases, the quantity of water surplusing has been reduced and, hence, less water is available to downstream users. Whether the benefits resulting from a changed pattern of water use warrant the negative trade-offs depends on the specifics of the tank system and on which social group is considered. It also depends on the scale considered. At a wider scale, the increased agricultural production and potentially more productive water use may be more acceptable than might be the case at the household scale.

In theory, it is possible to increase inflows into tanks without impacting on the incomes of the new irrigator farmers in the catchment area. This could be achieved in part by clearing feeder channels that are currently clogged and that are not important sources of groundwater recharge and, in part, by promoting more efficient and productive use of water in the catchment area. However, without the removal of or modification to larger structures and major changes in the system of incentives and disincentives under which farmers make decisions, it is unlikely that any "additional" water resulting from productivity improvements would flow into the tank. It is more likely that individual farmers will use this water to irrigate a larger part of their holdings or to grow additional summer crops. Alternatively this water will be accessed by farmers in the command area who do not currently have access to water for irrigation. Promotion of community or affinity group groundwater and surface water management also has the potential to lead to more productive and equitable water use. In some cases, this could involve the fitting of gates on larger structures and the development of operating rules that involve letting early runoff events flow to tanks. However, as the tank and tank command area are often located in different village areas, with the exception of improving feeder channels, it seems that there are no win-win options that will see the tanks return to anything near their pristine state. Changes in government policy and a shift towards demand management could help. However, the profitability of irrigated agriculture is such that many demand management measures will not be accepted readily by farmers whose incomes are based on using large volumes of water. This issue has been studied by the APWELL Project which has also piloted novel approaches to participatory hydrological monitoring (APWELL 2003a and 2003b).

Although there is a tendency to consider government programmes aimed at increasing water harvesting (e.g. watershed development programmes, source protection component of

Livestock near Gosanapalli tank, Dhone

rural water supply programmes) to be entirely benign, it is clear they can have a big impact on the viability and utility of traditional tank systems and on patterns of water availability and use within a tank catchment and command area. This impact appears to be most marked in low rainfall years and when increased water harvesting in the tank catchment area is coupled with increased groundwater extraction. The changed pattern of water use and associated changes in access to water for domestic and productive purposes results in trade-offs and distinct winners and losers. Although these trade-offs might be acceptable and, in some circumstances highly desirable, they should be considered explicitly in strategic-level and village-level decision making processes which, ideally, should be based on principles of integrated and adaptive water resource management (Batchelor *et al,* 2001). It is clear also that programmes of tank rehabilitation should consider the multiple trade-offs both within the individual tank system (i.e. catchment area, command area and the tank itself) and the larger macro-catchment before decisions are taken on whether rehabilitation of individual tanks is needed. It is clear also that programmes of tank rehabilitation must be careful to differentiate between symptoms and causes of decline in tank utility and to be sure to address causes such as those affecting tank inflows.

The following points provide a summary of the main findings of analysis relating to the impacts of water harvesting on patterns of availability and use:

- **In the study mandals, water harvesting and groundwater-based irrigation have in recent years had a major impact on patterns of access and use of water for irrigation. This has led to major improvements in the livelihoods of many households once they have paid off the debt incurred in the process of becoming irrigator farmers (e.g. borewell construction).**

- **In many areas, intensive water harvesting coupled with over-exploitation of groundwater is impacting on downstream water availability and, in particular the utility of tank systems. Hence, significant negative trade-offs are often associated with the changed pattern of use.**

- **With a few notable exceptions, government and NGO watershed development or rural water supply source protection programmes, regard water harvesting as a totally benign technology. In contrast in semi-arid areas, downstream communities are becoming increasingly aware of the problems caused by intensive drainage-line treatment in upstream areas.**

4.4 Annual water balances

Figure 33 presents indicative estimates of the components of the annual water balance for Dhone and Kalyandurg at the macro-watershed scale. These estimates have been produced on the assumption that, on average, storage terms will be insignificant. This figure shows that evaporation from rainfed arable areas is the largest component of the water balance. In both mandals, evaporation from different surfaces or land uses is the fate of approximately 95% of the rainfall. These figures contrast with the statewide water balance figures of the Andhra Pradesh Water Conservation Mission (Anon, 2003) which suggest that the fate of annual rainfall is as follows: evapotranspiration – 41%, surface runoff – 40%, percolation to groundwater bodies – 9% and retained as soil moisture – 10%.

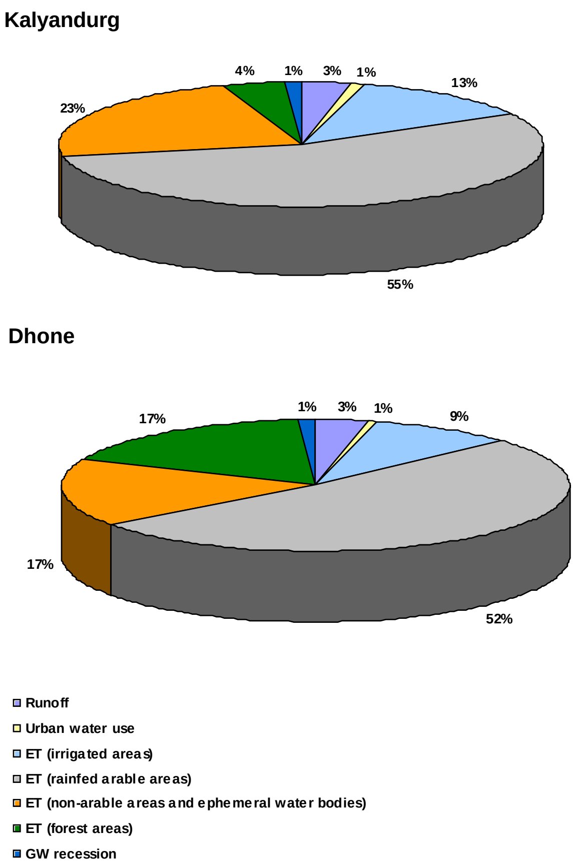
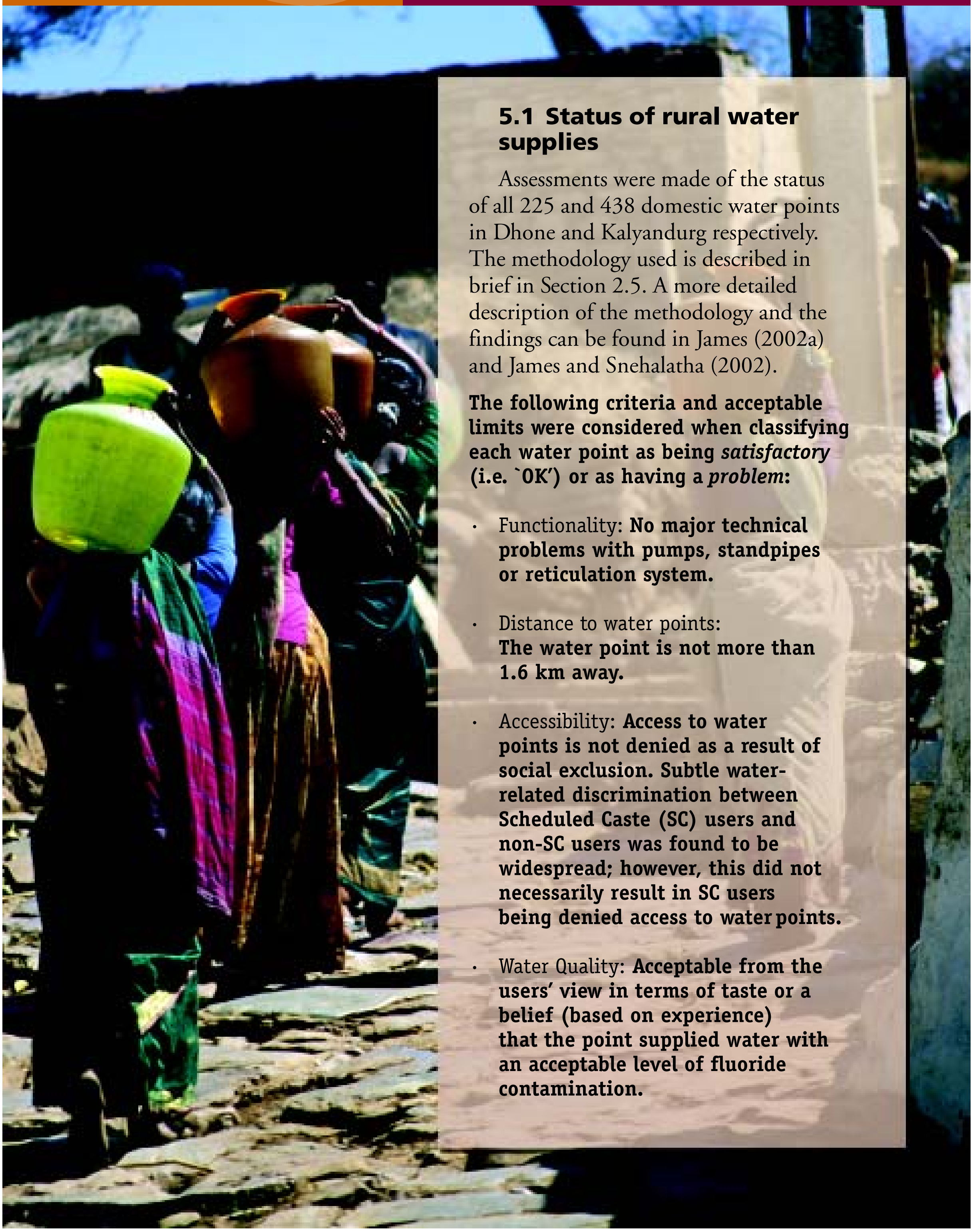


Figure 33. Annual macro-watershed or basin scale water balances

5 Access to water resources



5.1 Status of rural water supplies

Assessments were made of the status of all 225 and 438 domestic water points in Dhone and Kalyandurg respectively. The methodology used is described in brief in Section 2.5. A more detailed description of the methodology and the findings can be found in James (2002a) and James and Snehalatha (2002).

The following criteria and acceptable limits were considered when classifying each water point as being *satisfactory* (i.e. `OK') or as having a *problem*:

- Functionality: **No major technical problems with pumps, standpipes or reticulation system.**
- Distance to water points: **The water point is not more than 1.6 km away.**
- Accessibility: **Access to water points is not denied as a result of social exclusion. Subtle water-related discrimination between Scheduled Caste (SC) users and non-SC users was found to be widespread; however, this did not necessarily result in SC users being denied access to water points.**
- Water Quality: **Acceptable from the users' view in terms of taste or a belief (based on experience) that the point supplied water with an acceptable level of fluoride contamination.**

- Adequacy of supply: **Adequate supply of water for domestic uses, from the users' point of view.**

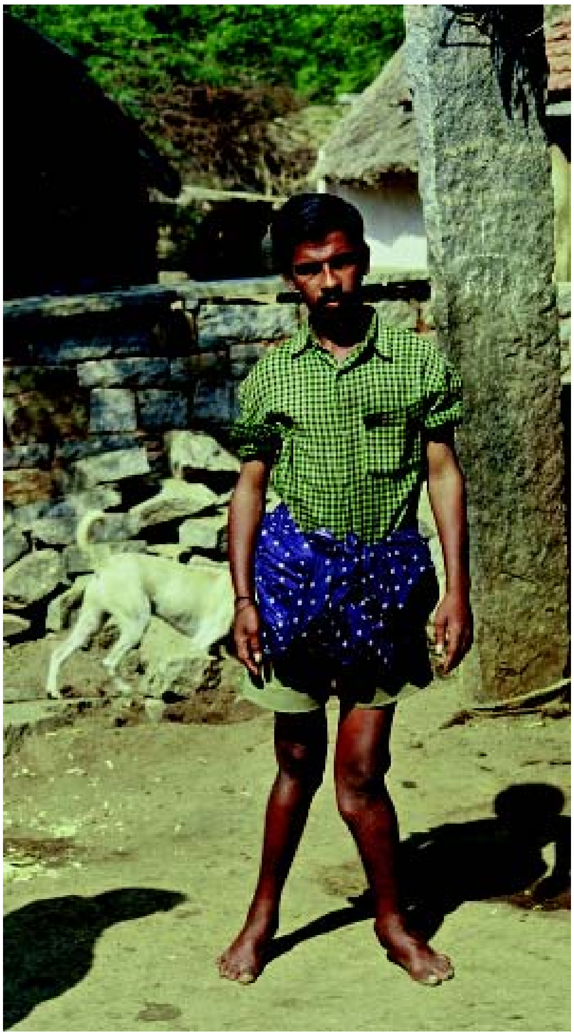
- Peak summer availability: **Water collection time and effort not much more during peak summer months than in other months.**

- Over-crowding: **No more than 250 users per water point.**

Using these criteria and acceptable limits, Figures 34 and 35 summarise the users' view of the status of water points in Kalyandurg and Dhone respectively. A water point was classified as being a "problem" water point if, in the view of the users, it failed to meet the acceptable limits of any one of the criteria. This assessment indicated that, although no water point was more than 1.6 km away or had more than 250 users, 51% and 24% of water points in Kalyandurg and Dhone respectively were either not functional or failing to meet the adequacy of supply and water quality norms of the Rajiv Gandhi National Drinking Water Mission (see Box 11). These figures contrast starkly with official figures for "problem" water points that showed only a small percentage of water points as having a problem. One reason for this is the fact that the official statistics concentrate almost entirely on the functionality of water supply systems and on whether or not a supply of 40 lpcd can be provided. Also, the official statistics do not give much attention to problems of peak summer availability and the problems experienced by women particularly in queuing for water during these lean times.

Fluoride problems in Battuvanipalli

In Battuvanipalli village near Kalyandurg town, villagers complained of the symptoms of fluoride contamination (pain in the joints, falling teeth, bleeding gums and brittle bones), even though the fluoride testing of the water source by the RWS showed a concentration of only 1.7 ppm (i.e. in excess of the permissible limit of 1.5 ppm). Action was not taken since the "operational" limit being used was 2.0 ppm. Even worse, subsequent analysis of this source by the WHiRL Project showed that fluoride concentration was actually in excess of 4 ppm.



25 year old man suffering from skeletal fluorosis, Battuvani Palli, Kalyandurg

Washing clothes in the Pennar river

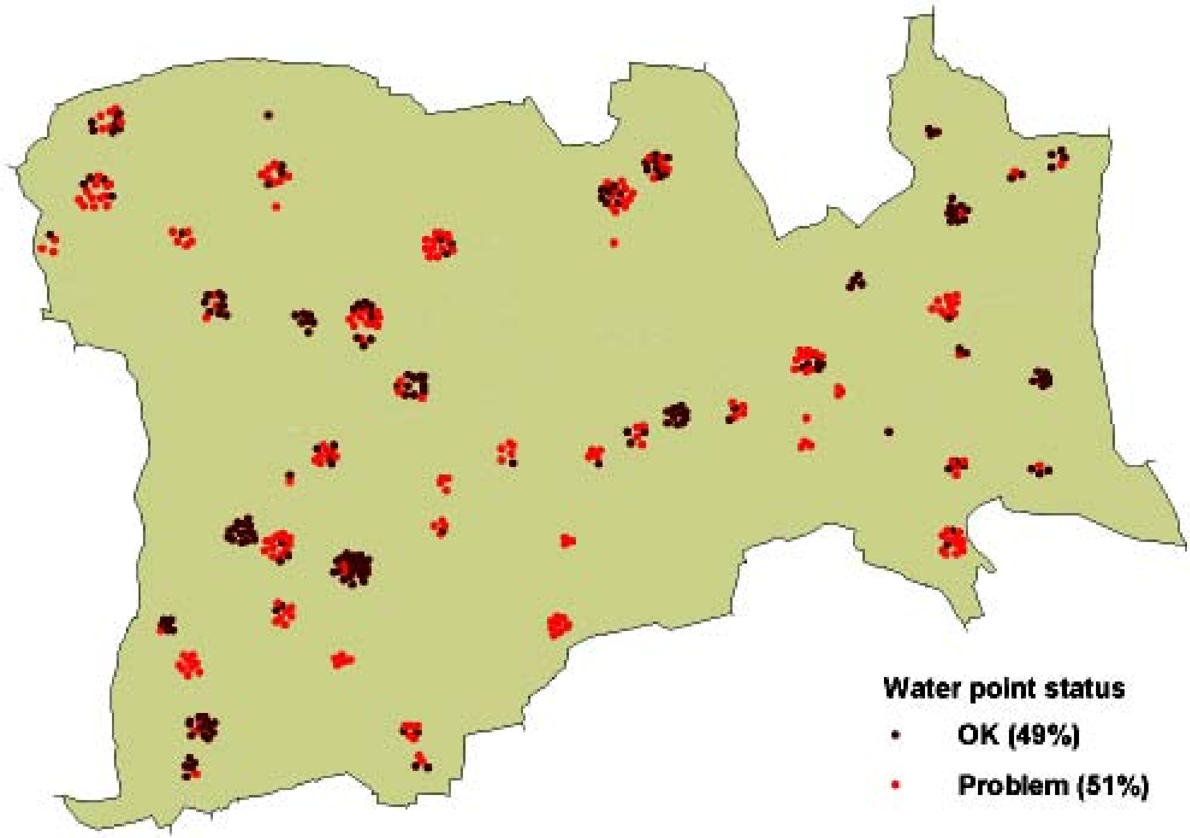


Figure 34. Users' view of status of domestic water points in Kalyandurg

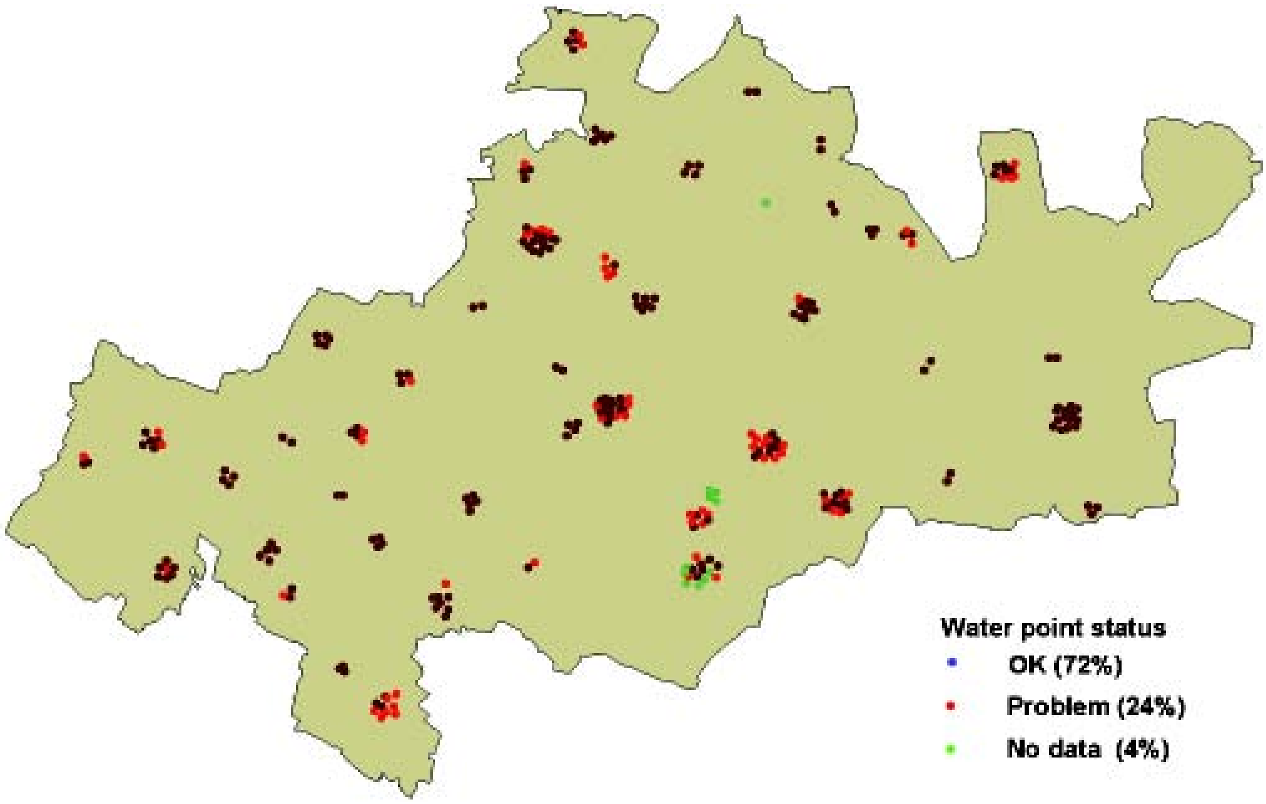


Figure 35. Users' view of status of domestic water points in Dhone

Box 11: Criteria for Identification of Problem Habitations

A habitation which fulfils the following criteria may be categorised as a Not Covered (NC)/No Safe Source (NSS) Habitation:

(a) The drinking water source/point does not exist within 1.6 km of the habitations in plains or 100 m elevation in hilly areas. The source/point may either be public or private in nature. However, habitations drawing drinking water from a private source may be deemed as covered only when the water is safe, of adequate capacity and is accessible to all.
(b) Habitations that have a water source but are affected with quality problems such as excess salinity, iron, fluoride, arsenic or other toxic elements or biologically contaminated.
(c) Habitations where the quantum of availability of safe water from any source is not enough to meet drinking and cooking needs. [Estimated at 40 litres per person per day, including drinking (3 litres), cooking (5 litres), bathing (15 litres), washing utensils and house (7 litres) and ablution (10 litres)]

Hence in the case of a quality affected habitation, even if it is fully covered as per the earlier norms it would be considered as a NSS habitation if it does not provide safe water at least for the purpose of drinking and cooking.

Habitations which have a safe drinking water source/point (either private or public) within 1.6 km. in the plains and 100 m in hilly areas but where the capacity of the system ranges between 10 lpcd to 40 lpcd, could be categorised as "Partially Covered (PC)". These habitations would, however, be considered as "Safe Source (SS)" habitations, subject to the water quality parameter.

All remaining habitations may be categorised as "Fully Covered (FC)".

Source: RGNDWM (2000).

Figures 36 and 37 provide information on the most common water point problems encountered by users in Kalyandurg and Dhone respectively. It can be seen that unacceptable water quality and non-functional water points were the problems that were most frequently cited in Kalyandurg and Dhone respectively.

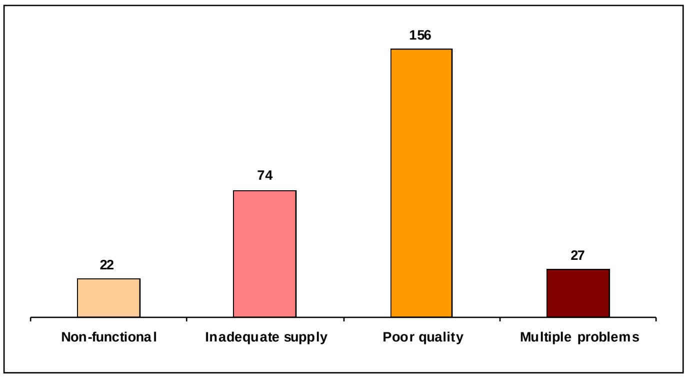


Figure 36. Types of domestic water supply problems, Kalyandurg Mandal, October 2001

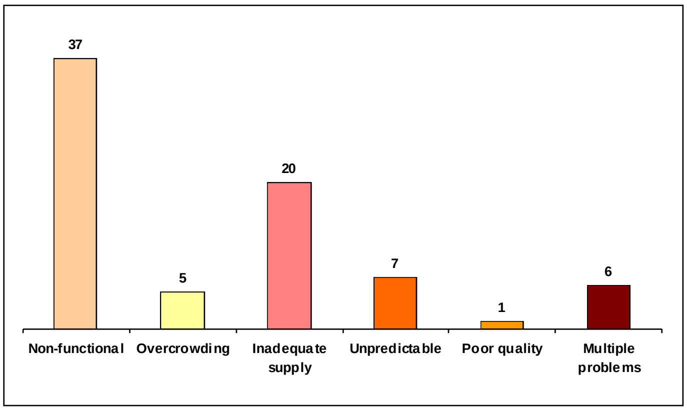


Figure 37. Number of water points with different types of problems, Dhone Mandal, March 2001

The users' assessments in Kalyandurg also considered a number of "minor" problems which, following appropriate capacity building, could be solved locally. These were:

- Leakage: **Many pumps, standpipes, taps and reticulation systems had leaks;**
- Malfunctioning hand pumps: **Many hand pumps were malfunctioning as a result of inadequate maintenance;**
- Unsanitary conditions around water points: **Inadequate drainage around many water points was the main cause.**

Misleading Figures:
The Case of Pathacheruvu

On paper, there is only one functioning hand pump for all 45 households of Pathacheruvu. A visit however showed up two agricultural bore wells near the village settlement (closer than the hand pump) with sufficient water to meet all domestic needs of those households, besides providing irrigation and livestock needs. However, the hand pump that was used most had a fluoride concentration in excess of 2 ppm.

In summary, important findings from the assessment of the status of domestic water supplies included:

- **Users' views of the status of domestic water supplies are not captured by the current procedures for monitoring rural water supplies;**
- **There is a major disparity between the users' views of the status of rural water supplies and official statistics;**
- **The nature and intensity of problems vary not only across villages but also within villages. Some households were more affected than others since the nature of the problems vary from water point to water point. Moreover, detecting problems with domestic water supply can be quite complicated. Water from a water point may be used for different purposes (such as for livestock, domestic uses, and irrigation) depending on the quality and quantity of water. Thus, a large number of water points in a village and/or adequate quantities of water at all water points may conceal problems with water quality (e.g. fluoride contamination) or social discrimination.**

5.2 Water-related social discrimination

Social restrictions on use of drinking and domestic water sources by Scheduled Castes (SCs) and Scheduled Tribes (STs) were found in all villages surveyed. These restrictions took two main forms.

- **SCs and STs cannot touch ('contaminate') open-well water, but can use public taps and hand pumps. Wherever scarcity forces villagers to use open wells as a source of domestic supply, SCs and STs bring their vessels to the well but cannot draw water from it. They have to wait for upper caste villagers to fill their pots with water.**
- **In many villages, separate hand pumps or public taps have been set up in parts of the village where SCs and STs stay (commonly called 'SC colonies'). When water is scarce and insufficient in the "upper caste" areas of the village, but available in the SC colony, upper caste villagers come to fill their vessels. The result is the SC and ST families have to wait till the upper castes have taken their fill before collecting the remaining water from public taps or hand pumps installed for their exclusive use.**

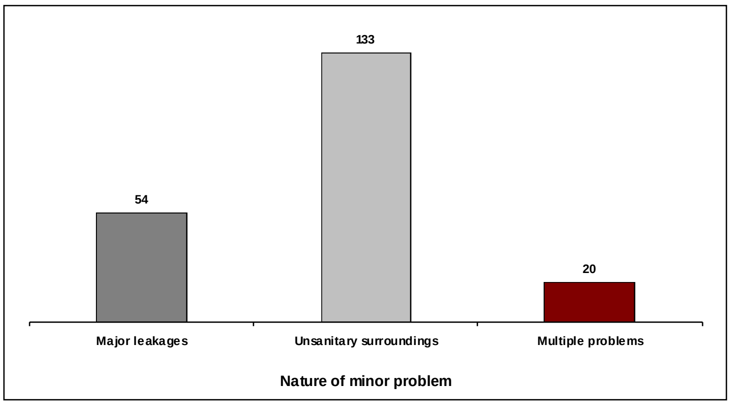


Figure 38: Nature of minor problems, Kalyandurg Mandal, October 2001

Caste Restrictions in Kocheruvu

A large cruciform step well in the centre of the old village settlement was being used for drinking water in December 2000 because the piped water supply was not functioning as a result of a major pump breakdown. Upper caste men and women walked down the steps and filled their vessels directly from the well. Lower caste men and women, however, had to wait half-way down the steps for an upper caste person to favour them by filling their vessels. Not all upper castes did this and sometimes the lower caste person had to wait for some time.

As lower caste villagers are not allowed to take water directly from the open well, a higher caste woman is filling the pot of the lower caste woman, Kocheruvu, Dhone

SC Colony in Manirevu

In December 2000, the newly-elected sarpanch had provided the SC colony with 4 new public taps so as to improve the colony's water supply that was hitherto dependent on hand pumps. But while public taps in the main village are outlets from small storage tanks that are, in turn, supplied by the piped system, the new taps in the SC colony are not connected to storage tanks. This means that if and when electricity fails and the main pump of the piped system stops working, the taps in the SC colony run dry while the taps in the main village continue to flow, using the water stored in the storage tank.

5.3 Water-related functionality of village-level institutions

Strong village-level institutions are a vital element of the proposed reform of rural water supply and sanitation services coordinated by the Rajiv Gandhi National Drinking Water Mission (see Box 13). Andhra Pradesh has an impressive history in forming women's self-help groups (SHGs), and it is normal to expect that village decision-making has been strengthened by this development. The participatory assessments sought to find out the extent to which village institutions like the panchayat and SHGs, respond to water-related problems.

In Dhone, assessments for the 42 villages surveyed indicated that in a majority of villages the panchayat was unsympathetic to problems concerning water supply (and sanitation). In Kalyandurg in contrast, it was found that in almost half the villages the panchayat was sympathetic and effective as far as water-related problems were concerned. The results for Kalyandurg are summarised in Figure 39 along with the questions that were used as part of the ordinal scoring system.

Box 12: RWSS Sector Reform Project

This project is being implemented in 58 districts in 22 states all over the country, including Chittoor, Nalgonda, Prakasam and Khammam in Andhra Pradesh. This project advocates four key principles for sustainable RWSS systems:

1. **Changing the role of government from provider to facilitator**
2. **Increasing the role of communities in the planning and management of their own facilities**
3. **Users paying all operation and maintenance costs, and at least 10% of the capital costs of supply**
4. **Promoting *integrated water resource management***

The institutional arrangements to implement the project include the formation of Village Water and Sanitation Committees (VWSCs), as sub-committees of the Gram Panchayat, to manage implementation and subsequent maintenance at the village level.

Source: Note on Andhra Pradesh Pilot Projects: Rural water supply and sanitation sector reforms, Water and Sanitation Program – South Asia, September 2000.

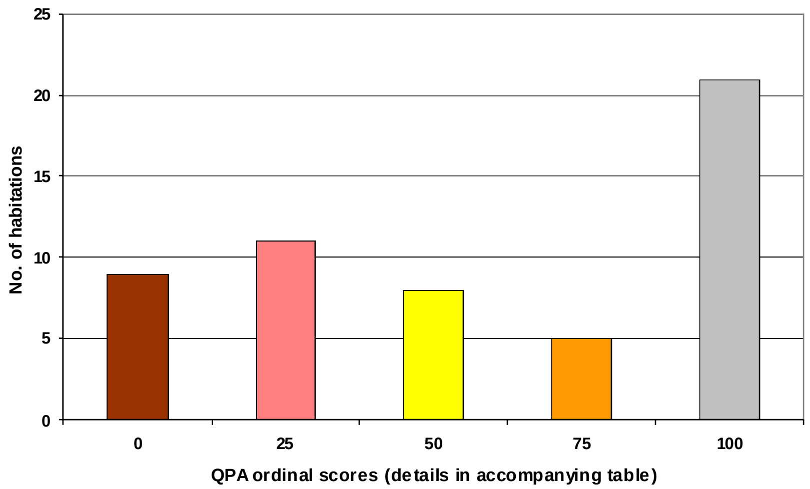


Figure 39. Panchayat Response to Water Related Problems, Kalyandurg Habitations, 2001

QPA Ordinal Scoring Options	Ordinal Scores	Number of villages
Listens, but no action is taken	0	9
Listens and acts, but no follow up and hence no result	25	11
Listens and acts, but results come after a long time	50	8
Listens and acts, gets quick results but not effective	75	5
Listens, acts, and gets quick and effective results	100	21

Two main reasons were identified for the poor response by the panchayat. These were;

- **Apathetic leaders: These included sarpanches of the revenue village living in one of the constituent habitations and paying relatively less attention to complaints from the other habitations.**
- **Fund constraints: Even when sarpanches were interested in taking action, funds were often a major constraint.**

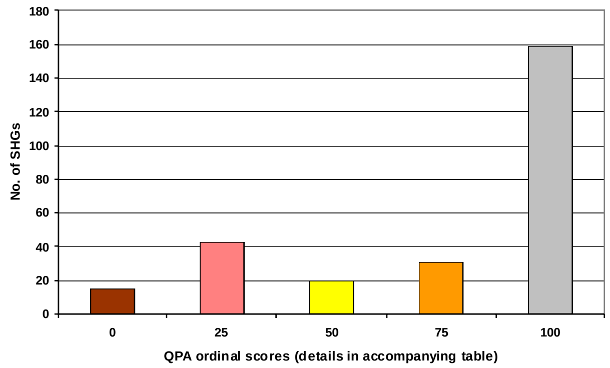


Figure 40: Status of SHG functioning: Kalyandurg SHGs, 2001

QPA Ordinal Scoring Options	QPA Scores	Number of SHGs
Only saving; no loans	0	15
Saving and loans only for consumption purposes	25	43
Saving, effective utilisation of loans & for at least one productive purpose (no results)	50	20
Saving, effective utilisation of loans & for at least one productive purpose (breakeven)	75	31
Saving, effective utilisation of loans & for at least one productive purpose (with profits)	100	159

5.4 Functionality of SHGs

The assessment of SHGs indicated that many were being very successful in terms of thrift and credit but few had any interest in or experience of tackling water-related problems. This finding casts some doubt on the proposals from some quarters to involve SHGs in water-related challenges. In some villages, particularly those with weak panchayats, it was found that spontaneous community action was leading to solution of water-related problems. This action, however, even when it involved SHG members, was not organised by the SHGs.

Figure 40 presents the results of the participatory assessment of the functioning of SHGs in Kalyandurg. This shows that the village-level perception is that 159 of the 268 SHGs (or nearly 60%) fall into category "Saving, effective utilisation of loans for at least one productive purpose (with profits)." Figure 41 presents the results of the assessment of SHG influence on community decision-making in villages of Dhone. This shows that in 36 of the 42 villages (or 86%) surveyed SHGs were not effective in influencing water-related community decision making. These findings suggest that women's SHGs will need considerable strengthening before they can take on the role of change agents in the habitations in the two study mandals.

Box 13: Some villagers' view on the response of the panchayat to water supply problems

"Since Sarpanch is residing in Chapiri, he has not taken any interest and no response, in spite of people's request." (Chapirithanda habitation, Chapiri revenue village).

"No response from panchayat, as Sarpanch was from other village." (Mallapuram habitation, Palavoy revenue village).

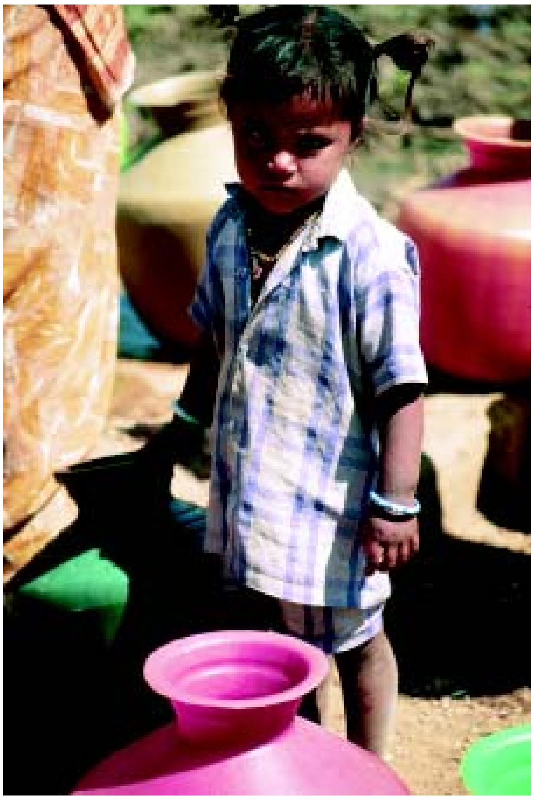
"Panchayat listens, but no action taken, because of no funds to panchayat." (Varli habitation, Varli revenue village).

"When motor underwent repairs seven times, on all occasions, the panchayat took immediate and effective action." (Duradakunta habitation, Duradakunta revenue village).

"Panchayat listens to problem and acts quickly in case of handpump repair at all times." (Palavoy habitation, Palavoy revenue village).

5.5 Participation of the poor and women in community decision-making

Even if a community decides to act on a water-related issue, the decision to act is not always made collectively or democratically. The participatory assessments explored this issue and the results are summarised in Figures 42 and 43. Figure 42 shows that in 91% of the villages in Kalyandurg, the poor participate in meetings and in 67% of the villages the poor both participate and influence decisions affecting them. Figure 43 shows that the situation in Dhone is not so encouraging, in that the poor participate in only 50% of the villages, and the poor both participate and influence decisions affecting them in just 16% of the villages. The relatively high figures for Kalyandurg can be attributed to the fact that an NGO, namely the Rural Development Trust, has been working in Kalyandurg for more than 25 years. One of the main thrusts of their work has been empowerment of the poor.



Waiting to fill water pots, Kocheruvu, Dhone

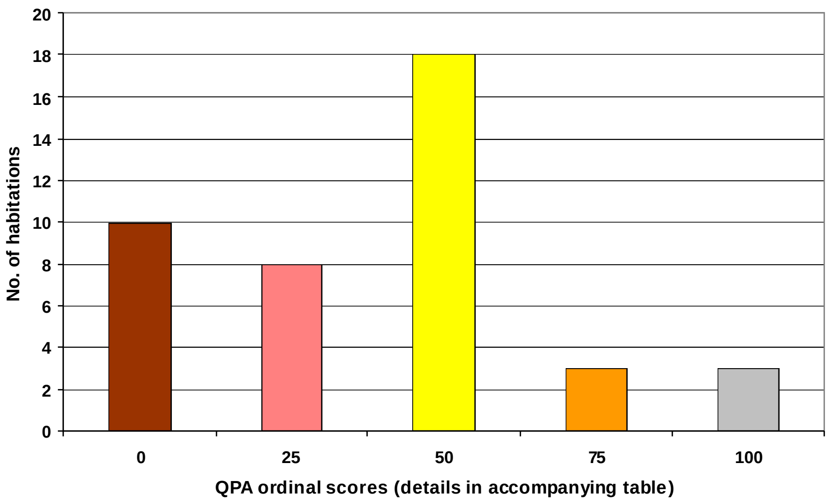


Figure 41. SHG influence on community decision-making, Dhone, 2001

QPA Ordinal Scoring Options	QPA Scores	Number of Habitations
Groups do not play a role, it is left to individual members	0	10
Groups represent, but do not pursue, even to get assurances of future action	25	8
Groups represent pursue and get assurance of action, but no effective action occurs	50	18
Groups represent, pursue, and get effective action	75	3
Groups listen, act, and get quick and effective results	100	3

Box 14. Some villagers' views on decision-making involving the poor, Kalyandurg

"Because of disunity, disputes and misunderstanding, nobody participates in community decision-making." (Balavenkatapuram).

"In spite of the large number of poor people, we are unable to influence the decisions taken by the non-poor." (Dodagatta).

"Since, it is a single community, all families are relatives." (Pathacheruvu).

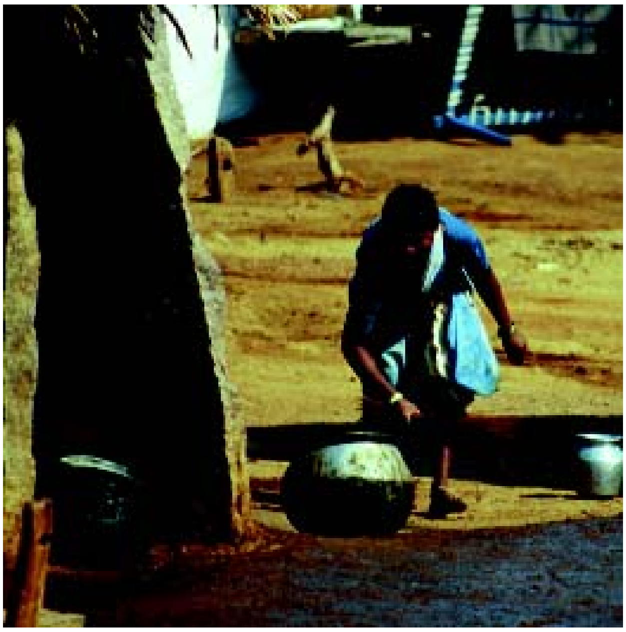
"Poor and non-poor participated in decision making and constructed two *ratchakattas*, one in the SC colony and the other in the bus stand." (PTR Palli).

"The whole village is participating in annual meetings (on every *Shri Rama Navami*) and they discuss and make decisions about village problems and the means to solve them." (Vitlampalli).

"Poor could influence in getting housing scheme, pipeline, electricity etc." (Bedrahalli).

"Non-poor give preference to poor in decision-making; and poor also accustomed to give their opinions to community. Repair work done to Mariamma temple, *ratchakatta* constructed in SC colony. Poor influence decisions concerning themselves." (Mudigal).

Hand pump in Obulapuram, Kalyandurg



Traditional practice of applying a mix of water and dung to the ground in front of houses, Pathacheruvu village, Dhone

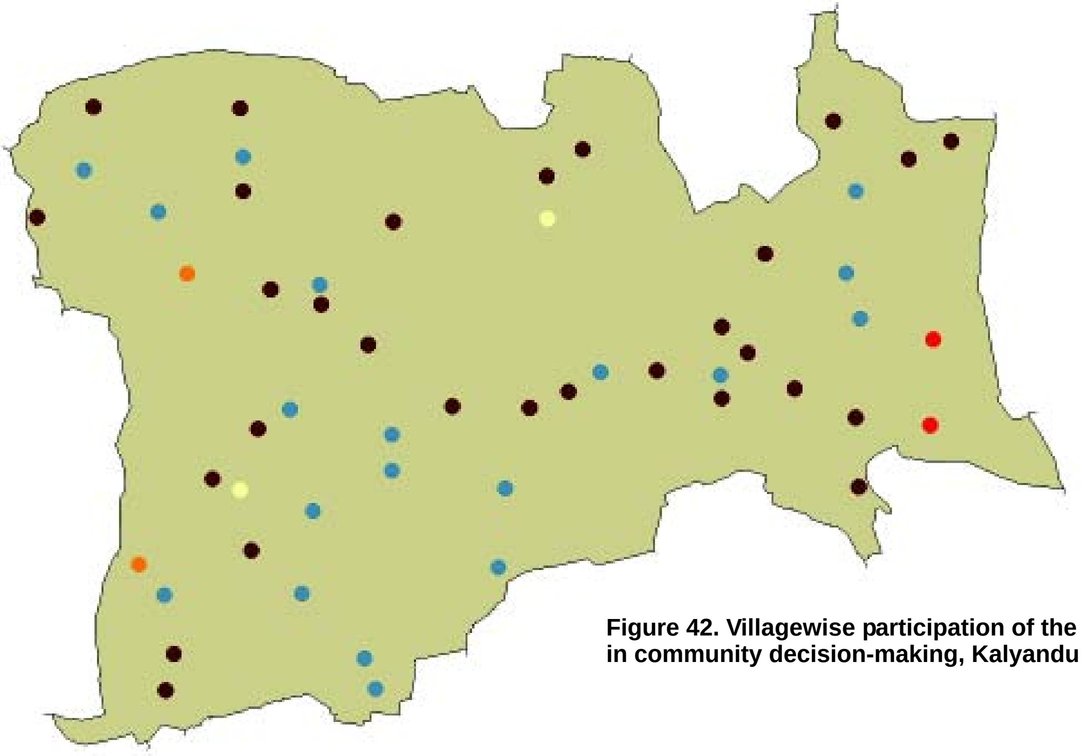


Figure 42. Villagewise participation of the poor in community decision-making, Kalyandurg

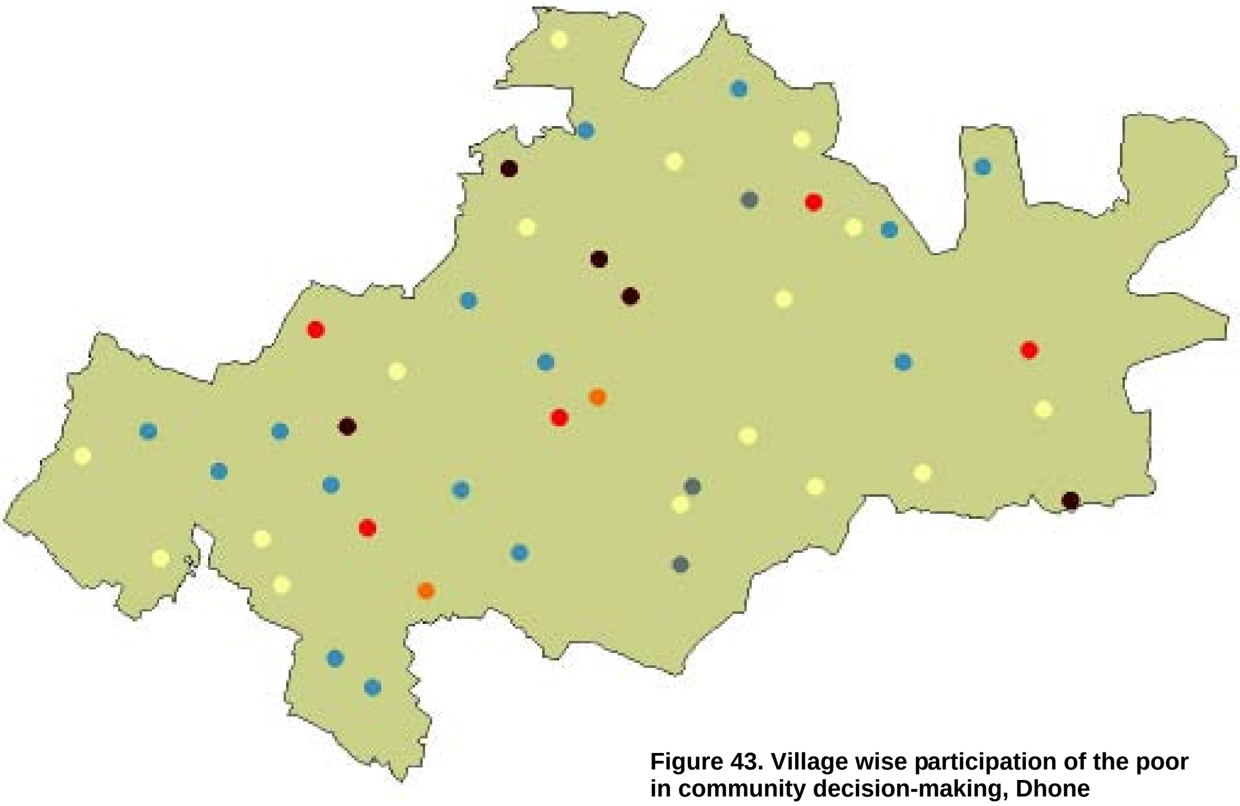


Figure 43. Village wise participation of the poor in community decision-making, Dhone

- Poor hardly ever go to meetings
- Poor go to meetings but do not participate
- Poor go to meetings but mostly let non-poor take decisions affecting them
- Poor attend meetings, participate, but do not influence decisions affecting them
- Poor attend, participate and are able to influence decisions affecting them
- No data

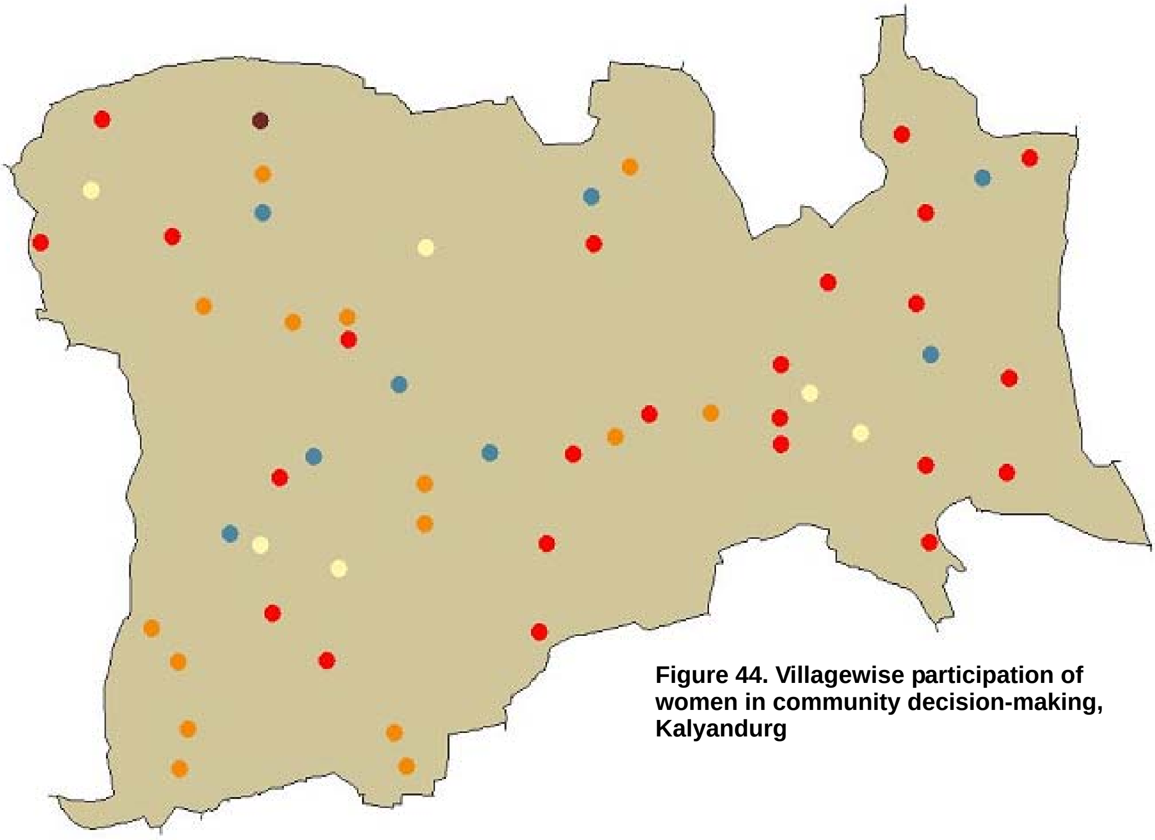


Figure 44. Villagewise participation of women in community decision-making, Kalyandurg

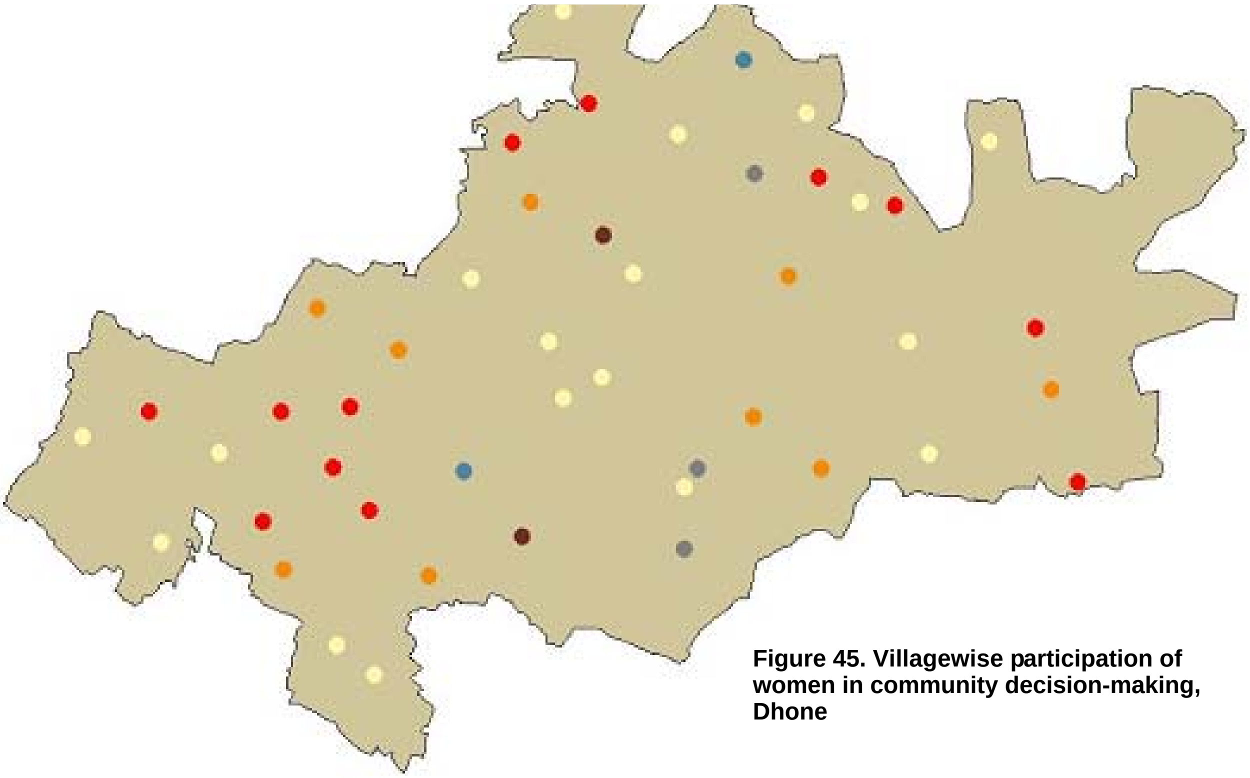


Figure 45. Villagewise participation of women in community decision-making, Dhone

- Women are not involved in community decision-making
- Women are in committes but do not attend
- Women attend meeting but mostly let men take major ddecisions
- Women attend, participate but cannot influence major decisions
- Women attend, participate and are able to influence major decisions
- No data

Figure 44 and 45 summarise findings relating to the participation of women in community decision-making in Kalyandurg and Dhone respectively. These figures show that in Kalyandurg women were only participating in meetings in 17% of the villages and participating and influencing decisions in 4% of the villages. In Dhone, women were participating in meetings in 14% of the villages and participating and influencing decisions in 5% of the villages. For Kalyandurg in particular, there is a stark contrast between the figures on the participation of the poor and of women in meetings. These findings confirm that, although poor men participate in meetings, women, and particularly poor women, rarely participate in meetings. In summary, despite impressive advances in women's empowerment through the SHG movement in Andhra Pradesh, women still do not participate effectively in community decision-making. Even in a mandal like Kalyandurg, which has a good record in remedial action by panchayats and community participation, participation by women in community decisions is low. In a majority of the habitations (all except 2), women were either not involved in community decision-making, or did not attend meetings or influence major decisions on community issues relating to water and sanitation.

5.6 Access to irrigation water

Access to reliable water supplies for irrigation, livestock and other productive purposes is extremely important to the livelihoods of a large number of people living in the study mandals. Although there is some growth in the service sector, the majority still rely heavily on agricultural production. There is a strong belief amongst small and marginal farmers, based on experience, that gaining access to water resources and becoming an irrigator farmer is a reliable means of escaping from poverty. Hence, considerable amounts of money have been and continue to be invested in borewell construction in Dhone and Kalyandurg. Private borewell investments total around Rs. 4 crores in Dhone and around Rs. 22 crores in Kalyandurg (based on a cost of Rs. 35,000 per borewell at 2002 prices). This level of investment reflects the relative profitability of irrigated cropping. However, over-exploitation of groundwater in both study mandals has led to a situation whereby investments in irrigation have become a widespread cause of poverty (see Box 16).

Box 15. Villagers' views on women's participation in decision-making

"Women are not included in community meetings. They are scared to participate. Women participate only for their problems, and are not involved in community problem solving." (Manirevu).

"Men are not giving much importance to women's participation in community meetings." (Obalpuram).

"Women are not encouraged to participate in community decisions, even though most of them have minimum education." (Kadadarakunta).

"Women are not being allowed and also women are not interested in participating." (Venkatampalli).

"Women mainly participate in Vidya Committee meetings. But once they made a *dharna* for water problem at Kalyandurg MRO office." (Vitlampalli).

"Women participated in community decision-making; asked for community latrines. Decision taken and work also done." (Mudigal).

"DWCRA groups participated in road formation by *shramadan*. Women attend community and *Gram Sabha* meetings and speak about their problems." (Golla).

Overhead tank in Kocheruvu, Dhone

Box 16. Mechanisms that link poverty to overexploitation and competition for groundwater resources in crystalline basement areas

Failed borewell investments. **Investment in well construction is a gamble with high risks, particularly in ridge areas and other areas with low recharge potential. Farmers who take loans to construct borewells but are unable to find groundwater, will not be able to make repayments and, in many cases, will quickly spiral into debt.**

Higher borewell costs of latecomers. **Latecomers to borewell construction often have to make larger investments than firstcomers. This is because groundwater levels have already fallen, and siting a successful borewell involves drilling to greater depths. Also latecomers often have smaller land holdings and, as a result, the scope for siting a successful well is more limited. The net result is latecomers have to take larger loans and, consequently, are more likely to default.**

Competitive well deepening. **Wells owned by rich farmers tend to be more productive and/or generate more income. If groundwater overexploitation takes place and water levels decline, richer farmers are more able to finance competitive well deepening. Also, as wealthy farmers tend to have established their wells before competitive deepening starts, they are in a much better position to take new loans. As latecomers are often unable to finance competitive well deepening, their wells fail and they are unable to repay loans and often have to sell their land to moneylenders, who are in many cases the rich farmers.**

Impacts on domestic water supplies. **Overexploitation of groundwater for irrigation has lowered water tables in aquifers that are also sources of urban water supply. This has led to a reduction in supply, particularly, in peak summer and periods of drought. Collecting water takes more time and involves carrying water longer distances. In some extreme cases, competition between agricultural and urban users is leading to complete failure of the village water supply. In these cases, villagers sometimes have to use water sources that are not safe and suffer illness as a result. Illness usually represents both a loss of income and expenditure on medical treatment.**

Crop failure or low market prices. **If crops should fail for any reason (e.g. major interruption in electricity supply, wells running dry) or if there should be a steep fall in market prices of produce, farmers with large loans for borewell construction are extremely vulnerable. If they should fail to make repayments on loans, which typically have interest rates of 2% per month in the informal money market, they can easily spiral into indebtedness with little hope of recovery.**

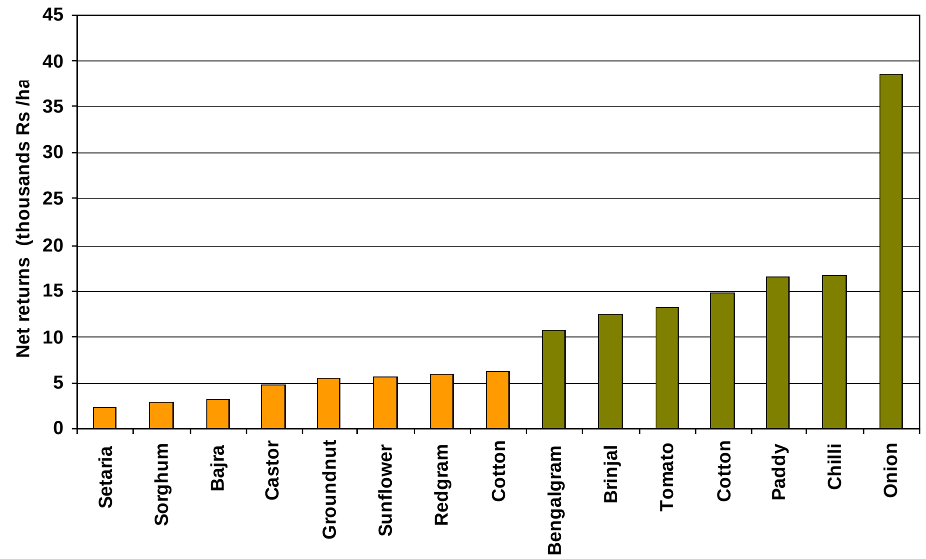
Falling groundwater levels. **Falling groundwater levels in many areas have increased the risk of wells failing during periods of drought as there is no longer a groundwater reserve or buffer to maintain supply during dry seasons and droughts. It is often poor and marginal farmers that have borewells that are most likely to fail albeit temporarily during such periods.**

Impact of intensive drainage line treatment. **Intensive drainage line treatment as part of watershed development and other programmes can impact on the pattern of recharge. The net result is that, in semi-arid areas, some borewell owners can see the yields of their borewells increase but others (usually located downstream) see their borewells become less productive.**

Reduction in informal water vending. **Informal markets for groundwater have emerged in recent years in these parts of semi-arid India, as farmers with access to surplus supplies sell water to adjacent farmers who either lacked the financial resources to dig their own wells or had insufficient supplies in the wells they did own. Now as well yields decline, water markets are becoming less common as well owners keep all available supplies for their own use.**

Source: Batchelor et al. (2003)

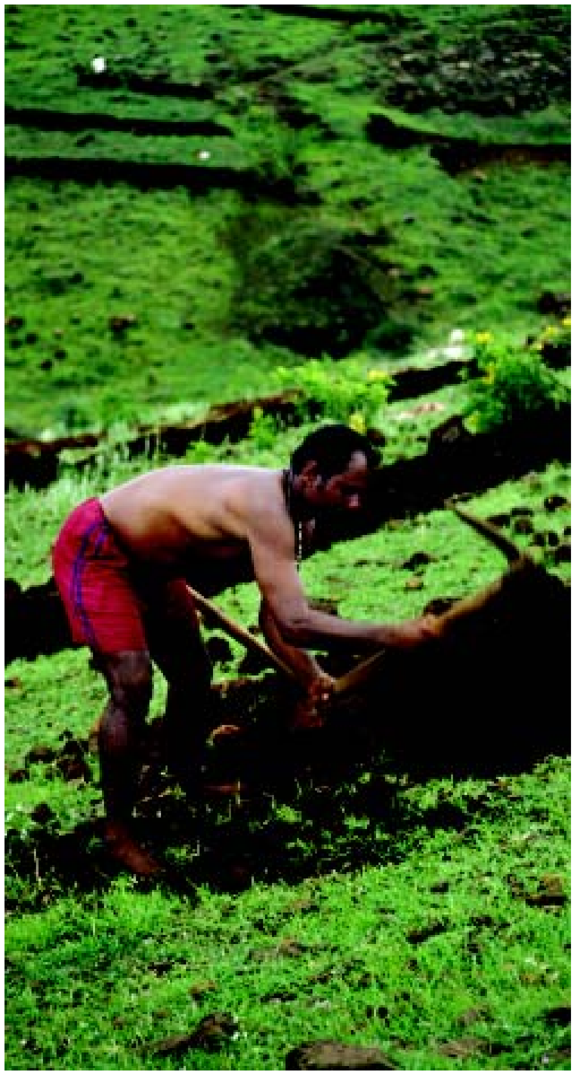
Figure 46. Relative profitability of rainfed crops (brown bars) and irrigated crops (green bars), Dhone



5.7 Profitability of irrigated cropping

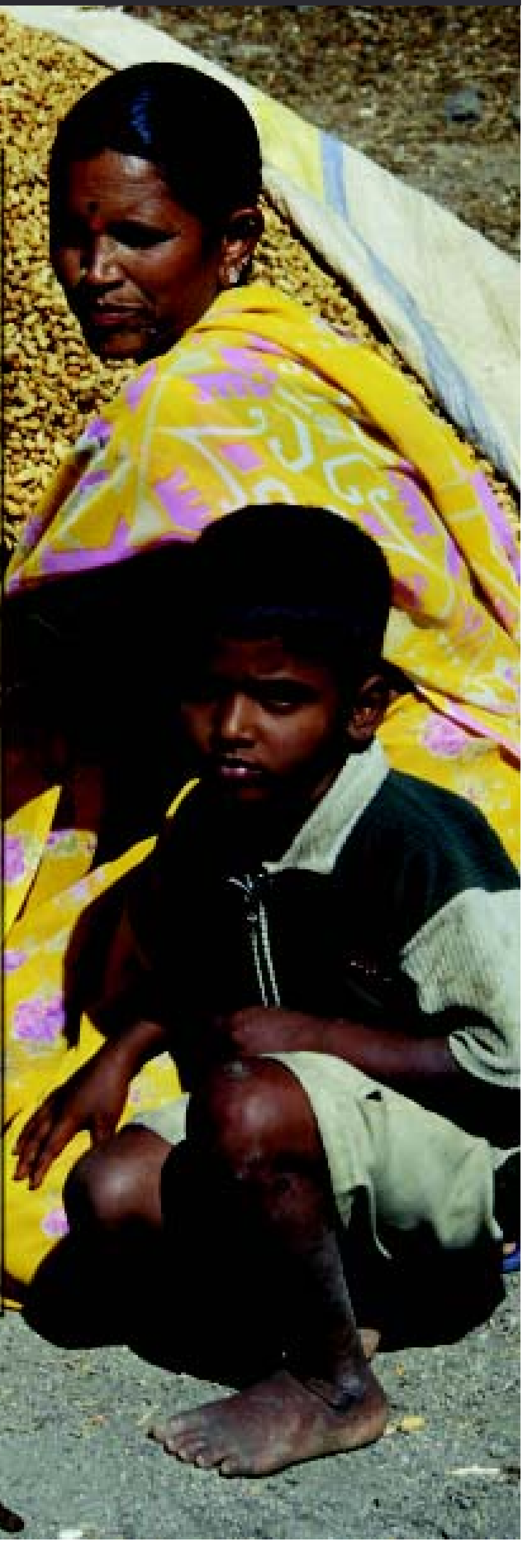
Profits per hectare from irrigated agriculture are, on average, twice those from rainfed farming. The lowest profit from an irrigated crop is often higher than the highest profit from a rainfed crop. Using data from Dhone, Figure 46 compares the profitability of rainfed and irrigated crops. Cultivation of some crops, however, is not `economic', and farmers continue to cultivate largely because they do not have to buy the inputs they require. Compared to areas under rainfed cropping, a relatively small proportion of the cultivable area of each mandal is irrigated. Although the large kharif areas under rainfed groundnut are justified by the high relative profits, areas under other crops do not generally correlate with the net returns per hectare. Crops with high returns (e.g., mulberry, onions, vegetables) are grown on comparatively smaller areas because of local factors such as access to market, high cultivation costs, production risks and lack of local storage and processing facilities. Food crops (e.g., jowar), on the other hand, are grown on larger areas than warranted by their relative profit because they provide other benefits (e.g. food security).

Water is not such a big constraint on non-agricultural activities such as brick-making, making pottery and operating tea stalls/kiosks. However, ready access to small volumes of water at times when it is needed is still critical to the success of such enterprises. More information on the economics of different water use options can be found in James (2000b).



Contour trenching

6 Constraints and risks



6.1 Water-related constraints

Constraints that limit the number of resource-focused options that can and should be promoted by the APRLP and similar projects include (not in order of importance):

- Climate: **The climate of the study areas is semi-arid and, consequently, rainfall is extremely variable in time and space. Hence, groundwater recharge and runoff into tanks is also extremely variable, as is the productivity of rainfed arable and non-arable lands.**

- Extreme events: **Meteorological drought and floods are recurring natural phenomena that have a relatively greater impact on the poor and vulnerable.**

- Aquifer characteristics: **Hardrock aquifers are prevalent in the study areas. These aquifersstore only limited quantities of water in shallow weathered and deeper fractured layers.**

- Water resource availability: **In many areas, current usage of water resources approximates and even exceeds annual replenishment. In the absence of inter-basin transfers, the scope for augmenting water resources by developing additional ground and surface water resources is limited.**

Water tanker operating near Anantapur in March 2003

- Government policy: **Currently, there are few incentives or disincentives to encourage individuals or groups of water users to maximise water use efficiency and/or productivity. This is despite there being an active debate on this topic.**

- Specialist knowledge: **Although specialist knowledge and experience exists, this is not always readily available to, or used by, villagers and the implementors of watershed development or rural water supply programmes. Careful targeting of interventions to particular physical, social and institutional settings is rarely practiced. Consequently, the tendency is to fund and implement the same interventions everywhere, regardless of the setting or priority needs.**

- Poor quality information: **Much water-related decision-making is based on official statistics that are incorrect and/or out of date.**

- Population increase: **Year by year a larger proportion of groundwater recharge and surface water storage is needed to meet domestic and urban water requirements. As a consequence, the water available for other uses is reducing. In addition, with increasing population and in the absence of improvements in water use productivity, there will be a decrease in the proportion of the population that can rely on land-based activities as a main source of income.**

- Small and fragmented land holdings: **In general, farmers have holdings that are becoming increasingly fragmented. This makes good land husbandry and good water management difficult.**

- Indebtedness: **Small and marginal farmers tend to have high levels of debt. Debt repayments and the cost of borrowing reduce their ability to use land and water resources efficiently. Levels of indebtedness amongst relatively richer farmers have also risen for reasons that are listed in Box 16. In some villages, this is leading to a consolidation of power within a relatively small elite group.**

- Electricity supplies: **Frequent and prolonged power cuts, particularly during summer months, encourage farmers to over-irrigate when power is available. Power surges often damage transformers and, thereby, cause shortages of pumped water for domestic use and irrigation.**

- Awareness: **The Water Audit has shown that, in general, there is a lack of awareness at all levels, of the severity and complexity of water resource problems in the study mandals.**

- Short-termism: **There is a belief, generated in part by watershed development propaganda, that there are quick fixes to the water-related challenges facing communities in semi-arid areas of southern Andhra Pradesh.**

- Water-related myths: **A number of water-related myths have become accepted wisdom at the policy level in Andhra Pradesh (see Box 17). Subscription to these myths can lead to poor decision-making, ineffective policies and wastage of financial and human resources.**

Box 17. Water-related myths

Water-related myths that were found to be relatively common during the Water Audit included:

- Water harvesting is a totally benign technology. **Although water harvesting technologies can produce huge benefits, intensive drainage line treatment, in particular, can significantly reduce water resource availability to "downstream" communities. In some cases, this negative trade-off does not matter; in others, severe hardship can result.**

- Planting trees increases local rainfall and runoff. **The reality is that forests exert a small, almost insignificant influence on local rainfall and, notwithstanding a small number of exceptions, catchment experiments generally indicate reduced runoff from forested areas as compared to those under shorter vegetation.**

- Runoff in semi-arid areas is 30-40% of annual rainfall. **Although localised runoff and runoff from individual storms can be high, annual runoff at the micro-watershed scale (or greater) in semi-arid areas tends to be much lower than 30-40%.**

- Rainfall has decreased in recent years. **With few exceptions, studies of long-term rainfall records, that have used data from a single set of rain gauges, have not shown a significant decrease (or increase) in mean annual rainfall.**

- Aquifers are underground lakes. **The reality is that check dams and other water-harvesting structures usually only have localised impacts on groundwater levels and aquifers rarely behave like underground lakes. Or put another way, localised recharge in one place rarely leads to an immediate rise in groundwater levels many kilometres away.**

- Water use of crops depends mainly on crop type. **A common misconception is that the daily water use of crops is directly related to the crop type and that evaporation rates are many times higher from some crops as compared to others. The reality is that, assuming that a crop is well supplied by water and has a full canopy (i.e. the crop completely shades the ground), the daily rate of evaporation is driven primarily by the meteorological conditions (e.g. radiation, wind speed, dryness of the air).**

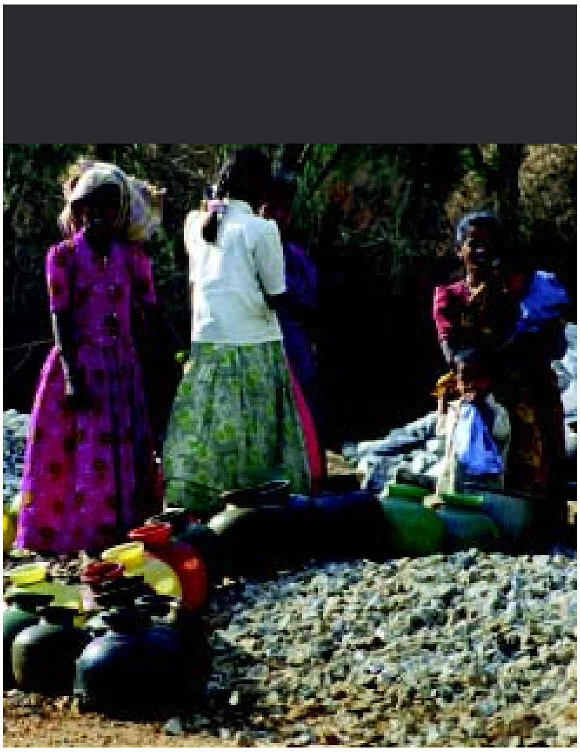
- Aquifers once depleted stay depleted. **A pessimistic view of aquifer depletion is that this is an irreversible process. The reality is that, in most cases, aquifers can be re-established or replenished as long as the balance between recharge and extraction is swung towards recharge. This can occur as a result of increased recharge, decreased extraction or both.**

6.2 Water-related risks

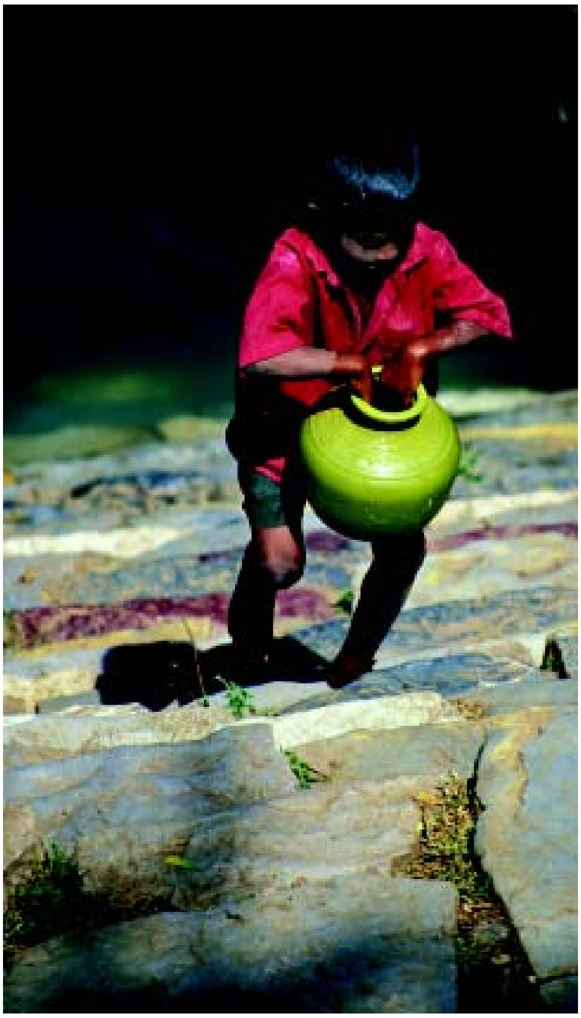
Experience in the region has shown that there are a number of water-related risks associated with watershed development and with the source protection measures implemented as part of rural water supply programmes. These include:

- Increased borewell construction and increased irrigation by individual landowners: **In most cases, the prime motivation of farmers to become involved in soil and water conservation programmes and the construction of water harvesting structures is not altruistic. It is to increase the water resources that are available to them for irrigation.At the watershed scale, this is justified only if the resources that are being "harvested" do not have a higher value if they are put to other uses.**

- Increased borewell construction and increased irrigation by "poor" landowners: **Successful watershed development projects often improve the financial status of relatively poor farmers such that they are able to take loans for constructing borewells and installing pumps. As above, this is fine as long as the water they "harvest" does not have alternative higher-value uses (e.g. as a source of domestic water supply).**



Waiting for water at a water point in Yapadinne, Dhone



Kocheruvu open well, Dhone

- Deterioration in village water supplies: **There is a high risk that project interventions will reduce runoff into tanks or other structures that are important sources of recharge of the aquifers that meet urban water requirements. Project interventions can also lead indirectly to increased pumping of groundwater for irrigation in urban and peri-urban areas, thereby, increasing the risk of failure of village water supplies during the summer months. Finally, project interventions can lead to increased consumption of water: per household, by livestock, by horticulture within the village and by non-land-based activities.**

- Conflicts within villages and between villages: **Some interventions, that involve changing land use or patterns of water availability and use, result in distinct winners and losers. If there is a risk of this happening, conflicts should be managed by ensuring that losers are compensated in some way. As above, decisions on whether an intervention should take place should be based on economic and social value.**

- Reduction in net productivity: **There is a risk that promotion of interventions with a high social value will lead to reductions in net productivity at the village or watershed scale. For example, use of water for irrigation on marginal lands (usually owned by poorer farmers) will tend to be less productive than use of the same water on better quality land (usually owned by relatively richer farmers). Ultimately, determining the balance between acceptable social and economic value is a political decision.**

- Increase in environmental degradation: **It is generally assumed that an increase in forestry equates to environmental improvement in watersheds and that this is sufficient in terms of meeting environmental sustainability targets. In many cases, increased forestry will lead to significant improvements in biodiversity, particularly if indigenous tree species are planted. There are risks, however, that changing patterns of land and water use and, hence, the hydrology of watersheds will lead to reduction in biodiversity in areas other than forested areas (e.g. in wetland areas, in ephemeral streams, in and around tanks). There is also a risk that project interventions will adversely affect water quality (e.g. pollution resulting from: increased use of agro chemicals).**

7

Water resource planning and option selection

7.1 Impacts of watershed development

Arguably, "traditional" watershed development has become synonymous with the construction of check dams and other water harvesting structures. Soil and water conservation activities are seen as an initial step towards sustainable development and as a cost-effective means of disbursing substantial amounts of funding. Box 18 summarises the positive and less positive aspects of "traditional" watershed development. The recommendations that follow in Section 8 are aimed at addressing the less positive aspects of current approaches whilst not negating the positive aspects and benefits.

Box 18. Positive and less-positive aspects of "traditional" watershed development

Results from the Water Audit indicate that positive aspects of the ongoing watershed development programme include:

- **Increases in net agricultural production on arable and non-arable lands;**
- **Development of village-level institutions;**
- **Substantial improvements in the livelihoods of some social groupings;**
- **Implementation of an approach that has widespread political and public support.**

The less positive aspects of the programme in dryland areas include:

- **Certain groups capture water resources, often at the expense of the poor;**
- **New village-level institutions are usually outside government and, consequently, they often have a short lifespan and minimal political or legislative support for any actions or decisions that they might take;**
- **Protecting drinking water supplies is not seen as an integral part of watershed development;**
- **Emphasis is on development of water resources (i.e. on increasing water supplies by constructing check dams, rehabilitating tanks, etc.) and not on management of water resources (i.e. on managing demand and on maximising the social and economic value of water).**
- **As planning takes place at the village-level, a whole range of wider issues is ignored (e.g. upstream-downstream equity, inter-village equity, flood protection, drought preparedness, pollution of water courses, biodiversity and protection of rare habitats etc.)**
- **Watershed development publicity or propaganda (e.g. wall paintings, street plays etc.) is often misleading in that it suggests that there are quick fixes to water-related problems in semi-arid areas.**

After: Batchelor et al. (2003)

Masonry check dam

7.2 Adaptive water resource management

The history of water management is, in many ways, a history of searches for universally applicable solutions (Moench, 1999). The "development era" focused on construction of large-scale infrastructure projects such as dams and municipal supply schemes. In a similar manner, many now advocate economic pricing, basin approaches, integrated planning, the development of participatory water management institutions and demand management as "the" solution to management needs. The principle of adaptive management turns many current debates on resource management on their head. Instead of getting bogged down debating whether or not decentralised participatory approaches are better than centralised ones for water management, the principle of adaptive management involves working from the specifics of a given problem outwards, to the best solution for addressing it. Some problems may be best addressed through decentralised participatory approaches; others may require more centralised forms of planning and intervention (Moench, 1999, Batchelor 2001).

Adaptive management is also a process by which management actions and directions are adjusted in the light of new information on current and likely future conditions. It recognises the limitations of current knowledge and the potential impacts of current resource management strategies and also recognises that there is a disjuncture between the inherent variability of natural and social systems and the tendency for management approaches to cluster around a few management models. New management paradigms emerge in response to the limitations in earlier ones. When these new paradigms become dominant, their inherent limitations emerge and they are gradually discarded in favour of new "better" paradigms.

The rapid pace of technical, social and economic change in Andhra Pradesh is such that it is very difficult to predict future patterns of water supply and demand with any great confidence. The possible impacts of short and long term climate changes add further uncertainty. This being the case, resource management systems are required that are flexible and able to adapt to new challenges.

7.3 Integrated water resource management

In many areas, competition and equitable access to water resources was not an issue as long as the size of the "cake" was growing. Now, however, competition over access is emerging as a major issue in semi-arid areas and one that has the potential to have a serious long-term impact on the livelihoods of people living in these areas.

Lack of integration between the sectors involved in water resources planning and management is a fundamental impediment to improved water resource management. In general, there is little integration between the watershed development, water supply and sanitation (WSS) and power sectors despite the fact that all three sectors impact hugely on the availability and access to water resources and, hence, on the livelihoods of urban and rural communities. For example, in semi-arid India, an unintended impact of watershed development and RWSS source protection measures is an increase in groundwater extraction for irrigation that can lead to an increasing risk of resource-related failure of village water supplies. A potential unintended impact of power sector reform is also a big increase in groundwater extraction that may also impact adversely on rural drinking water supplies. Given that the profitability of "commercial" irrigated cropping is so high, new tariffs are unlikely to limit groundwater extraction by larger farmers. However, they are likely to make pumping costs too high for poor and marginal farmers that are growing subsistence crops. In contrast to the previous two examples, in many areas, the livelihoods of all farmers (i.e. the relatively rich and the poor and marginal farmers) are being affected by the reallocation of water resources, that they were using for irrigation, to meet the ever increasing demands of urban areas.

Regardless of official policy (or norms), access and allocation issues tend to have major political and economic ramifications. Furthermore the mechanisms used for allocation, touch deep cultural, ethical and often religious sensitivities. Clearly integrated water resource management is needed that involves identification of the multiple impacts and trade-offs resulting from current or proposed sectoral policies. Once these impacts and trade-offs are identified (by water auditing or other procedures) it is then up to the political process to make informed decisions.

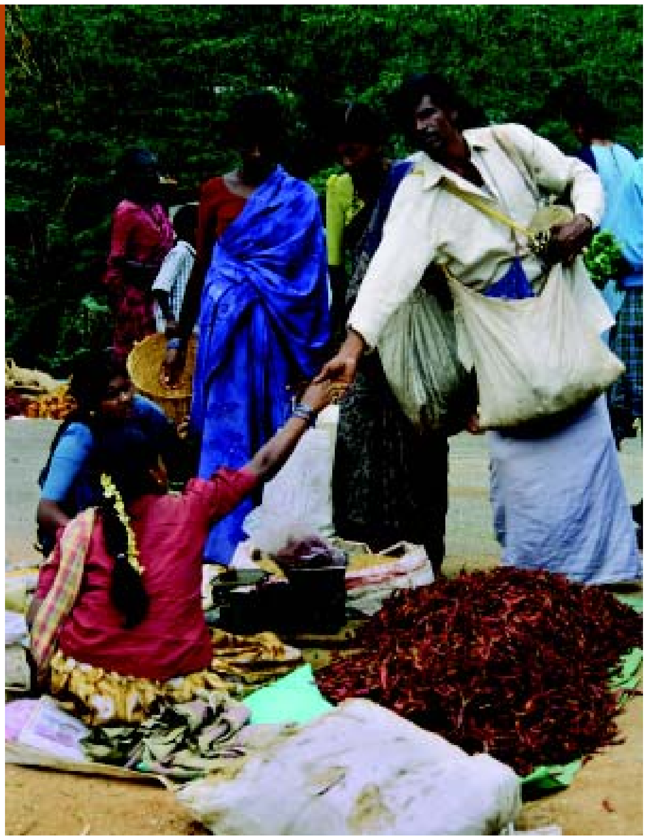
7.4 Water-related trade-offs and win-win options

Opportunities for improving water use efficiency or productivity in the study mandals fall into four categories (after Seckler, 1996):

- **Increasing output per unit of evaporated water;**
- **Reducing pollution and degradation that diminishes the value of usable water;**
- **Reallocating water from lower to higher value uses;**
- **Reducing losses of usable water to sinks.**

All the options listed in Section 8 fall into one or more of the categories listed above. Wherever possible APRLP should promote win-win options. However, when a range of scales is considered, there are few options that can be classified as being win-win, regardless of the physical and social setting. Hence, minimising trade-offs by matching options to a given setting is crucially important.

Using IWMI's terminology, most of the river basins in southern Andhra Pradesh are now approaching the status of being *closed basins* whereby utilisable outflows are, on average, fully committed. Hence, there is only limited justification for attempting to augment water resources by creating additional storage in the form of, say, check dams with high crest heights, nala bunds and small dams. There is, however, a strong argument for ensuring that water is impounded where it provides the highest value range of goods and services. In some cases, achieving this objective might involve installing new structures along drainage lines and removing existing structures, lowering their crest heights or installing sluice gates that are left open during at least part of the rainy season.



Vegetable market

Watering livestock from a domestic water point in Manirevu, Kalyandurg

8 Recommendations

8.1 Summary of main recommendations

Analysis of information from the study mandals and subsequent discussions at the district and state levels with senior government officers, line department specialists, senior researchers, NGO staff and APRLP staff led to the identification of six main recommendations. These are summarised below and discussed in greater detail in subsequent sub-sections.

Recommendation 1. **Projects involving watershed development-type activities should promote a wider range of options/interventions and, in particular, options/interventions aimed at: protecting drinking water supplies, improving the access of poor households to water for productive purposes and reducing the impacts of droughts on rural livelihoods.**

Recommendation 2. **Projects involving watershed development-type activities should target and match interventions to the specific physical, social and institutional settings.**

Recommendation 3. **Village-level water-related participatory planning should take place within a wider *district planning framework*.**

Recommendation 4. **There should be a much greater emphasis on water resource management and a shift of emphasis from supply to demand management of water resources.**

Recommendation 5. **As part of a larger programme of making better use of water-related information in decision-making processes at all levels, GIS-linked participatory assessments should become part of routine M&E of rural water supply and sanitation programmes.**

Recommendation 6. **A major effort is needed to update and improve the quality of the water-related information that is being used to underpin water-related decision making at all levels. Effort should also be directed towards making information more accessible to potential users, particularly at the district level.**

The recommendations listed above should be viewed within the overall recommendation that the APRLP and similar programmes should adopt and build capacity at all levels in adaptive and integrated water resources management principles and methodologies.[5]

8.2 Recommendation 1 – Wider range of options

Although the study findings suggest a rather gloomy state of affairs in terms of the current and future status of water resources in the study mandals, one positive conclusion is that there are a large number of water management options that could be promoted by APRLP. These are summarised in Tables 13-19. All these options have the potential to increase the productivity of water use and/or to improve equitable access to water resources. However, matching of options to particular physical, social and institutional settings is crucial. As part of this targeting process, particular consideration should be given to the trade-offs associated with each option or sequence of options.

5 GWP (2000) provides a good description of the principles of integrated water resources management.

Table 13. Rainfed arable cropping options

Options	Specific details	Potential trade-offs
Increasing the productive use of water	. Selection of appropriate crops . Use of good genetic material . Seed priming . Good crop nutrition . Good weed and pest control . Minimising post-harvest losses . Intercropping systems . Making use of specialist advice	Drainage and, hence, groundwater recharge may be reduced as a result of increased vegetative cover and healthier deeper-rooting crops
Reducing soil evaporation	. Planting early in Kharif . Maintaining crop cover and/or mulches during rainy periods . Managing crops and cropping systems in response to specific weather patterns (see Figure 47)	
In-situ soil and moisture conservation	. In-field soil moisture techniques matched to the different soil type, slope and other factors (see Figures 48 and 49)	

Table 14. Rainfed non-arable options

Options	Specific details	Potential trade-offs
Making more productive use of water on CPR lands	· Alternative land use systems · Dryland horticulture · Silvo-pastoral systems · Income generation, particularly, during droughts from timber and non-timber forest products	Changing land use and management of common-pool resources may result in distinct winners and losers. The rights of existing users (e.g. livestock owners, gatherers of fuelwood) may not be catered for in new management arrangements. In some cases, soil and water conservation measures and improved vegetative cover may reduce recharge and runoff to tanks
Improved management of CPR land	· Joint forest management · Community grazing schemes · Community fuelwood schemes	
Making more productive use of water on privately-owned non-arable land	· Planting of grasses and fodder legumes · Application of fertilisers · Establishment of energy coppices · Dryland horticulture	
Concentrating rainfall where it can be used productively	· Directing runoff to arable areas and/or to tanks · In-situ soil moisture conservation (see Figure 49)	
Reducing soil evaporation	· Maintaining cover with vegetation with high economic, social environmental value · Concentrating rainfall wherever soil evaporation losses can be minimised (e.g. near useful vegetation)	

Figure 47. Cropping systems for improved rain water management

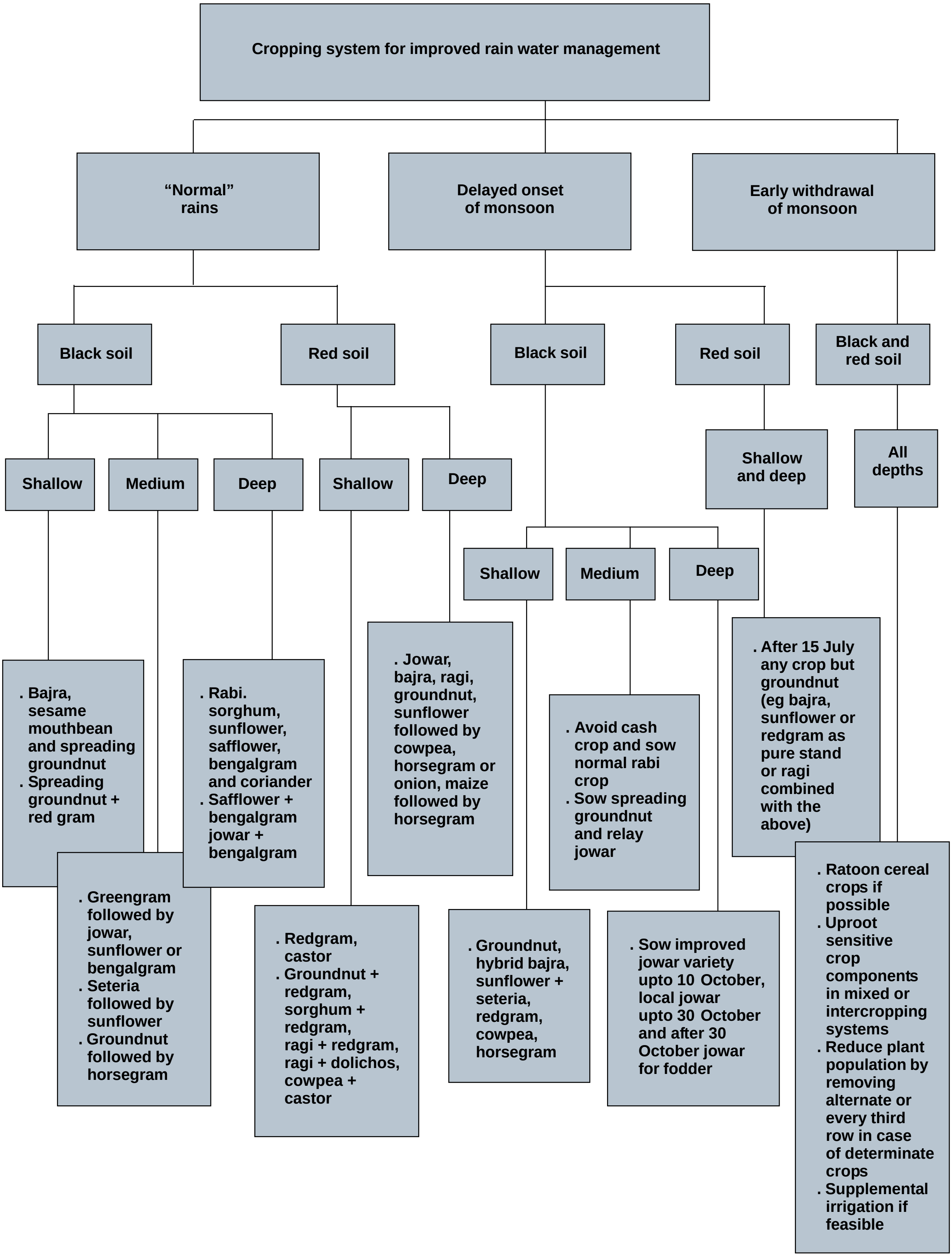


Figure 48. Soil and water conservation measures

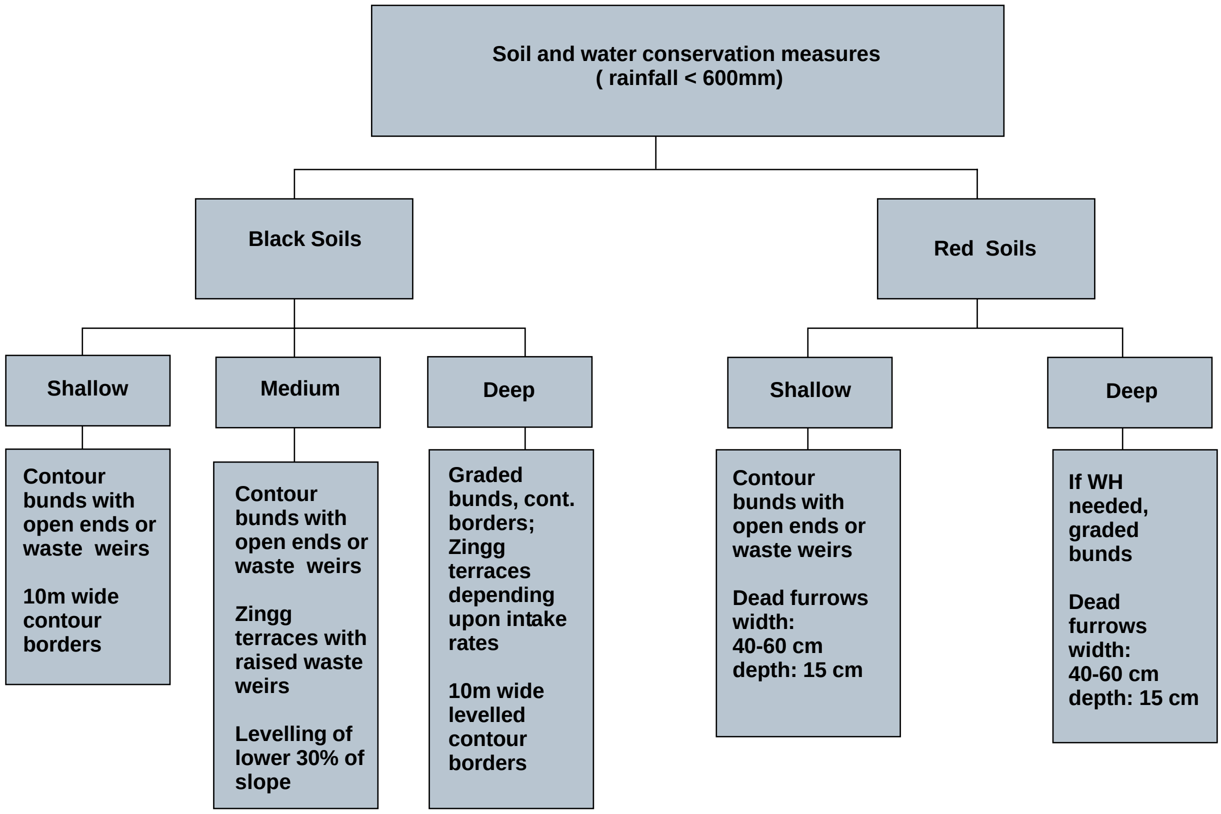


Figure 49. In-situ soil and moisture conservation

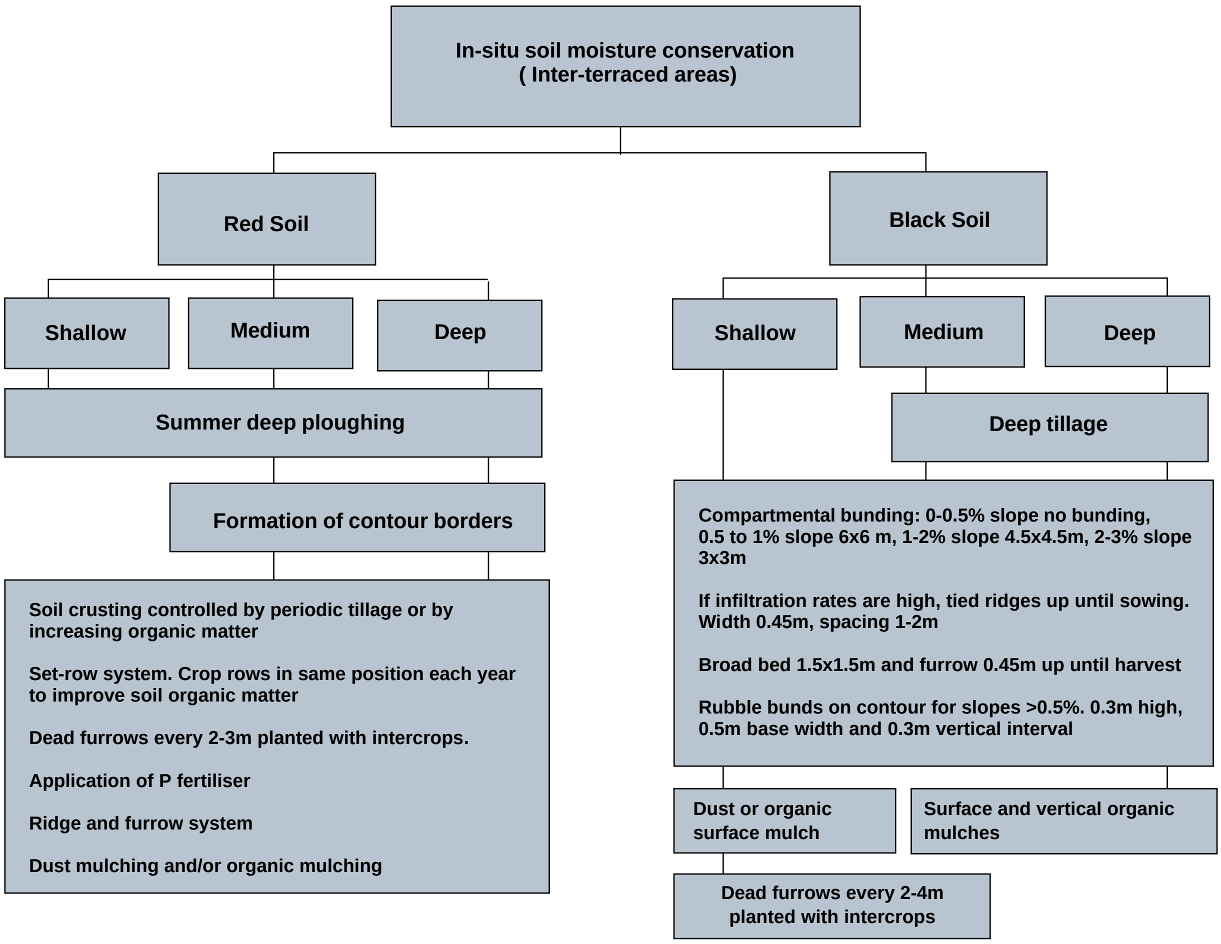


Figure 50. Treatment of non-arable lands

Treatment of non-arable lands
(rainfall < 600mm)

Exclude biotic influences (e.g. cattle) by establishing a social fence

Hills (betta)
(slope >10 %)

Mounds (Dibbe)
(slope 5-10 %)

Wastelands
(slope 0-5 %)

Gully lands
(halla)

Construct a trapezoidal diversion drain with 0.2-0.5% bed slope large enough to divert runoff from upstream area. Spoil on downstream side of drain. Runoff diverted to recharge pond and used to establish a community irrigation scheme

Construct a diversion bund. 0.4-0.6m² x- section. Vegetative protection required

Hills (betta):

Contour trenches 0.5x0.5x4m in size. Trenches at 10m horizontal interval planted with trees at 1m interval

Catch pits between trenches. 0.5x0.5x0.5m in size. Trees planted in pits

Seed rest of area with harmata fodder legumes etc

Apply 20 kg DAP/ ha

Mounds (Dibbe):

Gradonis 5-10m wide depending on the slope

Beds of Gradonis planted with appropriate grasses and trees planted on the benches

Apply 20-25 kg DAP/ha

Wastelands:

Silvi-pastoral systems

Contour trenches or crescent shaped pits 4-10m spacing

Plant trees in pits or trenches and suitable grasses in between pits or trenches

Apply 20-25 kg DAP/ha

Gully lands (halla):

Easen the side slopes and plant with trees

Construct small earthern bunds across the gully 1m wide and 0.15m high

10-20m interval plant bunds with suitable vegetation

Threshing redgram in Kocheruvu, Dhone

Table 15. Irrigated land options

Options	Specific details	Potential trade-offs
Increasing useful output per unit of water (more crop per drop)	· Select high value crops · Crop varieties responsive to irrigation · Select good genetic material · Good pest and weed control · Good nutrition · Minimise post-harvest losses · Minimise water lost during land preparation · Minimise risks of soil salination	Although farmers may increase the efficiency or productivity of irrigation water use per unit area this does not necessarily mean that they will reduce their total irrigation water use. In some cases this might happen but, for many farmers, it is water that is limiting rather than land. These farmers are likely to use any surplus water resulting from efficiency gains to increase their gross irrigated area. Hence, overall improvements in water availability or equity, resulting from increased water use productivity or efficiency may be negligible or non-existent
More effective use of rainfall	· Plant early in Kharif · Good irrigation scheduling	
Better in-field distribution of water	· Land levelling in surface irrigated areas · Adopt sprinkler or drip irrigation	
Localised irrigation	· Use drip, pitcher or subsurface pipe irrigation or similar where appropriate	
Reduce conveyance losses	· More reliable electricity supplies making it possible to pump water direct to fields instead of into storage tanks · Line channels and storage tanks	
Reduce need for "insurance" irrigation	· More reliable electricity supplies · Community-management of groundwater	
Reduction in soil evaporation	· Localised irrigation · Select crops, crop varieties and cropping systems that shade the ground effectively · Use mulches where appropriate	
Establishment of community irrigation schemes	· Sharing of wells and pumps is quite common amongst members of the same family · A number of farmers using the same well but with their own pumps is also possible · Many different "share cropping" arrangements are also possible	Increased irrigation, for whatever purpose, may exacerbate groundwater depletion and competition for water between domestic and agricultural water users

Table 16. Management of groundwater resources

Options	Specific details	Potential trade-offs
Community management of groundwater	Findings and recommendations of the DFID-supported COMMAN Project (Community Management of Groundwater Resources in Rural India) can be found via: www.bgs.ac.uk/hydrogeology/comman/home.html	There is a risk that community management of groundwater will lead to exclusion of some social groups.
Improving groundwater recharge	· Ideally in areas in which it has highest social, economic and environmental value · Range of water harvesting techniques can be used	Improving groundwater recharge in one part of the watershed may be at the expense of existing users elsewhere
Demand management	· Different options are listed in Section 8.5	
Promote use of shallow wells for irrigation and deep wells for RWSS particularly in peri-urban areas	· Reduces energy required for pumping · Helps re-establish a groundwater buffer that can meet domestic water needs during dry seasons and periods of drought · Farmers who adopt measures to improve groundwater recharge are more likely to see benefits as recharge of shallow aquifers tends to be relatively localised when compared to recharge of deep aquifers	Initially groups of farmers will have to reduce groundwater extraction until the shallow aquifer is replenished. Once it is replenished, they can return to extracting groundwater at rates that are equivalent to annual recharge. The transition costs of this approach would be high as in many areas farmers would have to switch from using borewells to wide diameter wells or collector wells[6]. Note that this approach will only be successful if carried out in conjunction with some level of demand management

6 A collector well is a shallow hand-dug well of large diameter with horizontal boreholes drilled radially from the base to a distance of approximately 30m, typically in four directions

Table 17. Management of surface water resources

Options	Specific details	Potential trade-offs
Village-level participatory planning within a District Planning Framework	· Needed to ensure that attention is given to the many surface water resource management issues that are not addressed during local-level participatory planning. See Section 8.4	Local-level ownership of planning processes may be reduced. Additional work for district-level line department staff
Re-establishing inflows to tanks	· Fix gates in drainage-line structures and leave these open except during early and mid-monsoon. · Instead of surface structures with high crest heights, low check dams using loose boulders or subsurface "dyke" barriers · Re-establish shallow aquifers and thereby improve base flows · Renovation and clearing of existing feeder and diversion channels to improve runoff to the tank · Remove some gully-control structures or reduce their crest heights · Fill in old brick pits	In most cases, this option will result in distinct winners and losers. Increasing tank flows significantly can only be achieved at the expense of current water users in the tank catchment areas
Establish or re-establish tank management systems	· Based on affinity groups that represent the multiple uses of tanks · Groups should be linked to Panchayati Raj institutions	There is a risk that changing and introducing tank management procedures will lead to exclusion of some social groups
Repair tank sluices and bunds	· Should be carried out with community involvement / supervision	Seepage losses may be an important source of recharge downstream of the tank
Reduce evaporation losses by deepening tanks or ponds	· Reduces the surface area to volume ratio · Increases the storage capacity	Deepening tanks may reduce the fodder and forage value of the areas on which grasses grow as the tank water recedes. This option may also impact on the environmental and biodiversity value of tanks and the areas surrounding tanks
Reduce siltation of tanks	· In-field soil and water conservation measures · Gully control structures	Less silt available to farmers that traditionally use silt as a means of improving soil fertility of their fields
Pisciculture	· Increase number of water bodies used for pisciculture · Establish local management groups	

Table 18. Management of water resources in urban and peri-urban areas

Options	Specific details	Potential trade-offs
Use waste-water for productive purposes	· Drain runoff of acceptable quality to areas where it can be used for fodder or horticulture · Minimise health risks · Establish user groups	Reduced groundwater recharge
Increased groundwater recharge	· Direct good quality runoff from roads, open areas, rock outcrops, roofs etc. into soak pits	There is a risk that polluted water will also enter the soak pits resulting in pollution of aquifers
Harvesting of water into cisterns	· Good quality runoff from roads, open areas, rock outcrops, roofs etc. can be piped into private or community-owned cisterns. This is a good option in areas with polluted groundwater or rapid groundwater recession · Water can be used for domestic or productive purposes	Reduced groundwater recharge
Minimising risk of ground and surface water pollution	· This includes safe handling of agro-chemicals and industrial effluents · Treatment and disposal of sewage	Additional costs may be incurred by small and large industries
Establishment of community or nutrition gardens	· Using harvested or piped-water supplies, allotment-type gardens can provide landless families with a source of vegetables for home consumption or sale	
O&M of environmental sanitation systems	· Action by community groups or the panchayats · Improves the urban and peri-urban environment and reduces health risks	Less silt available to farmers that traditionally use silt as a means of improving soil fertility of their fields
Flood control	· Maintenance of drains and routine clearance of rubbish from streams flowing through urban areas · Construction of bunds to protect housing at high risk of flooding	

Table 19. Protection of domestic water supplies

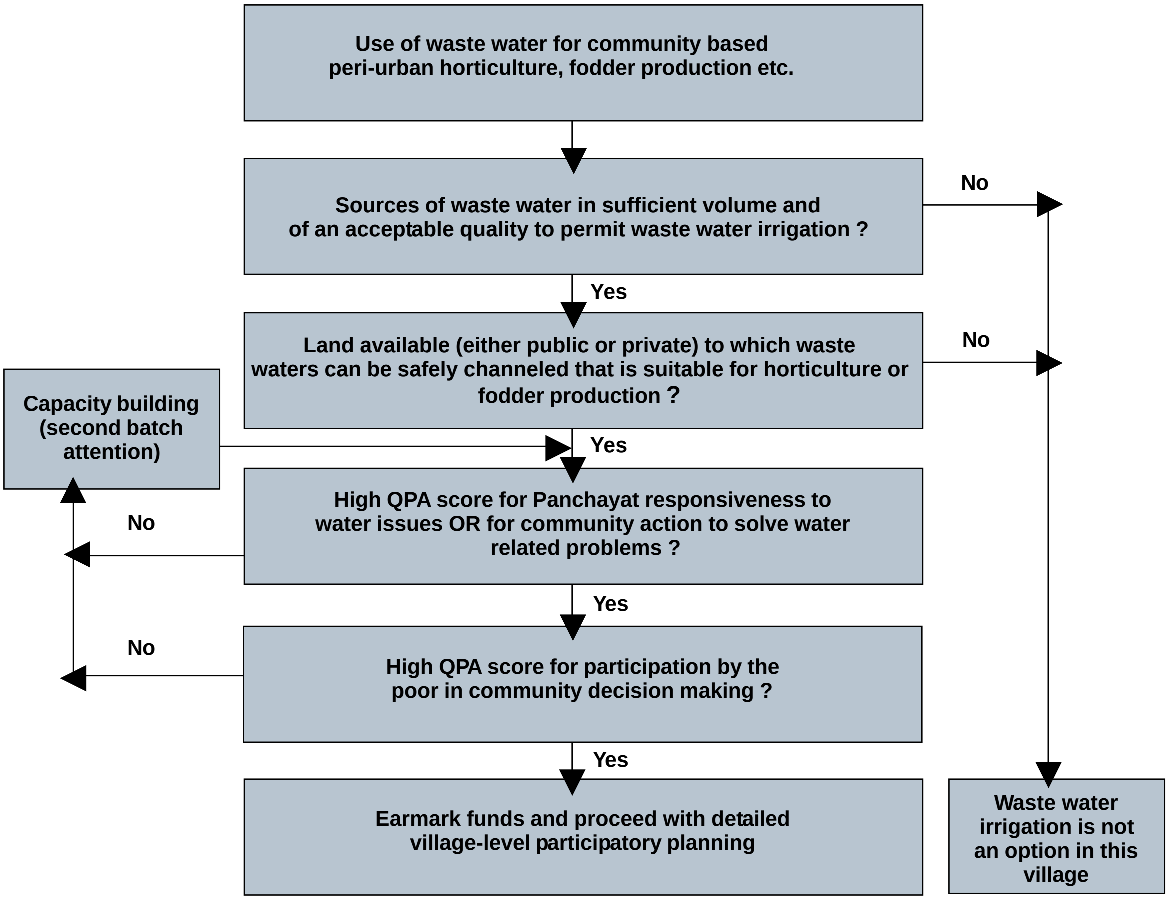
Options	Specific details	Potential trade-offs
Improve quality of drinking water	· Identification of water point with levels of F, TDS etc. above permissible limits · Identification of alternative sources of water · Household water treatment	
Source protection measures	· Increasing recharge near to domestic groundwater sources and controls on extraction for other uses · Minimising pollution risk to water sources · Establishment of ground or surface water reserves (or buffers) that are sufficient to meet domestic water needs during dry seasons and periods of drought	Reduced water availability for agriculture
Community management of ground and surface water resources	· Collective responsibility and management of water resources developed ideally in conjunction with the panchayats · Establishment and management of a basic human needs reserve · Enforcement of legislation relating to spacing between domestic and agricultural wells	
District Planning Frameworks	· Regional planning and regulation used to ensure that surface water resources of any given village or town are not captured by upstream users	Less water available upstream

8.3 Recommendation 2 – Targeting of options

In general, watershed development-type programmes do not try to target activities to appropriate physical, social and institutional settings nor do they attempt to regulate the number or scale of interventions (e.g. the number of check dams along a particular drainage line). The current tendency is to use a “one-size fits all” approach and to work under the assumption that water harvesting technologies are totally benign. The underlying logic is that even intensive use of water harvesting technologies will not result in unintended negative impacts. In contrast, results presented in this report show that the majority of water-related interventions promoted by watershed development-type programmes have potential negative trade-offs associated with them. The results also show that the scale of these negative trade-offs is, in many cases, directly related to the density of the interventions and the scale of the additional storage capacity that is created.

Better targeting of interventions can be achieved by using decision trees that utilise a combination of physical, social, economic and institutional data in the decision-making process. This approach can be used by NGO staff as part of a participatory planning process or it can be used by line department staff at the district level as part of a process that involves stakeholder representation. Although potentially time consuming, using decision trees can become simple and rapid, once data are readily available (e.g. once a water audit has been completed and a GIS database created). Also the approach can easily be incorporated into a more general MIS system. Figure 51 is an example of a decision tree that uses numerical, physical, social and institutional data collected by the Water Audit to identify villages in Kalyandurg in which “peri-urban” irrigation with waste waters is potentially a good option.

Figure 51. Example of decision tree that uses physical, social and institutional data



Gated check dam under construction near Battuvani Palli, Kalyandurg

ID code	Village Name	Panchayat response to WSS Problems	Community participation in solving RWSS problems	Participation by poor in community decision making	Participation by women in community decision making	Strong panchayats and/or community action	Strong participation by the poor	Both tests
1	Hulikal	25	75	100	100	0	1	0
2	Vitlampalli	15	70	75	75	0	0	0
3	Mallikarjunapall	60	70	90	90	0	0	0
4	Chapiri	80	0	80	80	0	0	0
5	Madhireddipalli	25	80	100	100	0	1	0
6	**Chapirithanda**	**0**	**100**	**100**	**100**	**1**	**1**	**1**
7	Mudigal	80	0	85	75	0	0	0
8	Borampalli	100	80	90	50	1	0	0
9	**Golla**	**100**	**0**	**100**	**75**	**1**	**1**	**1**
10	**Seebai**	**100**	**100**	**100**	**35**	**1**	**1**	**1**
11	Pathacheruvu	100	0	60	0	0	0	0
12	Manirevu	0	75	75	0	0	0	0
13	Obulapuram	80	50	100	0	0	1	0
14	**Nusikattala**	**50**	**100**	**100**	**0**	**1**	**1**	**1**
15	Kondapuram	0	0	75	0	0	0	0
16	Kondapurampalli	15	75	80	75	0	0	0
17	Nusikottalathand	80	0	100	75	0	1	0
18	Thimmasamudram	0	0	100	0	0	1	0
19	Mangalakunta	50	0	100	0	0	1	0
20	Kadadarkunta	50	0	0	0	0	0	0
21	Balavenkatapuram	20	0	0	0	0	0	0
22	Pinjirikottala	50	90	100	50	0	1	0
23	Muddinayanampall	50	0	100	0	0	1	0
24	Venkatampalli	90	25	100	0	0	1	0
25	PTRPalli	20	15	65	0	0	0	0
26	Mouthikapuram	95	90	100	50	0	1	0
27	Kaparalapalli	0	65	100	35	0	1	0
28	PTRDiguvaThanda	20	75	80	0	0	0	0
29	**PTREguvaThanda**	**60**	**100**	**100**	**0**	**1**	**1**	**1**
30	**Varli**	**90**	**100**	**100**	**25**	**1**	**1**	**1**
31	Kodipalli	0	80	100	0	0	1	0
32	**Mallipalli**	**25**	**100**	**100**	**75**	**1**	**1**	**1**
33	Thimmaganipalli	100	85	75	35	0	0	0
34	Battuvanipalli	25	100	75	0	1	0	0
35	Ontimidi	25	50	75	35	1	0	0
36	Kurakulathata	100	85	100	30	0	1	0
37	**Devadulakonda**	**50**	**100**	**100**	**0**	**1**	**1**	**1**
38	Dodagatta	100	25	25	25	0	0	0
39	GubanaPalli	90	30	65	10	0	0	0
40	**Garudapuram**	**40**	**50**	**100**	**75**	**1**	**1**	**1**

Figure 52. Example of decision-support Excel work sheet.

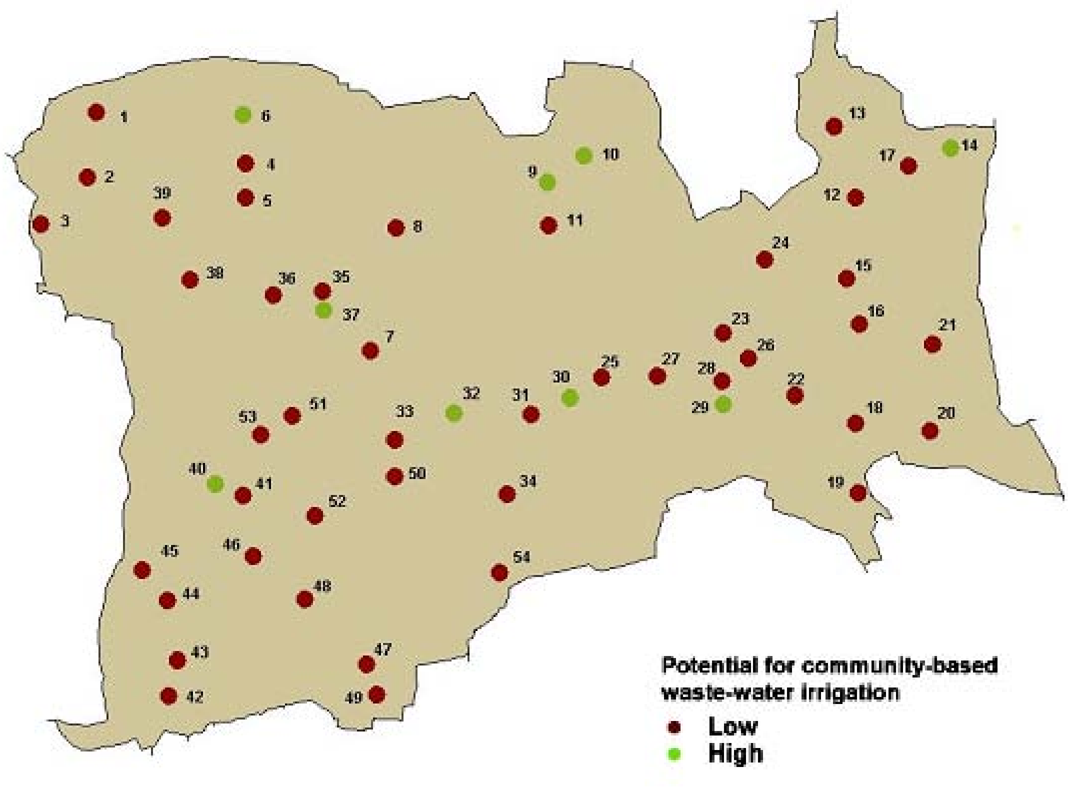


Figure 53. Example villages targeted using the decision tree presented in Figure 51

The example decision tree presented in Figure 51 has four tests. The first two tests require physical data relating to water quality, volumes of waste water, availability of land and the technical feasibility of channelling water to this land. The third test requires data relating to the functionality of institutions in the village and whether or not these institutions have a history of being effective in tackling water-related challenges. The fourth final test requires information on whether poor social groups are involved in decision-making. The assumption behind this final test is that irrigation of horticulture or fodder using waste water is an activity that could provide landless groups with access to irrigated land.

This type of decision tree is only feasible because of the ordinal scoring system used during the Water Audit's participatory assessment in all the villages in Dhone and Kalyandurg. Or put another way, such decision trees when developed as Excel-driven methodologies, will not fit well with the qualitative information that is normally collected during participatory assessments. Figure 52 is an example of an Excel work sheet which shows the villages from Kalyandurg that passed all the tests. In theory, as this selection process has not involved village-level participation, the next steps for the APRLP should be to earmark funds and proceed with detailed village-level participatory discussions and, if there is strong local interest in this option, proceed with planning and implementation. Figure 53 presents these "selected" Kalyandurg villages as a GIS layout.

Additional prototype decision trees for better targeting of interventions have been developed and it is strongly recommended that these be developed further. It is also recommended that this approach be field tested by the APRLP and, if appropriate, combined into the MIS that the APRLP is also developing and piloting.

8.4 Recommendation 3 – Village-level participatory planning within a wider District Planning Framework (DPF)

The aim of proposed District Planning Frameworks is to ensure that water-related planning and regulation issues not covered in village-level planning (see Box 19) receive attention when decisions are being made on the allocation of funds at the district and state levels.

The method that is recommended is modelled on the approach to water resource planning and management that is currently being pioneered in South Africa. This recommendation may seem to many like a retrograde return to top-down master planning; however, it is clear from this study that water resource planning and management is needed urgently at levels above the village if many large scale equity and sustainability challenges are to be addressed.

Box 19. Issues not normally addressed in village-level participatory planning

These include:

- **Inter-village equity and/or upstream-downstream equity;**
- **Rural-urban equity and anticipated increases in demand for water in urban and peri-urban areas and by industrial users;**
- **Inter-generational equity and consequences arising from demographic change and increased demand for water per household;**
- **Protection of biodiversity and rare habitats in a given micro-watershed;**
- **Protection of surface and groundwater from pollution whether this be domestic, agricultural or industrial;**
- **Flood protection. Poorly-rehabilitated tanks can pose a threat to communities living downstream.**

Figure 54 is the proposed process by which a DPF would be developed. It is recommended that, at least initially, outputs from the DPF would be consistent with norms, estimates of stage of development and limits of acceptable change that, in theory, are currently used for decision-making at the district level. Once a limit of acceptable change has been set for, say, surface water resource development in an area, this figure can be used in a computerised system to map out areas in which certain activities (e.g. additional construction of check dams) would be permissible as part of government-funded programmes. It is envisaged also that DPFs could be used pro-actively in identifying and managing reserves of ground and surface water resources that would meet basic human needs during

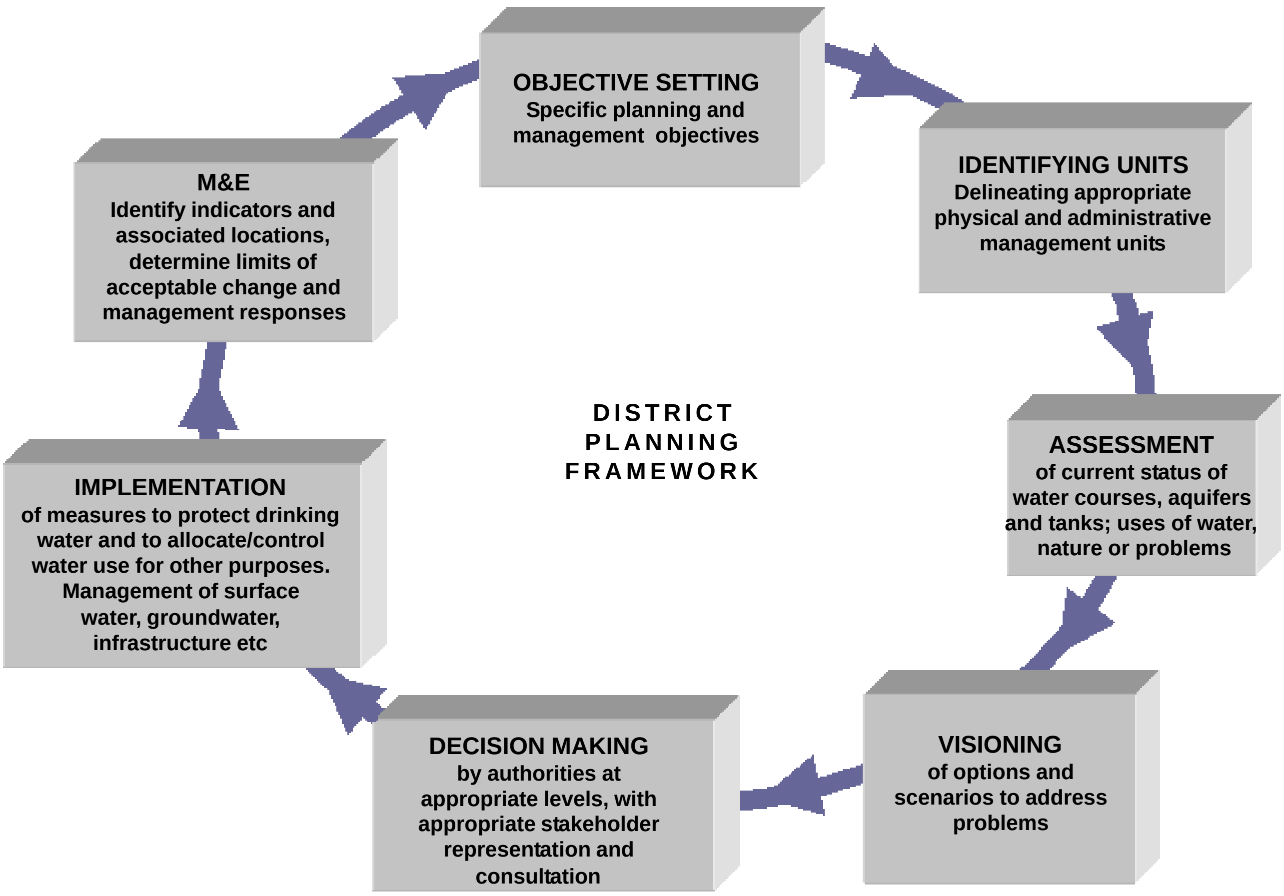


Figure 54. Proposed process for developing a water related District Planning Framework

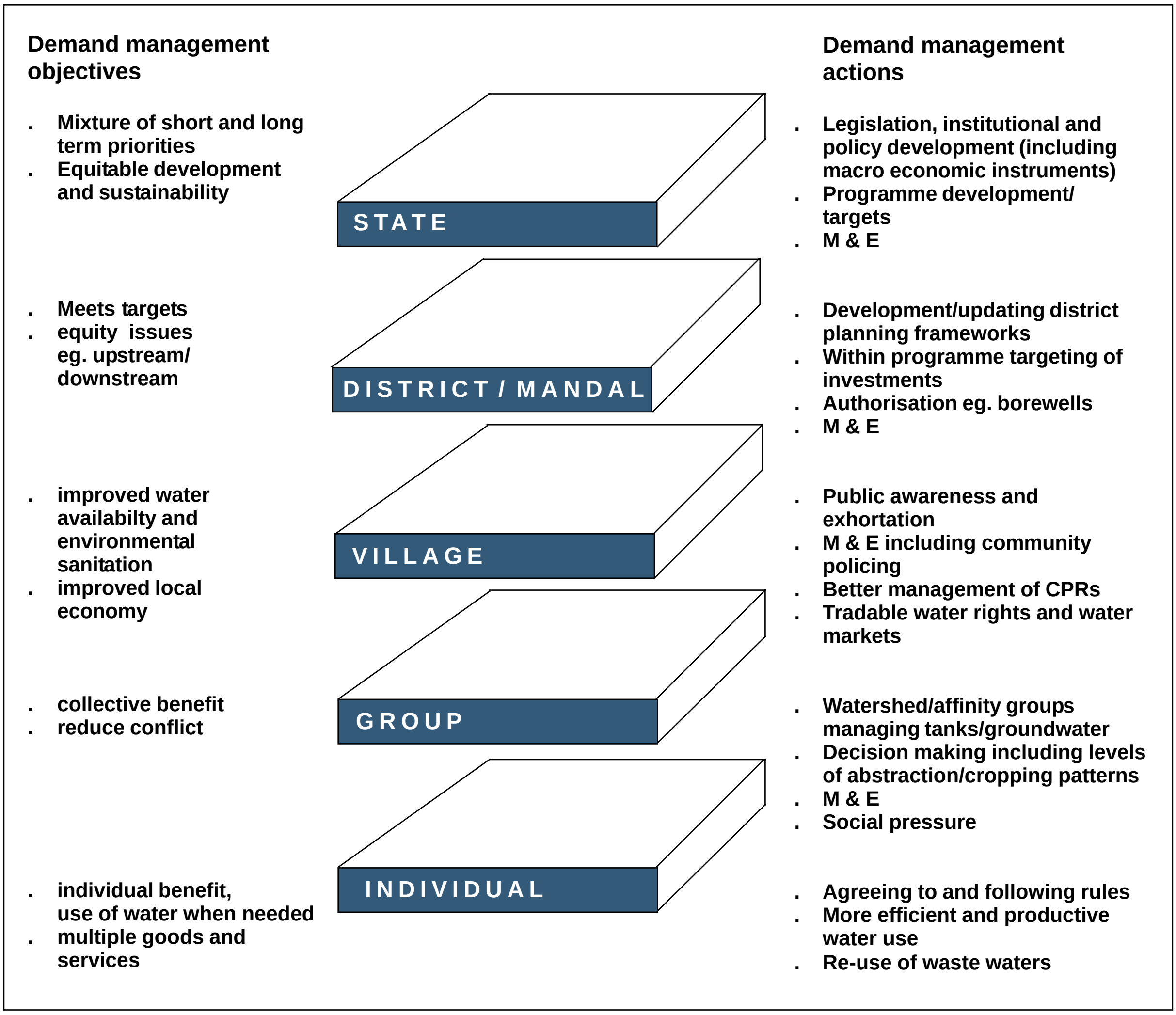
periods of drought. Finally, it is recommended that DPFs be used to identify and set management guidelines for protecting rare and important aquatic eco-systems.

8.5 Recommendation 4 – Shift from supply to demand management of water resources

Demand management seeks to maximise the services provided by a given volume of water mainly by curbing non-essential or low value uses through price or non-price measures. Although demand management actions are clearly not to be preferred to supply-side actions in every case, it is apparent that they need to be given more attention than is currently the case. The results of the Water Audit show clearly that the emphasis of the APRLP and similar programmes should be on resource management as opposed to resource development or augmentation. Although demand management of water resources has a vitally important role to play in the future in semi-arid areas of Andhra Pradesh, it is not going to be a panacea, nor will it provide an instant solution to current and future challenges. If demand management is to be politically acceptable and receive public support, its introduction needs to be handled sensitively and be associated with appropriate public awareness raising campaigns. Additionally demand management has many potential unintended consequences some of which could impact severely on poorer social groupings.

It is fundamentally important that policies and a legislative environment are created that provide incentives for more productive use of water by individual users and disincentives for practices that are wasteful or lead to environmental degradation. Recent and current state-level policies (e.g. grants for well construction, subsidised electricity for pumping irrigation water, support prices for paddy) have the unintended consequence of encouraging inefficient and inequitable use of water. Watershed development propaganda, in the form of wall paintings, street plays and exhortations from NGO staff and many newspaper articles have also created the mindset that water harvesting as part of watershed development can result in almost limitless augmentation of water resources in semi-arid areas. Changing this mindset will be not be an easy task.

Figure 55. Demand management options and objectives



To date, much of the debate in Andhra Pradesh has centred on only two demand management options, namely, introduction of irrigated-dryland crops (i.e. crops with an assumed higher water use productivity than paddy rice and sugar cane) and increased electricity tarifs for pumping groundwater for irrigation. However, as Figure 55 shows there are many other demand management options that could be considered. Figure 55 also illustrates that demand management actions and objectives vary with scale.

8.6 Recommendation 5 – Use of GIS-linked participatory assessments as part of the M&E of rural water supply programmes

Participatory assessments carried out as part of the Water Audit revealed a major disparity between official statistics and the users' view of the status of domestic water supplies. One reason for this disparity is the strong emphasis of current rural water supply M&E on the functioning of infrastructure and the meeting of supply norms (i.e. 40 lpcd). Many of the other potential problems faced by users are ignored by existing M&E systems. However, these additional problems can be considered and appropriate steps could be taken if routine M&E and response systems take users' views into account.

With regard to routine M&E, the participatory assessment methodology used during the Water Audit does not have many of the constraints of participatory rural appraisal-type methodologies. In particular, it is rapid (a small team takes one day per village) and it produces numerical data that can be stored and analysed with relative ease and presented in tables, GIS layouts or other formats that are easy to assimilate and act upon by decision makers.

8.7 Recommendation 6 – Reassessment of "official" water-related statistics

The survey work carried out primarily by government departments to groundtruth secondary data has shown large discrepancies between "official" water-related statistics and the reality observed in the study mandals. The "official" statistics that showed the largest and most important discrepancies included: well numbers, land areas under irrigation and numbers of domestic water points not meeting Rajiv Gandhi National Drinking Water Mission norms. Since well number and irrigated area statistics are used for estimating stage of groundwater development, this is currently grossly underestimated. The discrepancies relating to domestic water supplies, if they are representative of the region, put in question the state level statistics. More recent information gathered on fluoride levels by the WHiRL project casts some doubt over official statistics relating to the incidence of fluoride in domestic water supplies. Many of the statistics listed in this report are used to underpin policies and inform decisions that involve disbursement of huge amounts of expenditure, for example, decisions relating to: watershed development-type work, groundwater development, NABARD loans, power sector reform, protection of rural water supplies, river basin management, inter-basin transfers, tank rehabilitation and irrigation development. Findings from the Audit have also shown that some of the beliefs that also underpin the many programmes (e.g. annual runoff is 30-40% of annual rainfall) need to be re-evaluated. Hence it is strongly recommended that further checks on relevant official statistics be carried out.

In discussions with line department and NGO staff, the accessibility of information was frequently cited as being a problem. Although, in many cases, relevant staff know that the water-related information they need is being collected or held by a particular department, it is not always readily accessible in a format that makes it immediately useful. It is therefore recommended that consideration be given to creating systems that improve both the quality and accessibility of water-related information. Given the importance of water resource management in Andhra Pradesh, it is also recommended that consideration be given to setting up a unit that has specific responsibility for the management of water-related information.

9 Proposed follow up activities

Discussions before, during and after the final workshop of the APRLP Water Audit in September 2002 led to the identification of a number of follow-up activities. These included (not in order of importance):

- "Demonstration" watersheds and villages. **In the light of the findings and recommendations of the Water Audit, it is suggested that clusters of micro-watersheds or villages in Dhone and Kalyandurg be developed into "model" watersheds that can be used primarily for demonstration and training purposes. By July 2003, Water Audit recommendations were being piloted and refined in four "pilot" villages in Kalyandurg as part of the WHiRL Project.**

- Critical review of AP's water harvesting policies and practices. **A key conclusion of the Water Audit is that intensive water harvesting along drainage lines is causing water shortages in many downstream areas particularly during years with low rainfall and runoff. Hence, it is suggested that concerned government officers undertake a critical review of current policies and programmes.**

- Water auditing manual and interactive CD. **As shortcomings have been identified in important water-related statistics, it is strongly recommended that further water auditing takes place. It is suggested that a water auditing manual and an interactive CD would be of value in any scaling up of the work already taken.**

- Awareness raising. **Current watershed development publicity is often highly misleading in that it suggests that there are quick fixes to water-related problems in semi-arid areas (e.g. check dam construction, contour bunding and tree planting). It is suggested that more realistic awareness raising material be developed.**

- IWRM capacity building. **Capacity building is required 98at all levels if Andhra Pradesh is to move rapidly towards adopting the principles and practices of *integrated water resource management* and water-related *project-cycle management*. It is suggested therefore that an appropriate capacity building programme be developed using materials proced by the GWP, the EU (e.g. EC, 1998) and others as a starting point.**

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Glossary

Adangal: Village record.

Adaptive water resource management: The principle of adaptive resource management is to start with identification of specific problems or needs and to select solutions that are directly relevant to addressing these problems or needs. Adaptive management is also a process by which management actions and directions are continually adjusted in the light of new information on current and likely future conditions.

Antispoofing: The Global Positioning System can be used for a range of unintended military purposes. Hence, antispoofing is the practice of deliberately degrading the utility of the system during times of political unrest.

Aquifer: A geological formation that has sufficient water-transmitting capacity to yield a useful water supply in wells and springs. All aquifers have two fundamental characteristics: a capacity for groundwater storage and also for groundwater flow.

Available water: The amount of water available to a service or use, which is equal to the inflow less the committed water.

Bajra: Pearl millet.

Base flow: That portion of flow in streams that originates from springs or groundwater seepage.

Betta: Hill.

Bucket-type water balance model: A mathematical model that describes a hydrological or hydraulic process as a network of interconnected buckets (or storages). The model works on the principle that only when a bucket (or storage) is full can water move along a potential gradient to the next bucket in the network.

Bund: A ridge of earth used to control runoff and soil erosion. Sometimes used also to demarcate a field or plot boundary.

Catch crop: A fast maturing crop that is often planted as an additional crop to make use of late rains or residual soil moisture.

Catchment: See "watershed".

Check dam: A structure placed across a water-course primarily to reduce or check the velocity of water flow. Check dams can be constructed using a wide range of designs and materials. Increasingly, check dams have been designed with the added purpose of impounding water so as to increase localised groundwater recharge.

Chickoo: Sapota – a horticultural crop.

Closed basin: A basin where utilisable outflows are fully committed.

Collector well: A collector well is a shallow hand-dug well of large diameter with horizontal boreholes drilled radially from the base to a distance of approximately 30 m, typically in four directions. This drilling technique has been used successfully by the DFID-supported Western Indian Rainfed Farming Project.

Command Area: Area of irrigated land downstream of a tank that receives (or used to receive) irrigation water from the tank via a system of canals.

Committed water: The part of outflow that is reserved for other uses (note this really applies to surface water).

Compartmental bunding: Water harvesting technique used on relatively flat land that involves bunds in the form of compartments.

Contour: An imaginary line joining points of equal elevation on a land surface.

Contour bunds: Earthen ridges or embankments that are constructed along the contours.

Contour trenching: Water harvesting technique that involves digging trenches along the contours of sloping land.

Cost recovery: Fee structures that cover the cost of providing the service or investment.

Crore: One crore = 10,000,000.

Dead furrows: These are the furrows that are created in rainfed arable areas between crop rows generally 30-45 days after sowing. The aim is to conserve moisture and dispose of excess water.

Decision tree: An aid to systematic decision making that simplifies a complex decision-making process into a series of "yes/no" questions.

Demand management: The use of price, quantitative restrictions, and other devices to limit the demand for water.

Depleted fraction: The fraction of inflow or available water that is depleted by process and non-process use.

Dharna: Non-violent "sit-in" demonstration.

Dibbe: Mound.

Domain: the area of interest bounded in time and space where water auditing or accounting is to be carried out.

Drainage lines (or drainage network): Network of stream and rivers that drain a watershed.

Drought proofing: A series of technical, social or institutional actions that reduce the vulnerability of a habitation or region to the shock of drought.

Ephemeral stream: Streams in which water flows for only part of the year.

Etti: Assistant to the Revenue Department Village Administrative Officer who lives in the relevant village or associated hamlets.

Evaporation: Process in which water passes from the liquid state to the vapour state.

Evapotranspiration: Total evaporation from a natural surface (i.e. sum of soil evaporation, evaporation of water transpired by vegetation and evaporation of rain or overhead-irrigation water intercepted by foliage and other vegetative material).

Externality: The unintended real (generally non-monetary) side effect of one party's actions on another party that is ignored in decisions made by the party causing the effects.

Fully committed basin: a water basin that has been developed to the extent that all water has been allocated or, in other words, all outflows are committed.

GEC Method: Groundwater Estimation Committee's methodology for estimating groundwater resources.
Used throughout India as the standard method.

Geographical Information System(GIS): A computer system for storage, analysis and retrieval of information, in which all the data are spatially referenced by geographic coordinates.

Global Positioning System: A system of 24 satellites which circle the earth twice a day in a very precise orbit and transmit information to earth. If GPS handsets are able to receive signals from three or more satellites, they are able to calculate the latitude and longitude of their current location.

Gradonis: Bench terraces of small width formed on contours by disturbing soil in areas having gentle to steep slopes.

Gram Panchayat: Elected village council.

Gram sabha: Meeting that involves the whole village.

Groundwater drought: A period during which aquifers become severely depleted such that wells run dry and demand for water is not met. In general, groundwater droughts are caused by a combination of meteorological drought and unsustainable extraction of groundwater for irrigation and other purposes.

Habitation: Village or hamlet having a population in excess of 250 people.

Halla: Gully lands.

Inbore well: Borewell drilled into the base of an openwell.

Indicator: A parameter or a value derived from parameters, which points to, provides information about, describes the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with a parameter value.

Information management: Process of gathering, storing and analysing information needed for a specific purpose, such as planning or making management decisions.

Integrated water resource management: Is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.

Inter-basin transfer: Practice of pumping or channelling water from one river basin to another.

Intercropping: Growing two or more crops in the same field at the same time.

Jowar: Sorghum.

Kharif: June to October cropping season.

Lakh: One lakh = 100,000.

Limit of acceptable change: Indicators only have meaning in the light of specific targets and threshold values. These targets or threshold values can be used as triggers for management responses, as warning signals or as a means of evaluating project performance. Depending on the context LACs may also be referred to as safe minimum standards, critical loads, or critical thresholds. LACs may be determined locally, nationally or as part of international conventions.

Livelihood: A livelihood compromises the capabilities, assets (including both material and social resources) and activities required for a means of living.

Management: The decision-making process whereby a plan or a course of action is implemented. Planning forms part of this process as does the allocation of resources and the resolution of conflicts of interest. Effective management is only possible if managers have access to reliable information.

Mandal: A sub-district.

Meteorological drought: A period during which rainfall is low and/or insignificant. Short periods of meteorological drought lead to depletion of soil moisture and damage to plants. In general, long periods of meteorological drought lead to surface-water drought and subsequently to groundwater drought.

Nala: A stream or dry water-course.

Nala bund: An earthen water-harvesting structure built across a nala.

Non-process depletion: depletion of water by uses other than the process for which the diversion was intended.

Open basin: a basin where uncommitted utilisable outflows exist.

Panchayat: elected council.

Panchayati Raj: Local government.

Parameter: A property that is measured or observed.

Process depletion: the amount of water diverted and depleted to produce an intended good.

Rabi: The cropping season that follows the kharif.

Ragi: Finger millet.

Ratchakattas: platform in the village where meetings take place.

Runoff (or surface runoff): The portion of rainfall that flows over the land surface. Runoff can concentrate in depressions or behind impounding structures or it can continue to flow over the land surface into water-courses.

Sarpanch: Elected head of the gram panchayat.

Seteria: Fox-tail millet.

Shramadan: The voluntary labour component of an organised community-based activity.

Stakeholders: In the context of this study, stakeholders are considered to be institutions and individuals that are concerned with or have an interest in water resources and that would be affected by decisions relating to water resource management. Stakeholders include people who may have little knowledge of such affects and lack the means to participate.

Surface water drought: A period during which surface water resources become severely depleted. In general, surface water droughts are caused by a combination of meteorological drought and unsustainable use of surface-water and groundwater.

Sustainable rural livelihood: A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain its capabilities and assets both now and in the future, while not undermining the natural resource base.

Taluk: Sub-district.

Tank: major reservoir or large water body.

Tank spillage: Volume of water that passes over the waste weir of a tank.

Thalarry: (same as etti)

Uncommitted outflow: Outflow from the domain that is in excess of requirements for downstream uses.

Watershed: An area drained by a river system; also referred to as a catchment area.

Waste weir: The part of a tank bund over which surplus tank water will flow once the tank has filled to its design capacity.

Zilla Parishad: District council.

Zingg terrace: Sometimes called a conservation bench terrace. A water harvesting practice that consists of a contributing area with natural or slightly altered slope and a receiving area with no slope in any direction. Rainfall runs off the contributing area and concentrates in the receiving area.

Abbreviations and Acronyms

AF	Accion Fraterna (an NGO)
AIS & LUS	All India Soil and Land Use Survey
AP	Andhra Pradesh
APARD	Andhra Pradesh Academy of Rural Development
APGWD	Andhra Pradesh Groundwater Department
APRLP	Andhra Pradesh Rural Livelihoods Programme
APSRAC	Andhra Pradesh State Remote Sensing Applications Centre
APWELL	Netherlands-assisted Andhra Pradesh Groundwater Borewell Irrigation Schemes Project
ARCVIEW	Geographical Information System software package (ESRI Inc.)
AWRA	APRLP Water Resource Audit
COMMAN	Project Community Management of Groundwater Resources in Rural India
CPR	Common pool resources
CRIDA	Central Research Institute for Dryland Agriculture
CSWCRTI	Central Soil and Water Conservation Research and Training Institute
CWC	Central Water Commission
DA	Daily allowance
DCBC	District Capacity Building Centre
DDP	Desert Development Programme
DFID	Department for International Development (UK Government)
DPAP	Drought Prone Area Programme
DPF	District Planning Framework
DRD	Department of Rural Development
DWCRA	Development of Women and Children in Rural Areas Programme
EC	European Commission
ETp	Potential evaporation
EU	European Union
F	fluoride
FAO	United Nations Food and Agriculture Organisation
FC	fully covered
GIS	Geographical Information System
GoAP	Government of Andhra Pradesh
GoI	Government of India
GPS	Global Positioning System
GWD	Groundwater Department
GWP	Global Water Partnership
Ha	hectare
Ham	hectare metre
HP	Horse power
ICAR	Indian Council for Agricultural Research
ICRISAT	International Centre for Research in the Semi-Arid tropics
IMD	Indian Meteorological Department
IRS	Indian Remote Sensing Satellite
IWMI	International Water Management Institute
KAR	Knowledge and Research
KAWAD	Karnataka Watershed Development Project
lpcd	litres per capita per day
M&E	Monitoring and evaluation
MIS	Management information system
MRO	Mandal Records Officer
NABARD	National Bank for Agriculture and Rural Development
NBSSLUP	National Bureau of Soil survey and Land Use Planning
NC	not covered
NGO	Non-Government Organisation
NRIS	Natural Resources Information System
NRSA	National Remote Sensing Agency
NRSP	Natural Resources Systems Programme
NSS	No safe source (refers to villages in the RWSS programme)
O&M	Operation & Maintenance
PC	partially covered
PC	Personal computer
PD	Project Director
ppm	parts per million
PR & RD	Panchayati Raj and Rural Development
PRP	Policy Research Programme
PSU	Project Support Unit
RDT	Rural Development Trust
RGNDWM	Rajiv Gandhi National Drinking Water Mission
ROR	Record of Right
R/S	Remotely sensed
RWS	Rural Water Supply
RWSS	Rural Water Supply and Sanitation
SC	Scheduled caste
SCS	Soil conservation service
SHG	Self-help group
SS	safe source
ST	Scheduled tribe
TDF	Total dissolved solids
QC	Quality control
QPA	Quantitative participatory assessment
VAO	Village Administrative Officer
VWSCS	Village Water and Sanitation Committee
WH	Water harvesting
WHiRL	Water, Households and Rural Livelihood Project
WHO	World Health Organisation
WL	Water level
WRA	Water resource audit
WSS	water supply and sanitation

Andhra Pradesh Rural Livelihoods Programme
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