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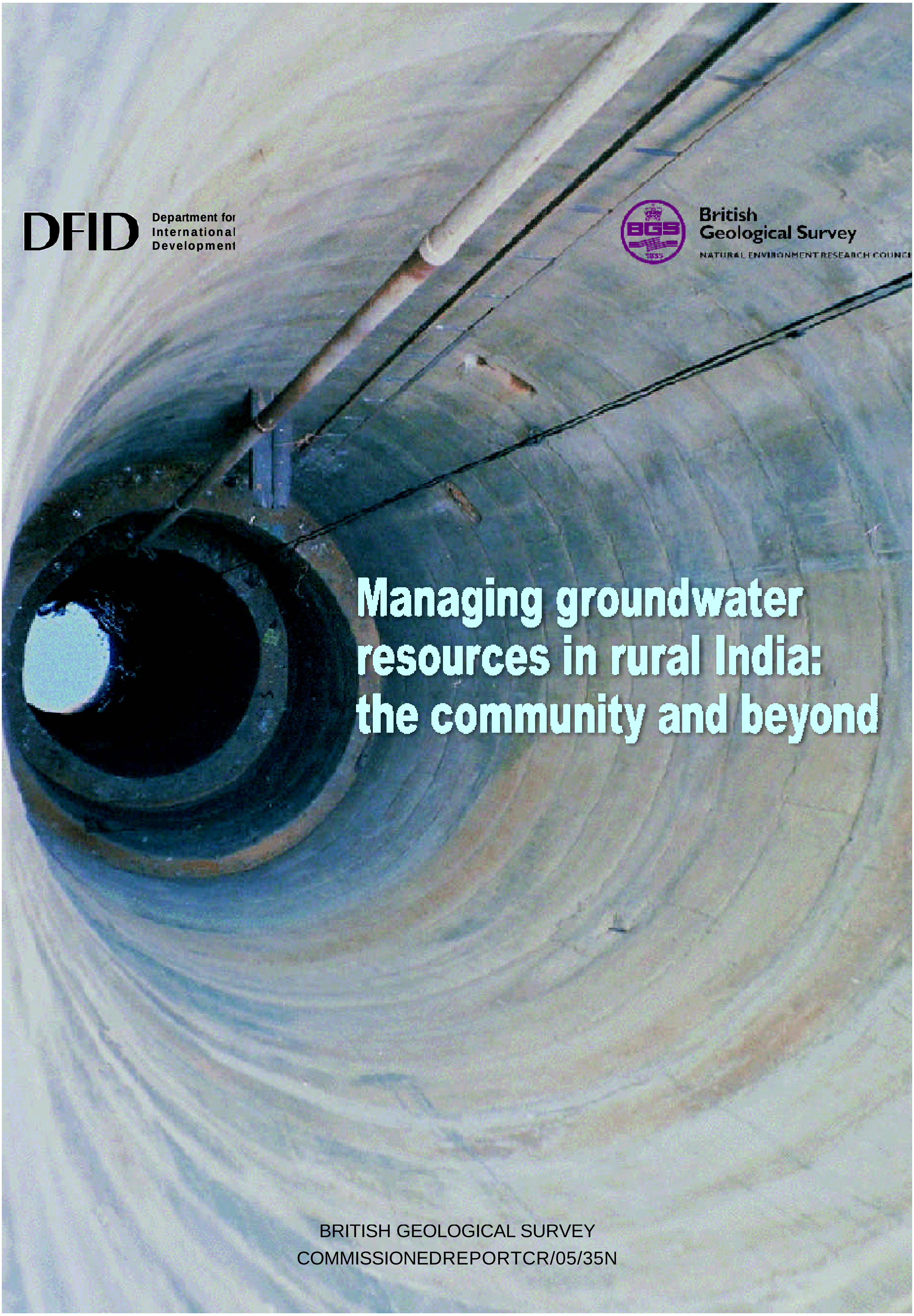

Managing groundwater resources in rural India: the community and beyond

BRITISH GEOLOGICAL SURVEY
COMMISSIONEDREPORTCR/05/35N

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Contributing organisations:

British Geological Survey
Institute for Social and Environmental Transition
Overseas Development Institute
Advanced Center for Water Resources Development and Management
Institute of Development Studies, Jaipur
Tamil Nadu Agricultural University, Water Technology Centre
Vikram Sarabhai Centre for Development Interaction

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

ADVANCED CENTERFORWATERRESOURCES DEVELOPMENT AND MANAGEMENT
ACWADAM

Overseas Development Institute

ISET
Institute for Social and Environmental Transition

WTC - TNAU

VIKSAT

Institute of Development Studies

Bibliographic reference: COMMAN 2005. Managing groundwater resources in rural India: the community and beyond. BritshGeological Survey CommissionedReport CR/05/36N. Copies of the report may be obtained via the web site: www.bgs.ac.uk/hydrogeology/comman.

This report has been produced for the Department for International Development (DFID) under its Knowledge and Research Programme, as part of the UK provision of technical assistance to developing countries. The report isan outputofprojectR8058,'CommunityManagementofGroundwaterResourcesinRuralIndia'.Theviewsexpressedare notnecessarilythoseofDFID.

AssistanceinDesigning&Editing ACWADAM,Pune

Designing & Printing ModelCommunications,Pune

ACKNOWLEDGEMENTS

The authors would like to thank all those who played a part in the Comman Project and in the production of this document. This includes: the staff of the collaborating organisations; the State Government staff, local NGOs and communities without whom it would not have been possible to carry out the case study work; all those who helped organise the many workshops held during the period of the project, and all those who attended and provided such valuable input; and the staff of those organisations which provided a steer to the project, including DFID, UNICEF and the Department of Drinking Water Supplies. We would also like to thank those who have given up time to provide a review of this document, and in particular Dr Tushaar Shah of the International Water Management Institute.

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GLOSSARY

DEFINITIONS

Aquifer	A volume of rock which allows a significant amount of water to flow and to be pumpedout. The productivity of an aquifer is determined by the amount of water it stores (porosity) and how easily water can flow within it (permeability).
Common pool resource (CPR)	Natural or man-made resources used simultaneously or sequentially by members of a community or a group of communities. They include rangelands, forests, seasonal ponds, wetlands and groundwater aquifers.
Community-based groundwater management	Management of groundwater at a community level with user-based institutions devising rules, monitoring arrangements and sanctions to control groundwater access and/or withdrawal.
Community-level water-focussed interventions	A wide range of interventions,fromtherelatively untested community-based management approach examined in this document, to the ubiquitous water harvesting techniques - gully plugs, checkdams andpercolation ponds etc employed in watersheddevelopment programmes.
Conventional groundwater management	A centrally driven 'command and control' approach basedonregulation andformally defined water rights as key management instruments. The approach focuses on basic hydrological units - aquifers or surface water basins - and aims to achieve a balance between water flows into and out of these units.
Coping mechanisms	Ad-hoc measures undertaken by those directly or indirectly reliant on groundwater in response to declining well yields. For example, a reduction in crop area, shifts to less water-reliant livelihoods and seasonal or permanent migration.
Groundwater over-abstraction (overdraft)	Groundwater abstraction that is unsustainable in the longer term as abstraction rates are greater than the infiltration of rainfall. The timing, extent and severity of the impact will be dependent on local climatic, geological and socio-economic conditions.
Indirect policy instruments to address groundwater problems	Interventions that indirectly affectthe useof groundwater, for example: electricity pricing and supply policies; subsidies andtaxes on irrigation equipment; and incentive mechanisms to align cropping patterns with the water endowments of regions
Livelihoods-based approaches to groundwater problems	Policy approaches that encourage livelihood diversification or adaptation to reduce reliance on limited local water budgets.

ACRONYMS

ACWADAM	Advanced CenterforWaterResources Development and Management
APRLP	Andhra Pradesh Rural Livelihoods Programme
AWP	Arwari Water Parliament
BGS	British Geological Survey
CGWB	Central Ground Water Board
Comman	Community Management of Groundwater Resources in Rural India
CPR	Common pool resources
DFID	Department for International Development, UK
GPP	Gram Gourav Pratisthan
IDS	Institute of Development Studies, Jaipur
IWRM	Integrated Water Resources Management
KaR	Knowledge and Research Programme
KAWAD	Karnataka Watershed Development Project
NGO	Non-governmental organisation
NWP	National Water Policy
ODI	Overseas Development Institute
PIP	Policies, institutions and processes
PRI	Panchayati Raj Institutions
SWOT	Strengths, weaknesses, opportunities and threats analysis
TBS	Tarun Bharat Sangh
VIKSAT	Vikram Sarabhai Centre for Development Interaction
VWC	Village Water Council
WHiRL	Water Households and Rural Livelihoods
WTC	Water Technology Centre, Tamil Nadu Agricultural University

Summary

SUMMARY

The Problem

The use of groundwater in India has grown enormously since the 1960s. Today, groundwater provides a critical source of domestic and irrigation water, and also underpins efforts to reduce vulnerability, support livelihoods and sustain food security. This reflects the fact that groundwater can be accessed relatively easily and cheaply and provides a reliable, and usually high quality, source of supply.

A large diameter well, Coimbatore District, deepened due to declining groundwater levels

In many areas of India, however, there is increasing evidence that the intensity of groundwater exploitation is not sustainable - as a result of sustained periods of abstraction that exceed long-term rainfall recharge or cause significant localised dewatering of aquifers - and that well yields are decreasing. The reduced access to groundwater may disproportionately affect poorer households - for example asset-poor farmers locked into the groundwater economy - and those dependent on shallow, community wells for their drinking water.

Addressing the problem of groundwater overdraft in India is a subject of major debate. Conventional wisdom prescribes a mix of regulatory and economic reforms to control groundwater use and balance demand and supply. Implementing such reforms, however, and creating management organisations with the mandate, reach and capacity to influence the decisions of millions of groundwater users, is a huge challenge. Against this background, *the development of user group institutions for groundwater management* is an attractive idea, particularly in the context of political and administrative decentralisation, and the shift towards more bottom-up planning processes.

The Project

The potential for local, user-based approaches to groundwater management is the subject of the DFID-funded research project 'Community management of groundwater resources in rural India' (Comman), funded by the UK's Department for International Development (DFID) under its Knowledge and Research (KaR) Programme. The primary aim of the Comman Project has been to assess the feasibility of applying local, user-based approaches to groundwater management as a means of mitigating, or avoiding, groundwater depletion problems in rural areas. The aim of this report is to locate the findings of the Comman

Addressing groundwater overdraft in India is a complex problem

Project in terms of the *feasibility of community-based responses, in the wider context ofthe groundwater management debate in India*, and so to guide those developingpolicypertainingtotheproblemsofgroundwateroverdraft.

Anirrigationwellin Rajasthanwith3dieselengines

The project specifically addresses problems occurring in rural areas resulting from over-abstraction of groundwater for agricultural production. Although community-based management has been attempted in forest, watershedandothernatural-resourcecontexts, the viability of the approach has not been explored for groundwater management. The project focuses on the groundwater resource, taking as its starting point the conventional meaning of groundwater management, as definedbelow.

> *Supply augmentation and demand managementtoachieveanabstraction ratesustainablein thelong-termwith a buffer for use in periods of drought, to address a predefined structure of demand.*

Although groundwaterresource problems are often accompanied by problems of groundwater quality, time and budgetary constraints did not permit the project to address quality issues specifically. However, the discussion of approaches to resource-related issues is relevant to those required to address accompanyingwaterqualityproblems.

The Comman Project is based on close collaboration between a number of IndianandinternationalNGOsandresearchinstitutes. Specifically:the British Geological Survey (BGS); the Overseas Development Institute (ODI); the InstituteforSocialandEnvironmental Transition (ISET); theVikram Sarabhai Centre for Development Interaction (VIKSAT); the Institute of Development Studies Jaipur (IDS); the Water Technology Centre (WTC) of the Tamil Nadu Agricultural University; and the Advanced Center for Water Resources Development and Management (ACWADAM). Collaboration on the project has focussedonaseriesofvillagecasestudies,withsupportingdesk-basedreviews. The main detailed case studies have been undertaken in the Aravalli Hills of Gujarat (led by VIKSAT), the Arwari Basin in Rajasthan (led by IDS) and Coimbatore District, Tamil Nadu (led by WTC). In addition, more limited assessments (referred to in the project as reconnaissance case studies, led by ACWADAM)werecarriedoutatlocationswheretherewasevidenceofsomeform ofgroundwatermanagementbylocalusers.

Keyresearchquestionsexploredinthedetailedcasestudiesincluded:

- howhavelevelsandpatternsofgroundwateruseevolved?
- whatdrivesgroundwaterabstraction?
- whataretheeffectsofgroundwateroverdraftineacharea?
- who has been negatively affected by groundwater overdraft, and how have peopleandinstitutionsresponded?

- how effective have existing responses been in mitigating the impacts of overdraft? and
- could community-based initiatives for managing small parcels of groundwater (as opposed to whole aquifers) solve some or all of the problems resulting from groundwater overdraft?

The Guidance

The groundwater challenge facing India is the shift from development (facilitating further exploitation of groundwater) to management. This report examines the feasibility and potential effectiveness of different management approaches, including community-based management of groundwater resources.

A small checkdam in Coimbatore District

Chapter 2 begins by examining conventional approaches to addressing over-abstraction problems, based on direct regulation. Chapter 3 then assesses whether community-based approaches to groundwater management offer potential remedies, summarising the conclusions of the Comman Project research. Chapter 4 draws together insights from the previous chapters, setting out the core findings of the Comman Project. These are, in brief:

1. Community-based strategies are unlikely to be effective as a principal response strategy *for addressing groundwater overdraft.*

   In some circumstances, communities can mobilise around demand-side management, limiting resource access and/or use in pursuit of agreed objectives. However, circumstances are restricted, and the benefits generated do not add up to a primary strategy for balancing demand and supply. In general, small groups are unlikely to be able to retain the water they conserve, even if agreements on abstraction and use can be reached; the range of interests within communities - in many cases growing with livelihood diversification - makes objective setting around demand management objectives more difficult; and the perceived legitimacy of customary groundwater rights continues to create strong disincentives for collective management.

The groundwater challenge: shift from development to management

2. Community-level watershed activities aimed at increasing the productivity of land and water can, however, generate substantial benefits for local people by:

   a. Increasing the social and economic returns to limited available water resources;

b. Increasing the retention of moisture in the soil, enabling rural households to grow crops where none would otherwise be possible;

c. Enhancing water availability in wells within the small command areas of recharge structures;

d. Providing a critical buffer of water supply for rural communities. Communities can use this to meet essential requirements for drinking, livestock watering and, in some cases, irrigation during droughts.

In conjunction with other watershed interventions, therefore, community-based approaches aimed at restricting demand may help mitigate the adverse impacts of groundwater overdraft on livelihoods. Attributing benefits to different types of intervention is difficult though. A tentative conclusion is that even at a local level, livelihood improvements may have more to do with soil moisture conservation and better land management than with impacts on groundwater conditions and local-regional water balances.

3. Conventional, regulatory approaches to groundwater management are also unlikely to be effective in reducing groundwater abstraction to sustainable levels across the large aquifers at risk in many rural areas.

Conventional approaches are based on technical, institutional and political preconditions that are difficult to meet, and cannot be easily applied to situations where groundwater is being abstracted by many thousands of small-scale users. However, such strategies could be implemented on key urban aquifers where widely shared services are threatened, and political support for action is more readily mobilised.

4. Neither conventional nor community-based strategies are likely to 'solve' overdraft problems in a general sense and maintain livelihood systems based on intensive groundwater use. More attention should therefore be devoted to processes that:

Power looms in a village in Coimbatore District

a. Increase the efficiency of groundwater use (i.e. ensure that the social benefits derived from groundwater use are maximised);

b. Anticipate and proactively support the adaptation of households, communities and regions to other forms of livelihood as intensive irrigated agriculture becomes increasingly less viable in locations where overdraft is severe;

c. Safeguard domestic water supplies, since this is the minimum requirement for households to remain in a region and undertake any form of

d. Increase the effectiveness of the wide variety of community responses to water scarcity, including the design and targeting of groundwaterrechargeactivities.

Chapter 4 outlines this more process-driven, less prescriptive approach to assessing groundwater problems and selecting interventions. Potential coursesofactionineachofthecasestudyareasarealsopresented.

1

Introduction

1. INTRODUCTION

1.1 Project background

The use of groundwater in India has grown over the past 40 years to levels that threaten the water security of future generations. In addition to providing essential drinking water and irrigation, groundwater also supports livelihoods and food security. Growing reliance on groundwater stems from its easy access, its relatively low cost and good reliability and because groundwater is generally of high quality.

Prior to mechanised pumps, water was lifted from wells by mhots - large leather pouches pulled by cattle

In many areas of India, however, there is increasing evidence that the intensity of groundwater exploitation is not sustainable - as a result of sustained periods of abstraction that exceed long-term rainfall recharge or cause significant localised dewatering of aquifers - and that well yields are decreasing. The reduced access to groundwater may disproportionately affect poorer households - for example asset-poor farmers locked into the groundwater economy - and those dependent on shallow, community wells for their drinking water.

How to tackle the problem of groundwater overdraft in India is a subject of major debate. Conventional wisdom prescribes a mix of regulatory and economic reforms to control groundwater use and balance demand and supply. Implementing such reforms, however, and creating management organisations with the mandate, reach and capacity to influence the decisions of millions of groundwater users, is a huge challenge. Against this background, *the development of user group institutions for groundwater management* is an attractive idea, particularly in the context of political and administrative decentralisation and the growing role of communities in service delivery and other types of natural resource management.

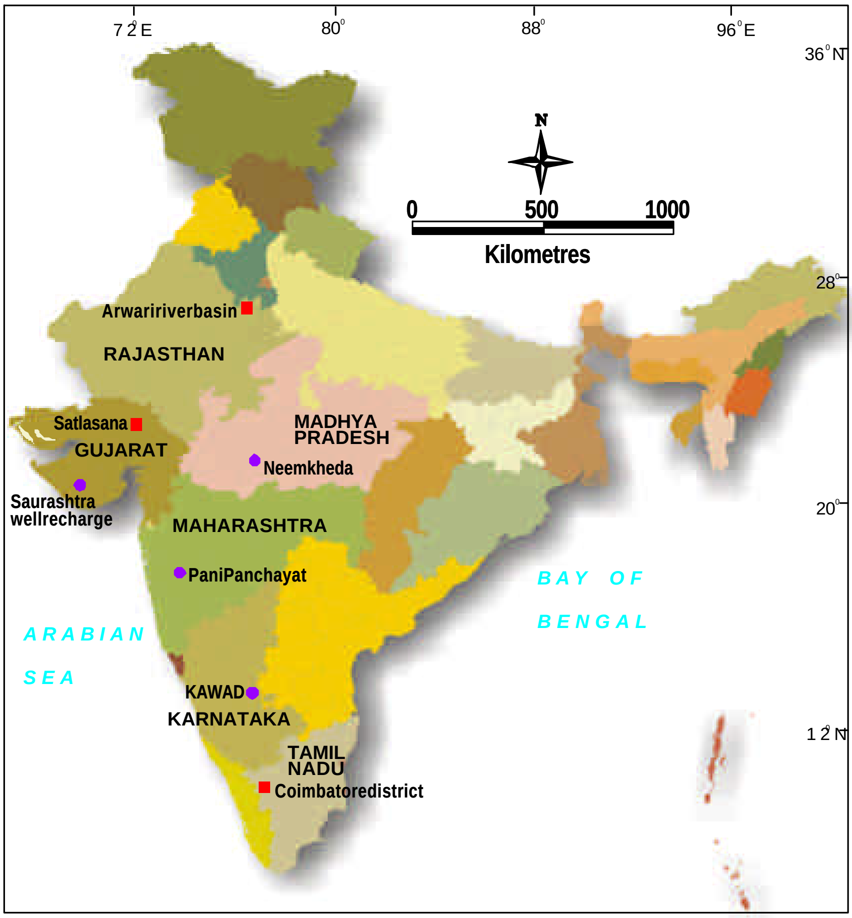
Reduced access to groundwater disproportionately affects poorer households

The potential for local, user-based approaches to groundwater management is the subject of the DFID-funded research project 'Community management of groundwater resources in rural India' (Comman), funded by the UK's Department for International Development (DFID) under its Knowledge and Research (KaR) Programme. The primary aim of the Comman Project has been to assess the feasibility of applying local, user-based approaches to groundwater management as a means of mitigating, or avoiding, groundwater depletion problems in rural areas. The aim of this report is to locate the findings of the Comman Project, in terms of the *feasibility of community-based responses, in the wider context of the groundwater management debate in India*. As such, it is intended as a guide to policy makers developing strategies for addressing the problems of groundwater overdraft rather than a set of project-level guidelines for implementing schemes for community management of groundwater resources.

The Comman Project has involved a close collaboration of Indian and international NGOs and research institutes. Specifically:

- Groundwater Systems and Water Quality Programme of the British Geological Survey (BGS), based in Wallingford, Oxfordshire;
- Water Policy Group of the Overseas Development Institute (ODI), based in London;
- Institute for Social and Environmental Transition (ISET), based in Colorado, USA;
- Vikram Sarabhai Centre for Development Interaction (VIKSAT), an NGO based in Ahmedabad, Gujarat;
- Institute of Development Studies (IDS), a research and teaching institute based in Jaipur, India;
- Water Technology Centre (WTC) of the Tamil Nadu Agricultural University;
- Advanced Center for Water Resources Development and Management (ACWADAM), an NGO based in Pune, Maharashtra.

Figure 1.1 Locations of project case studies (adapted from Map of India developed by KNVL, Pune)



BothVIKSATandtheWaterTechnology Centre havevaluableexperienceinthe implementationofcommunity-basedinterventions,however,theprimaryfocus of thefourIndianNGOsisresearchanddevelopment.

CommanProject: collaboration betweenIndian andInternational NGOsand ResearchInstitutes

Collaborationontheprojecthasfocussedonaseriesofvillagecase studies, with supporting desk-based reviews. The main detailed casestudieshavebeenundertakenintheAravalliHillsofGujarat (led by VIKSAT), the Arwari Basin in Rajasthan (led by IDS) and Coimbatore District, Tamil Nadu (led by WTC). In addition, more limited assessments (referred to in theproject as reconnaissance case studies) were carried out at locations where there was evidenceofsomeformofgroundwatermanagementbylocal users. These were undertaken by the four Indian NGOs, coordinated by ACWADAM. These reconnaissance case studies were carried out on: the Pani Panchayats of Maharastra;Neemkhedavillage, Madhya Pradesh;thewellrechargemovement inSaurashtra;andtheKarnatakaWatershedDevelopmentProject.

Thekeyresearchquestionsexploredinthedetailedcasestudieswere:

- Howhavelevelsandpatternsofgroundwateruseevolved?
- What has driven groundwater abstraction, in terms of the interaction betweenlocal (context-specific) factors and broader political and socio-economic processes?
- What has been the result of groundwater overdraft in each area, in terms of changing groundwater conditions and their socio-economicimpacts?
- Relatedto the above,who has been negativelyaffected bygroundwater overdraft,andhowhavepeopleandinstitutionsresponded?
- Howhaveexistingresponsesmitigatedtheimpactofoverdraft,ifatall?
- Could community-based initiatives to manage groundwater (as opposed to wholeaquifers)solvesomeorallofttheproblemsresultingfromgroundwater overdraft?

AcheckdamintheArwariRiverBasin

To address these questions, researchers assessed water and livelihoods at village and household levels and explored policies, institutions and processes (PIPs)thatmightbearongroundwatermanagement. Fieldwork wascarriedout inlate2002andearly2003,followingaworkshoponprojectmethodsandtools.

1.2 Nature of the groundwater over-abstraction problem

Groundwater plays a significant role in India's economy and will continue to help shape its future development. The rapid increase in the use of groundwater, primarily for irrigation, has contributed significantly to the agricultural and overall economic development since the 1960s. However, in many arid and hard-rock areas of the country, this level of groundwater development is not sustainable; yields from groundwater sources are declining with serious implications for agricultural production and drinking water supplies.

A group of farmers have joined resources to drill a borehole in the Satlasana area of Gujarat. Three previous attempts had found little water

Groundwater accounts for roughly 80 percent of water for domestic use in rural areas and around half of urban and industrial consumption (World Bank and Ministry of Water Resources - Government of India 1998). It is also essential for agriculture. Shah et al. (2003a) estimate that there are currently around 19 million mechanised wells and boreholes in India and that the annual groundwater yield from these is 1.5 x 10^{11} m^3 (an annual yield per source of 7900 m^3). More than half the population (55-60 percent) relies on groundwater as an immediate input for agricultural livelihoods.

In the 1950s, there were fewer than one million wells and boreholes in India. Since then the number has risen exponentially, encouraged in the 1960s and 1970s by India's objective of boosting agricultural production and achieving food self-sufficiency. The expansion of the farming areas and the double-cropping of existing farmland relied on significant development of groundwater. This was made possible by the introduction of mechanised drilling rigs and diesel pumps. Increasing rural electrification has more recently driven a change from diesel to electric pumps. In Maharashtra, for example, groundwater abstraction increased seven-fold between 1960 and 1990 as a result of a two to three-fold increase in the numbers of wells and a three-fold increase in average well yield (Macdonald et al., 1995).

Groundwater has contributed significantly to India's agricultural economy

Groundwater now supplies approximately 60 per cent of India's irrigated land (World Bank and Ministry of Water Resources - Government of India 1998) and, due to higher yields in groundwater-irrigated areas, is central to a significantly higher proportion of total agricultural output. Farmers prefer to irrigate with groundwater rather than surface waters from rivers, canals and impoundments, as groundwater needs no transportation and is available on demand. In drought years, groundwater is the most reliable source of water for irrigation.

However, over-abstraction is a concern in many areas and threatens the sustainability of the resource. Over-abstraction, as defined here, occurs where the rate of groundwater pumping is greater in the long-term than the rate of infiltration of rainfall. As described in more detail in Chapter 2, the nature of over-abstraction is heavily dependent on therocks that storethegroundwater (aquifers). The impacts are perhaps greatest in the crystalline hard-rocksthat underlie 60 per cent of India. Where the rate of abstraction from an aquifer is greaterthantherateofrecharge,theabstractionwillcausetheamountofwater stored in the aquifer to decline in the long-term. The impact of this decline is particularly severe in crystalline rocks as the overall storage is generally low. Thestorageinanaquiferactsas abuffer,allowinggroundwatertobeabstracted in years when rainfall is low. Where this store has been significantly depleted due to years of over-abstraction, the buffer may be negligible, meaning well yields are highly dependent on recent recharge. High rates of abstraction then become difficult to sustain, with impactsonbothirrigation and drinking water supplies.

Official figures (CGWB 1991, 1995) show that groundwater abstraction in blocksdefinedasdarkorcritical[1] increased at a continuous rate of 5.5 per cent over the period 1984-85 to 1992-93. At this pace, and without regulatory or recharge measures, over 35 per cent of all blocks will become over-exploitedwithin15years (World Bank and Ministry of Water Resources - Government of India 1998). Possible doubts about the accuracy of official estimates notwithstanding, the overall trend in overdraft is of growing concern.[2]

Sharingoutofinherited land,andinturnaccessto water,canmean competitionevenwithinwells. Here twopumpsetsarelocatedwithinashared dugwell

The rise and fall of groundwater economies in Asia is illustrated inTable1.1,basedonShahetal.(2003a).This showsatypicalprogression:instages1and2groundwaterpotentialisrealised and, supported by government subsidy, private investment in groundwater unleashes an agrarian boom; in stage 3, rapid and unchecked groundwater development results in some areas becoming over-exploited; and by stage 4, failure to exercise timely restraint leads, ultimately, to the decline of the groundwater socio-economy. Stage 5 - an extension of Shah's original - highlights shiftsinthestructureoftheruraleconomy,withlivelihoodstrategies changing in response to groundwater overdraft and independently of it as new non-farm opportunities emerge. Although rural-urban migration continues along with a move awayfrom irrigation-based agriculture, less water-intensive rurallivelihoodoptionshaveexpanded.

[1] Dark, or critical, blocks are defined as those where groundwater abstraction is estimatedtobeover85percentoftherecoverablerecharge.Officiallythereshouldbeno financialsupportforwelldrillinginsuchareas.

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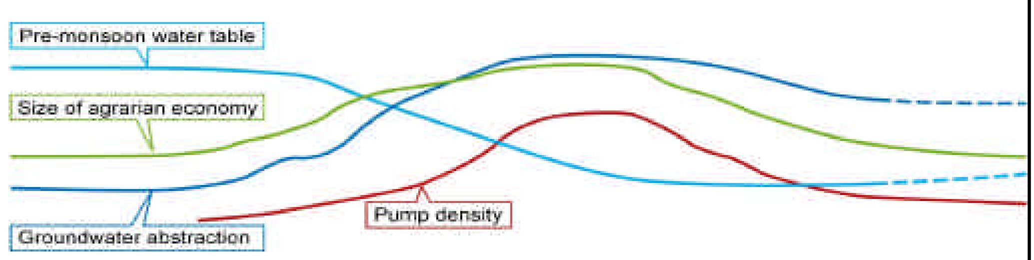
Table1.1 Rise and fall of groundwater socio-economies in South Asia (afterShahetal.2003a)

	Stage1	Stage2	Stage3	Stage4	Stage5
Stages	Theriseof Green Revolution andtubewell technologies	Groundwater- based agrarianboom	Earlysymptoms ofgroundwater over-draft/ degradation	Declineofthe groundwater socio-economy withimpoverishing impacts	Livelihood diversification - a copingstrategy for some,apositive choiceforothers
					
Project case studies			ArwariRiver Basin	PaniPanchayats Satlasana	Coimbatore
Characteristics	Subsistence agriculture; protective irrigation; traditional crops; concentrated ruralpoverty; traditional waterlifting devicesusing humanand animalpower.	Skewedownership oftubewells; accesstopump irrigationpriced; riseofprimitive pumpirrigation 'exchange' institutions. Declineof traditionalwater lifting technologies; rapidgrowthin agrarianincome andemployment.	Cropdiversification; long-termdecline inwatertables. Thegroundwater- based'bubble economy'continues booming; but tensionsbetween economyand ecologysurfaceas pumpingcostssoar andwatermarkets becomeoppressive; privateandsocial costsof groundwateruse partways.	The'bubble'bursts; agriculturalgrowth declines; pauperisation ofthe poorisaccompanied bydepopulation of entireclustersof villages.Water qualityproblems assumeserious proportions; the'smart'begin movingoutlong beforethecrisis deepens;thepoor gethitthe hardest.	Migration (temporaryand permanent)to urbancentres continuesalong with amoveaway fromirrigation- basedagriculture; lesswater intensiverural livelihoodoptions expandedto varyingdegrees; pipedsurface watersources foundtoreplace groundwater suppliesfor domesticuse.

AbananaplantationinCoimbatoreDistrict,irrigatedbywell-water

1.3 Focus of the Comman Project

The groundwater challenge facing India today is the shift from development (facilitating the further exploitation of groundwater) to management. The main management approaches for addressing problems associated with groundwater over-abstraction are:

- **Conventional groundwater management.** A centrally driven approach based on supply augmentation and demand management (the latter through regulation and water rights administration), which takes the hydrological system as a starting point, and a fixed profile of water-use categories. The primary aim is to achieve a balance between water flows into and out of the hydrological system.
- **Indirect management.** Non-water policies that can indirectly affect the use of groundwater, for example electricity pricing and supply policy; subsidies/taxes on irrigation equipment and incentive mechanisms to align cropping patterns with the water endowments of regions;
- **Community-level approaches.** These include water harvesting and watershed treatment but also direct community-based management of groundwater by a group of users devising rules, monitoring arrangements and sanctions for controlling groundwater access and/or use locally;
- **Livelihoods-based approaches.** In this report, we use this term to describe wider management approaches that put people, rather than the water resources they use, at centre-stage. Policies designed to stimulate the rural non-farm economy, for example, can support shifts to less water intensive (and therefore more sustainable) livelihoods, and may also (indirectly) ease pressure on the resource base.

The research undertaken by the Comman Project has focussed on the feasibility of implementing community-based management of groundwater resources, which sits within the third of these approaches. The project specifically addresses the problems occurring in rural areas where these are overwhelmingly the result of over-abstraction of groundwater for agricultural production. Although community-based management has been attempted in forest, watershed and other natural resource contexts, the viability of the approach has not been explored for groundwater.

A rural agricultural scene from Gujarat with a large dug well in the foreground

The project focuses on the groundwater resource, taking as its starting point the conventional meaning of groundwater management as defined above. Although groundwater resource problems are often accompanied by problems of groundwater quality, time and budgetary constraints did not allow the project to address quality issues specifically. However, the discussion of approaches to resource-related issues is relevant to those required to address accompanying water quality problems.

1.4 Objectives and structure of this guidance document

An aim of the Comman Project was to provide guidance to local, regional and national stakeholders on community-based groundwater management. Project research concludes that community-based approaches - in isolation - have limited applicability (see Chapter 3) as a means of controlling groundwater demand because many of the constraints faced are fundamental rather than context-specific. This report therefore has a broader focus, exploring the feasibility of community-based responses *in the wider context of the groundwater management debate in India*. This broader analysis of options is intended to inform and guide policy discussion around groundwater management, and specifically the means to tackle problems associated with groundwater overdraft.

The viability of community-based groundwater management not fully explored

Chapter 2 examines conventional approaches for addressing groundwater over-abstraction, arguing that, in the short-medium term, such approaches are feasible only in a few areas - for example on key urban aquifers - where specific preconditions can be met.

Chapter 3 assesses whether community-based approaches to groundwater management offer suitable remedies, summarising the conclusions of the Comman Project research. The limited applicability of conventional *and* community-based approaches leads into a discussion of the need to widen the resource-centric perspective of much of the management debate.

Chapter 4 draws together insights from the previous chapters to argue that 'single formula' approaches to groundwater management, based either on comprehensive demand-management strategies to balance demand and supply at the scale of aquifers, or on small groups of self-regulating users at village scale, are unrealistic. The key, Chapter 4 argues, therefore lies in (a) understanding which interventions are likely to be effective in addressing felt problems across a spectrum of socio-economic and physical environments; and (b) in recognising that the problems caused by groundwater overdraft can be tackled directly, by managing the water, and indirectly, by supporting transitions away from fragile, groundwater-based livelihoods.

A shallow irrigation pond for coconut trees

A more process-driven, less prescriptive approach to assessing groundwater problems and selecting interventions is therefore highlighted. The recommendations outline such an approach. In addition, potential courses of action in each of the case study areas are presented.

1.5 Dissemination and uptake

The report aims to show where the COMMAN Project findings sit in relation to *the wider context of the groundwater management debate in India*. It is written with the intention of providing guidance to policy-makers grappling with the problems of groundwater overdraft. However, the findings of this report are also intended to stimulate broader debate around management alternatives amongst a range of different stakeholders (see Table 1.2).

While the purpose of policy advice is to provide the foundations for concrete actions, the recommendations of this project should not be taken as prescriptions for action, not least because the problems caused by groundwater overdraft and their solutions will be situation-specific. Government staff, donors and other decision-makers need to be able to interpret the environments in which they work and plan interventions accordingly. The necessary levels of skill, and analytical ability and human resource development more generally, that this entails should therefore be viewed as integral to the processes of decentralised reform in India.

Table 1.2 Main stakeholder groups, project outputs and objectives

Level/*stakeholder group*	**Relevant outputs**	**Objective(s) - support needs**
National-state policy *Government and donor priorities and strategies*	• Common guidance document • Common research report • Project working reports	Information and influence debate on the groundwater management 'problem', questioning common assumptions and emphasising need for responsive, context - specific interventions.
Overall programme design *Donors, government and NGOs*	• Common guidance document • Case study survey tools and checklists*	Re-orientate programmes away from narrow, water-focussed objectives; highlight links with other, non-water sectors and policies
Project design and implementation *Government and NGOs*	• Common guidance document • Case study survey tools and checklists*	Encourage a more open-ended approach to identifying entry points for supporting vulnerable groups Illustrate diagnostic approach for assessing water-related problems and identifying feasible interventions

* It is planned that the tools developed by the COMMAN Project for assessing livelihood-water links will be combined with those developed on other ongoing DFID-funded projects (Secure Water Building Sustainable Livelihoods for the Poor into Demand Responsive Approaches; AGRAR Augmenting Groundwater Resources through Artificial Recharge) and disseminated via the project website www.bgs.ac.uk/hydrogeology/comman, and other media.

2

The Conventional Management Response

2. The Conventional Management Response

Conventional approaches to groundwater management emphasise the need for sustainable management of groundwater at the scale of the aquifer, defining sustainability in terms of the long-term balance between recharge and extraction. In theory, sustainable management is achieved by assessing groundwater conditions and trends, devising activities and policies that attempt to balance supply and demand, and implementing them at the aquifer scale through management organisations. Conventional, command and control approaches to groundwater management often use a combination of legal, regulatory and pricing mechanisms to balance extraction with long-term available supplies within clearly defined aquifers. They generally do not focus on the deeper social incentives that drive and shape water demand in the first place, or on the larger social and economic transitions that generate such incentives. Theory aside, in most situations the planning of groundwater use at 'aquifer' level is still not apparent, although discussions, technical or otherwise, tend to recognise different kinds of aquifers across India.

Beyond this common starting point, however, the views of different stakeholders begin to diverge. Some, particularly those with training in water management, emphasise the need for comprehensive and integrated approaches based on formal systems of water rights, economic signals and regulatory controls. Politicians are presented with proposed reforms that entail heavy technical and institutional requirements that would, if implemented, confront long-established customary rights and patterns of use. Popular resistance to such reforms combined with the formidable challenge of monitoring hundreds of thousands, if not millions, of wells makes them politically infeasible. As a result, less politically challenging interventions to increase the supply of water, or increase the efficiency of water use within existing sectors, are favoured.

2.1 Perspective

Conventional approaches to groundwater management combine scientific, technical and (typically hierarchically structured) institutional components to achieve socially defined management objectives. Most conventional approaches take the hydrological system as a starting point. Although this is not always achieved in practice, approaches focus on basic hydrological units - aquifers or surface river basins - as the most logical or 'natural' physical management units. Conventional management thinking is structured around mass balance concepts; that is, the balance between water and other mass flows into and out of hydrological units. It attempts to consider how those flows alter conditions such as groundwater levels, the stock of water available, flow directions or pressure gradients and the quality of water within units. Management institutions designed to meet conventional objectives would therefore be structured accordingly. Thus a relatively narrow set of managers, with access both to high-level technical expertise and stakeholder inputs, would be able to

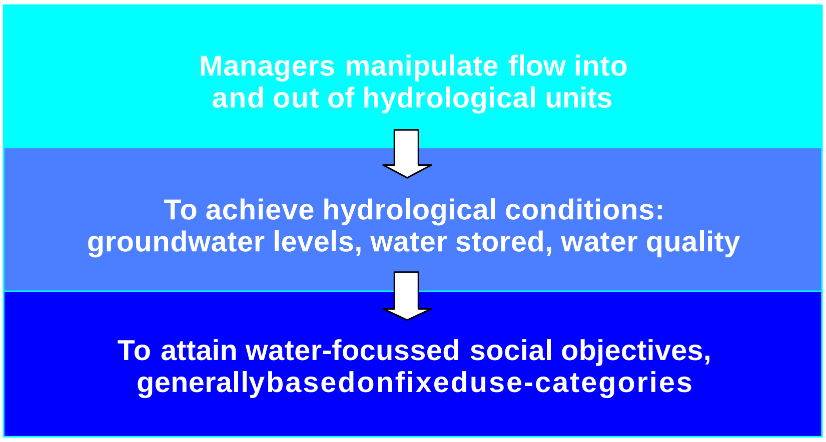
A large diameter well with a shallow water table

manipulate flows into and out of a given management unit to achieve the hydrological conditions necessary to attain a desired social, and more recently, environmental objective. Although there is a set of reforms focusing on drinking water in some Indian states that attempts to explore the possibilities of such a management model, attempts remain sporadic and are at a preliminary stage in India.

Management objectives can be defined in a variety of ways, but conventional approaches to groundwater management do not focus on the full range of social objectives that are theoretically possible. Instead, they are water-focussed and generally emphasise:

- Sustainability of the groundwater resource base (which in most cases is effectively defined as the sustained yield or balance between inflows and outflows from aquifers).
- Maintenance of water quality.
- Allocation of available water supplies to broad use categories (agriculture, domestic, industrial and environmental) along with, in many cases, the maintenance of water rights systems.

Figure 2.1 Conventional groundwater management



Although it can be structured in ways that are conceptually clear, in practice, 'sustainability' is a highly abstract and often unclear objective (Box 2.1). Notions of sustainability are, however, the starting point from which the groundwater monitoring programmes of many countries, including India's, are founded. India's monitoring programme, for example, is designed to produce estimates of recharge and extraction for local hydrological units across the country. Commonly, these units are watersheds, and not aquifers. In areas where recharge is estimated to exceed extraction by a large margin, the government provides subsidies to encourage groundwater development. In areas where extraction approaches or

Conventional approaches to groundwater management are water focussed exceeds recharge estimates, it reduces subsidies and discourages drilling of new wells. The objective is two-fold: first, to encourage utilisation of groundwater resources; and, second, to ensure that such utilisation does not deplete groundwater stocks thereby leaving subsequent periods (years or generations) with the same levels of overall water availability.

Given the limitations of sustained-yield concepts, management to attain sustainability and other objectives generally comes down to *maintenance of groundwater levels within a relatively narrow range.* More specifically, public debates on the need for management only start when water levels fall and begin to affect wells and pumping costs or when water levels rise to the point where water-logging becomes a concern. Most conventional management approaches attempt to maintain water levels within a range where the pumping costs for irrigation or other uses are low but the water table is sufficiently below ground level to avoid water-logging or soil-salinity problems. In addition, they usually seek to maintain groundwater storage as a buffer against drought and to avoid long-term water-level declines, even when such declines have few immediate economic implications.

The focus of conventional groundwater management is generally maintenance of water levels in wells

Groundwater management often focuses on water quality, too. However, in practice, most initiatives emphasise specific concerns such as the need to avoid or mitigate saline intrusion of coastal areas or to control point-source pollution problems. They rarely attempt to address long-term changes in water quality that are not due to point-source pollution problems. However, there is increasing awareness and sensitivity to such problems, particularly in the wake of publicity on natural groundwater contamination from arsenic and fluoride, and water quality is increasingly integrated into groundwater management approaches. Nevertheless, groundwater over-abstraction and water quality tend to be treated in isolation of each other while considering options in groundwater management. Since the Comman Project's primary focus is on managing the availability of groundwater supplies, the discussion from this point onward will not emphasise water quality and pollution. It is, however, important to recognise that water quality is central to conventional concepts of groundwater management and sustainability.

A borehole supplying drinking water in Rajasthan

It is important to note that conventional approaches tend to focus on technological interventions that change people's ability to extract water from an aquifer or the amount of water they require to meet existing uses and not on changing water use itself. In other words, conventional approaches to groundwater management in India assume that the basic structure of water demand is fixed. They focus, for example, on irrigation efficiency but generally do not question whether agriculture (especially with a certain cropping pattern) is an appropriate form of livelihood for the particular region. Sometimes management does attempt to change the structure of demand, for example, by regulating the types of crops grown to reduce water demand or reforming energy pricing for agriculture to make the use of irrigation pumps a more expensive option. However, these 'indirect' approaches are somewhat separate from the largely command and control-centric conventional approach.

Temporal as well as spatial variability in rainfall creates water scarcity, often compounding problems of groundwater overdraft

Conventional management initiatives do not generally address the livelihood systems that give rise to the structure of water demand. These are generally taken as 'givens'. As a result, most conventional approaches do not address the evolving social context in which interventions must fit, with the exception of questions such as whether or not adoption of key technologies is economically viable. This is a key distinction between resource-centred approaches and the more livelihoods-focussed, adaptive remedies discussed later in this document. Implementing conventional management theory becomes difficult as all of its underlying assumptions can seldom be met.

Box 2.1 Problems with the concept of sustainable yield

Even at a conceptual level, conventional notions of sustainable yield can begin to break down. One of the most important roles of groundwater is as a drought buffer. As a result, it is customary, where available, to draw groundwater storage down during droughts and allow it to replenish during normal years. But what is a 'normal' year? Precipitation levels and patterns are inherently variable. Recorded precipitation data are often discontinuous and available only for short periods and so may not reflect long-term averages. The densities of rain gauge stations are often not great enough to measure the variability in precipitation. Furthermore, given the prospect of climatic change, it is uncertain whether historical data will be of much use in predicting future precipitation levels. The problems multiply when one adds to this the changing patterns of land use (which often affect recharge), other human interventions in the surface hydrological system, and technical uncertainty regarding the nature of a given aquifer or regional hydrological system dynamics; it becomes virtually impossible to determine how much groundwater really could be extracted 'sustainably' without changing the stock in storage. If one adds changes in water quality potentially induced by groundwater utilisation then the picture is even further muddled. Finally, social goals often focus on livelihoods and the sustainability of economic or environmental systems, neither of which may be inherently related to the stock or quality of groundwater in storage.

2.2 Critical Assumptions

The management perspectives outlined above are underpinned by a set of assumptions. In terms of demand management, the principal focus of the ComMan Project, the reforms most commonly proposed in relation to Integrated Water Resource Management (IWRM) - see Box 2.2 - are based on a set of regulatory and economic principles that emphasise direct control of groundwater abstraction through formal government agencies. Since conventional approaches take notions of physically-defined sustainability within hydrological units as a starting point, they rely on a common set of capabilities, or assumptions, defined here as:

- Basic scientific understanding of aquifer parameters, and data on groundwater conditions, trends and patterns of use;
- Institutional capacity for implementing reforms, including monitoring and enforcement;
- Political feasibility, as new reforms cannot be implemented by unwilling governments and water users.

Monitoring of a well in Purandar Taluka of Pune District

If these conditions do not exist, then conventional approaches to groundwater management can, at best, serve only as partial solutions. In particular, the institutional and political dimensions of management are critical. Unless broad support exists for management, ratifying and implementing reforms will be difficult. And unless an institution capable of functioning at an aquifer or hydrological unit scale exists, then assembling the required scientific, technical, planning and wider regulatory or social influence capacities will be virtually impossible. In other words, the question of *who will actually do the management and how this can be achieved, given the scientific, political and institutional hurdles that need to be overcome*, is of fundamental importance to the viability of conventional approaches.

Collection of groundwater samples from Satlasana

Box2.2 Understanding the management priorities of different stakeholders

The mixofgroundwaterstakeholdersischanging inIndia.Adecadeago,the government administration and politicians were considered major stakeholders. Decentralisation and the process of liberalisation has expanded the list of stakeholders to include politicians, donors, NGOs and consultants, inaddition tovillagecommunities which have been empowered to participate actively in decision making concerning drinking water and sanitation. Different stakeholders often prioritise management options differently. It is important to understand what these priorities are, and why thedifferencesoccur.

Those pushing for new, principle-based reforms under the mantra of IWRM (e.g. donors, externalconsultants)viewwaterasbothaneconomicandsocial resource. Water should be supplied to meet basic needs, so the argument goes, with theremainder allocated to thosesectorsoffering highest 'returns', whilst protecting environmental services. In other words, demand managementshould embrace allocativeefficiency.However,suchmessages, and the economic and regulatory innovations involved, are not rooted in engineering science or easily assimilated by the bureaucracies, such as the CGWB, that have, for many years, been responsible for developing rather thanmanaging water. Neitherarethey rootedinruralcommunitiesthathave longconsideredwaterafreeentitlement.

In contrast, politiciansfaced with thechallengeofimplementing policies(and getting re-elected) prioritisethingsdifferently. Ways to augment the supply of water are favoured, as are efforts to increase the technicalefficiencyofwateruse.Henceefforts toincreaseirrigation efficiencyaresupported, as are groundwater recharge activities. Reallocation, on the other hand, is strongly resisted, as it carries high political risks in rural economies still dependent on groundwater-basedlivelihoods.Thevoiceand political power of agriculturalusers, and those purporting to represent them (such as the sugarcane industry), is therefore very strong, and capable of frustrating reforms on groundwater rights and power pricing that appear economicallyandenvironmentallyrational.

Asource ofdrinkingwaterforcattlein Gujarat

What havewelearned? The extent to which water policiesandinterventions arepoliticallyfeasible,sociallyacceptable andideologicallycompatible with prevailing beliefsisfundamentalto both the continuationof existingpolicies, andtheadoptionofnewones.Yettherereremainsanarmyof(largelyexternal) sector professionals who insist that centralised command and control, demand management reforms, based on major preconditions, can be implemented because they'makesense'.Thereisafailuretorealisethattheir logical remedies, based on the intuitively-appealing principles of IWRM, present huge political and institutional obstacles to those charged with implementingthem.

2.2.1 Technical and scientific requirements

Conventional approaches assume certain technical and scientific requirements have been, or can be, met. Without this expertise and information, new systems of water rights allocating shares in aquifer storage, for example, and the access and abstraction controls that follow, are difficult if not impossible to implement. Prerequisites include:

- The ability to define hydrogeological boundaries, within and between different aquifers (Box 2.3);
- The ability to provide reasonably robust estimates of groundwater recharge, storage and outflows, often based on other estimates such as aquifer characteristics, abstraction volumes and stream-flow discharges;
- Data on patterns and trends in groundwater access and abstraction, and the means to turn data into knowledge, and hence inform management.

In reality, these prerequisites are very difficult to meet. Why?

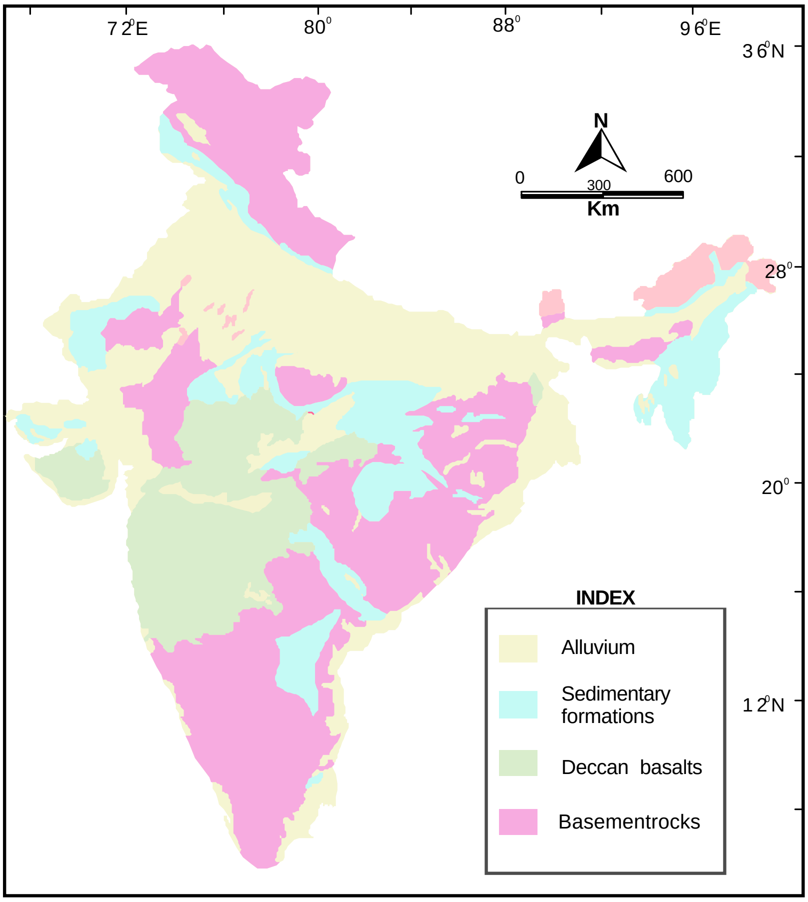
Despite large-scale efforts on the part of government and NGOs, a consistent and scientifically-informed *understanding of groundwater systems in India is far from achieved*. The situation described for watershed development in Box 2.4 is a case in point, as positive impacts on the status of groundwater resources across different physical environments are typically assumed rather than evaluated. This is also the case with debates over the efficacy of water harvesting for groundwater recharge. Gaps in hydrogeological understanding are particularly acute for the complex, heterogeneous conditions of the hard-rock aquifers extending throughout most of peninsular India (Moench 1996, Kulkarni et al., 2000). As Narasimhan states: "indiscriminate fitting of hydraulic test data to available mathematical solutions will but yield pseudo hydraulic parameters that are physically meaningless" (Narasimhan 1990, p. 362). Overall: "a sound rational basis does not exist yet for quantifying resource availability and utilization." (Narasimhan 1990, p. 354). While such quotes are old, and large investments have been made in many states and, under India's Hydrology Project, at the national level in monitoring, and the development of databases, we believe that the situation has not changed fundamentally. Despite some improvement in the approach to monitoring, there is still a large gap between the data that would be required to characterise groundwater conditions at the level of local aquifers or villages where community-based management might occur, and the types of data collected and available in existing databases. Furthermore, it is often unclear whether sufficient data are available for effective management even at higher, aquifer and watershed levels, given the high levels of variability in both the geohydrological and socio-economic factors that affect groundwater conditions in the Indian context. What data do exist?

Gaps in hydrogeological understanding exist for complex, heterogeneous hard-rocks

A quarry showing a shallow weathered zone overlying fractured hard rock

[3] http://wrmin.nic.in/investment/hydrology.htm

Figure 2.2 Simplified geological map of India



Where groundwater is concerned, the primary data collected in India for characterisinggroundwatersystemsinclude:

- Basic geological information along with a very limited set of pumping test datatocharacterisethehydrologicalcharacteristicsofformations;
- Water level data from networks of monitoring wells. The Central Ground WaterBoardoperatesalow-densitynationalnetworkofmonitoringwells.In addition,eachstatehasagenerallymoredensenetworkofmonitoringwells;
- Basicwaterqualitydata;
- Somebasicdataoncropwateruseandcroppedareas;
- Estimatesofwellnumbersandpumputilisation;and
- Associatedhydro-meteorologicaldataonrainfall,humidity,etc.

Problems within this basic data set have been widely discussed elsewhere (Moench1992a;Moench1994b;WorldBank and MinistryofWaterResources-Government of India 1998, Shah et al., 1998). Periods of record are short and theaccuracyofmuchofthesedataisquestionable.Inaddition,someofthedata on, for example, pump numbers and extraction rates are based on indirect measures (such as the number of loans issued for well construction) and probably do not reflect ground realities. Equally importantly, even if all data were fully reliable, the types of data collected are often insufficient for characterisingthehydrologicalsystem.Bi-annualwaterleveldatafromregional monitoring wells, for example, does not capture the seasonal dynamics that often dominate groundwater availability in hard-rock areas, or providetheresolution neededtocharacteriselocalisedflow regimes. Moreover, theyseldom refertowhich aquifer or groundwater system they represent. Similarly, daily rainfall data do not capture the intensity-duration characteristics of precipitation events that are centraltodetermining how much recharge might occur. Finally, key data for accurate estimation of water balances, such as evapotranspirationbynativevegetation,arenotcollectedatall.

Datacollected areoften insufficientfor characterising thehydrological system

That said, efforts to address data problems have been initiated but will need substantial time to produce the types of information and understanding requiredforeffectivemanagement.The Hydrology Project,withsupportfromthe World Bank, Government of Netherlands and Indian Implementing Agencies (Key Central and State Agencies), has attempted to establish a hydrological information system in seven peninsular states. Unfortunately, the project was recentlyterminatedfollowingtheGoIdecisiontorationalisedonorsupport.Ona much smaller scale, the intensive water resource audits carried out on a few watershed development projects in Karnataka and AP (Batchelor et al. 2000, Rama Mohan Rao et al. 2003) are designedtoprovide data supportforproject implementation and inform management plans. Inevitably, however, these are isolated and few in number, with little prospect (given funding and technical limitations) of major scaling up. Similarly, demand-led management of water resources isadevelopingapproachthatalsoattemptstointegratewater supply and sanitationinto integrated watersheddevelopment programmes, toachieve improved access and water management (DFID-funded projects WHiRL www.nri.org/WSS-IWRM/ and APRLPwww.aplivelihoods.org/). However, such intensive efforts are too few and far between to address the problem of groundwaterover-abstractioninIndia.

Overall, the above limitations on the availability and types of data and basic hydrological science substantially constrain India's ability to manage groundwater in a conventional manner. It is important to recognise, however, that the issues of variability and scientific limitations are not unique to India. Understanding often is not much better in closely monitored, extensively modelled and, from a hydrological perspective, relatively straightforward alluvial basins. In the San Luis Valley of Colorado in the USA, for example, hydrologists have been unable to resolve a 30 per cent gap in water balance estimates (between what they know flows into the valley and what flows out) despitethreedecadesofintensivemonitoring,consultinganalysesandresearch (ISETresearchprogrammeinterviews,1999).Lackofsufficientmonitoringdata andlimitationsonthetechnicalabilitytoquantifyflows,hydraulicconnections andthequantitiesofwateravailableingroundwater systems, lie at the heart of the many insoluble disputes over water rights and groundwater management acrossthewesternUSA.

An additionallimitationmaybethenatureofthemass-balance'sustained-yield' approach in the hard-rock systems that underlie some 60 per cent of India. Since storage in hard-rock systems is lowandconfinedtotheupperweathered zone,thesustained-yieldconceptmayhavelittleutility.Instead,itmaybemore appropriate to view wells in hard-rock areas more as cisterns where depletion and recharge occur over short periods of time. From this perspective, management would be more concerned with efficient use of water captured within the wellsthanwithmanagementoftheaquifer *perse*. Overall,however, thebasicscientificapproach to understanding groundwaterdynamics inhard-rock areas isfundamentally different fromthealluvial context which has been the focus of most hydrological work at a global level. Understanding the hydraulicsofhard-rocksystemsawaitsthebasicscientificadvancesnecessary fordeveloping thetechnical and scientific foundationof systemdynamics. This wouldcreateabasisformanagement.

Inherent scientific and data limitations arecompounded inIndiabythenature of hydrology training andthelocation and nature of management needs. As in most countries, the university system for training professional water resource engineers places little emphasis on the social context in which hydrological questions and data must be used. As a result, most engineers have little exposure to -- or resonance with -- the field and the larger policy context in which scientific analyses occur and where the results must be used. The gap betweenacademics (research andtraining)andfieldrealityisoftentoowidefor groundwatermanagement theorytotranslateintopractice.Furthermore,there is little incentive for well-trained hydrological engineers towork in rural areas where most groundwater problems currently exist. Most major consulting, governmental and non-governmental organisations working on water problems are located in urban areas where professional staff have access to key basic facilities (such as good education systems for their children). No such organisations or supporting environments are found in rural areas, where most groundwater management needstooccur. As a result, well-trained professionals face substantial disincentives todevotetimeandefforttoworkingatthe local level where groundwater problems directly affect communities. India does produce large numbers of engineers and techniciansbut most worklargelyinthe service delivery sector, where the focus is on water supplyand augmentationrather thanaround direct or indirectmanagementofgroundwaterresources.

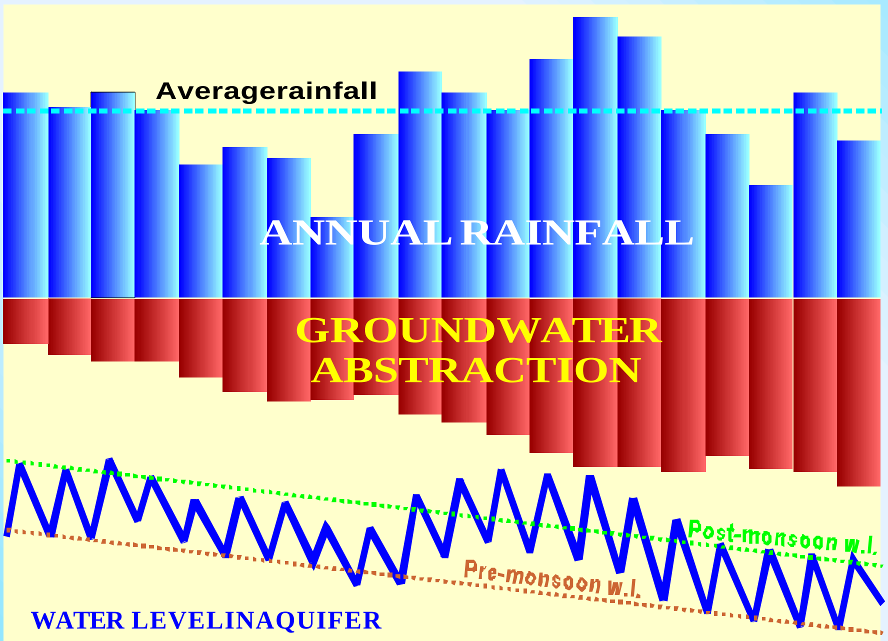
IntroductionofrigstoruralIndiahasenabled thedrillingofdeepboreholes

Beyond scientific limitations and the structural disincentives for engineers to work primarily in rural areas, data access isoftenamajorissue. Under the Hydrology Project, official 'data users' were identified. These approved data users ranged from governmentorganisationstoacademicentities andlocalNGOs. Theexperience of organisations withintheCommanProjectandothersthey have worked with, many of whom are approved data users, suggests this system is far from adequate. While there have been exceptions, membership of the approved group of data users has sometimes not enabled organisations to obtain access to data they know exists and should be available through the databases compiled by the Hydrology Project. If data access is complicated for groups that have already been approved, the situation for local management organisations is likely to be even more problematic.

Overall, it is far from clear how problems of data access and the basic scientific challenges to the understanding of regional hydrological systems can be resolved within the short to medium term. Given available budgets and staffing, the deployment of substantial additional governmental resources for this purpose is unlikely for most states. Furthermore, as is clear from experience in much of the industrialised world, even additional basic scientific research, while important, would probably not be sufficient to resolve many gaps in the mass-balance estimates within regional hydrological systems.

A key point to recognise here is that technical limitations facing groundwater management are as much a product of how management objectives are defined, as they are related to anything inherent in the hydrological system and the nature of scientific knowledge. The Central Ground Water Board's adoption of conventional groundwater management objectives in terms of sustainable aquifer yield, effectively multiplies the technical and human resource requirements for assessing groundwater status and trends. If instead, simple key indicators of groundwater conditions were used, such as water levels and water-level trends, technical challenges would be reduced. Here we come back to the issue of training, and the organisational and bureaucratic culture of formal water institutions in India. As long as training remains primarily technical and organisations continue to pursue a technical vision of how, ideally, groundwater should be managed (with goals defined intrinsically through the water system), then the knowledge-needs gap will remain large.

Figure 2.3 Long-term water-level decline in an aquifer



Box 2.3 Not all aquifers are the same

Aquifers vary in their properties, and this difference has influenced groundwater development and the timing and the degree to which over-abstraction has impacted. An aquifer is defined as a volume of rock which allows a significant amount of water to flow and to be pumped out. The productivity of an aquifer is determined by the amount of water it stores (porosity) and how easily water can flow within it (its permeability).

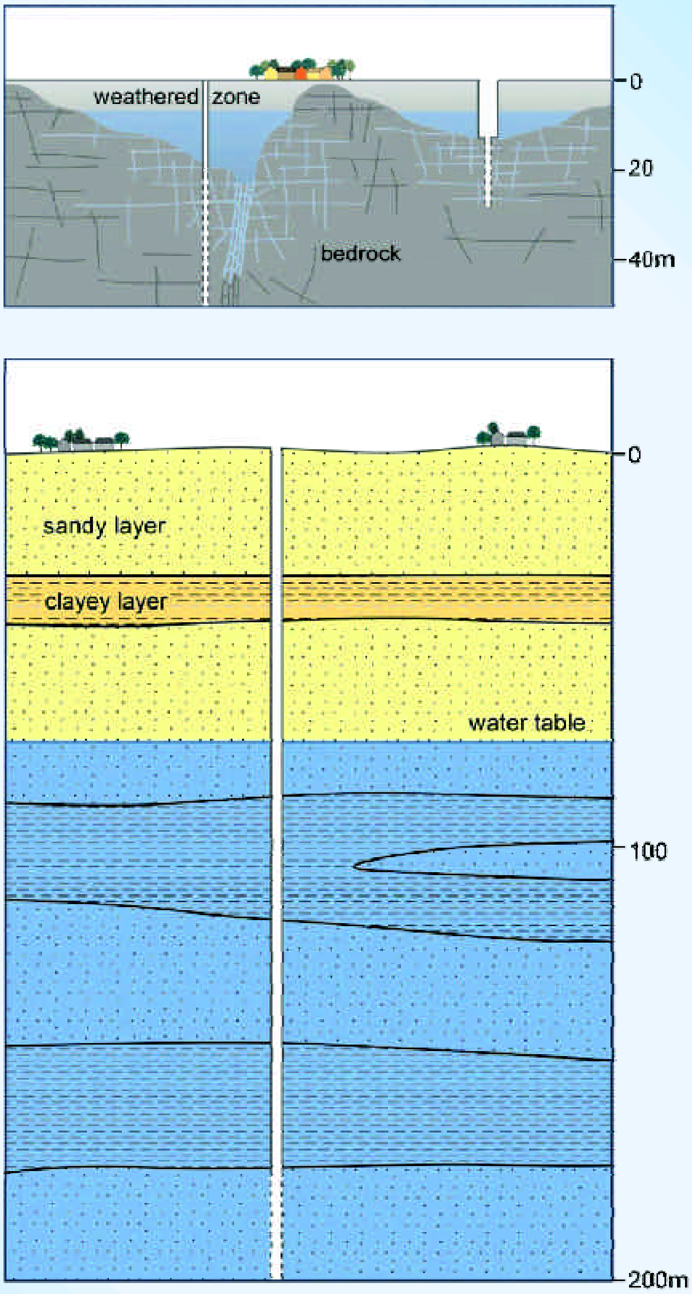
Around 60 per cent of India is underlain by crystalline rock, such as granites and basalts. In these rocks, porosity and permeability are a result of weathering and fracturing. Weathering causes the minerals in the rock to break down in varying degrees, allowing water to get in. Major fracturing tends to be localised, occurring in linear zones, sometimes as a result of relative movements of large masses of rock. The weathered zones account for the majority of storage whereas fractures allow relatively fast flow of water. However, weathered and fractured crystalline rocks, often referred to as hard-rocks, generally store less water than sedimentary rocks (Figure 2.4). Weathered hard-rocks have a porosity of 5-20 per cent but are generally limited in depth; fractured hard-rocks typically have a porosity of 1 per cent; sedimentary rocks have porosities of up to 30 per cent and can be extensive, laterally and in depth.

A large diameter dug well in the Deccan basalt

Over-abstraction from hard-rocks leads to depletion of stored water at the end of the dry season and so, in many regions, the water available for irrigation is very much dependent on the previous years' rainfall. The depth of the weathered zone may vary significantly over short distances and so small pockets of saturated rock can be formed. Large-diameter wells can only be easily dug into the highly weathered rock, and where this is deep, can result in significant yields. Although the permeability of weathered material is relatively low, the water stored in the large-volume wells can be pumped out during the day, and slowly refilled during the night. However, over-abstraction of groundwater in many regions has lowered the water levels in the weathered zone causing these wells to dry up, particularly in late summer. Many farmers have responded by drilling boreholes into the unweathered zone (bedrock) from the base of the wells (to form dug-cum-bore wells) or from the ground surface, but it is a risky strategy. Boreholes drilled into bedrock may be productive if they hit large networks of fractures, but they often do not and so yield only small amounts of water (Figure 2.5).

The other major aquifer type in India is formed from unconsolidated sediments, such as sands, silts and clays, themselves the decomposition products of pre-existing rocks. These may form thin layers overlying harder rocks but large volumes may also accumulate in deep basins, e.g. the Mahesana Basin in Gujarat. Coarser-grained sediments, such as sands, form highly productive aquifers within these large basins;. The coarse-grained sediments are very permeable and have big pores that can store large amounts of water. Even though the amount of water stored is relatively large, the impacts of over-abstraction are still seen, as the volume of water being abstracted so greatly outweighs the infiltrating rainfall. Over-abstraction results in water-levels in the alluvial aquifers falling, with implications for those that cannot 'chase the water table' (Moench, 1992b).

Figure 2.4 Main hydrogeological settings in India.



Shallow weathered hard-rock aquifers have both limited porosity and depth and are therefore relatively low in groundwater storage. Permeability will only be high in localised areas of fracturing. Deep sedimentary systems can include coarse-grained sandy layers, which are both high in porosity and permeability.

Box 2.4 Watershed development: a solution to the problem of groundwater overdraft?

Watershed development, with a strong emphasis on groundwater recharge, is being promoted in one form or another, in each of the case study areas of the Comman Project and by various government departments (and donors) across India. Micro-watershed management, including the construction of check dams, field bunds and percolation ponds, currently absorbs over US$500 million per year, channelled mainly from central government sources (Kerr et al., 1999). Watershed development projects surely go beyond simplistic management of water resources (like balancing supply and demand) and aim to address a wider array of issues ranging from natural resources management to livelihoods improvement (OIKOS and IIRR, 2000; Shah et al., 1998).

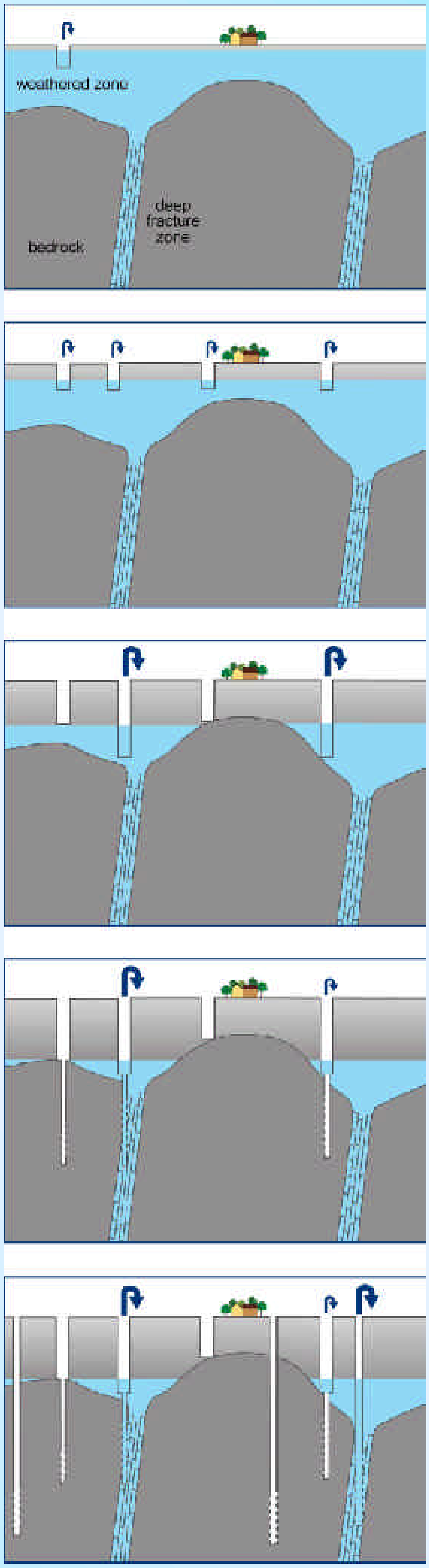
Notwithstanding the overall improvement to the natural resources and livelihoods regime, an underlying belief is that watershed treatment leads to increased recharge and a rise in groundwater levels in the area of intervention. Although many projects claim significant improvements in groundwater conditions, actual impacts are rarely scientifically evaluated or documented. Moreover, a belief, rightly or wrongly, that groundwater recharge has been increased can lead to further unsustainable development. Such 'long-term impacts' in watershed development programmes are poorly documented (Kulkarni, 1998).

Concerns have been raised that water harvesting activities are being seen too much as a panacea for stressed aquifers, without the necessary systematic evaluation of their potential in different climatic, agro-ecological and hydrogeological conditions (Gale et al., 2002). Ongoing research led by BGS (see Gale et al., 2003) and others (e.g. Kumar et al., 1999; Rama Mohan Rao et al., 2003) supports this view, suggesting that while recharge activities may, under certain conditions, have significant local effects their impact on wider groundwater conditions (the supply-demand balance) is marginal. The challenge is to be able to replicate these recharge activities over a wider area, although the assumption then is that there is sufficient surplus water available and that impacts on downstream users are not significant. Batchelor et al. (2000), commenting on programme experience in Karnataka and Andhra Pradesh, conclude that "...there is no evidence to suggest that traditional watershed development activities have halted degradation of water resources, or made villages less susceptible to the shock of drought". Moreover, the long-term sustainability of any (local) supply-side benefits that are realised can clearly be questioned in a context of unchecked demand (Lobo & Palghadmal, 1999; Batchelor et al., 2000).

What have we learnt?

- *Firstly, that watershed development in India remains a growing 'movement' to make people rally around issues like natural resources management and improved livelihoods. We accept the efficacy of watershed programmes around these issues.*
- *Secondly, the design, implementation and targeting of recharge activities within watershed development programmes is constrained by a lack of sound scientific knowledge and understanding about the appropriateness of different water harvesting activities in different environments. Hence, recharge activities alone are unlikely to provide remedies to the problem of groundwater overdraft, and certainly not if supply gains are negated by rising demand. The propaganda of watershed development, however, suggests that the scope for augmenting water resources is unlimited.*
- *Thirdly, and related to the above, the political attraction of supply-side solutions is such that 'unwelcome' knowledge and insights can easily be downplayed. So, while it is important to stress the need for rigorous evaluation, a dose of realism is needed: political processes tend to determine which knowledge is given attention and assimilated by those making water policy.*

Figure 2.5 Hard-rock aquifer scenario to illustrate the impact on groundwater resources of over-abstraction



Pre-1960s: agriculture primarily rainfed with limited groundwaterabstraction for irrigation.

1960s/1970s: groundwater developed in push to increase agricultural production

1980s:ratesofgroundwaterabstraction and number of wells increasing. Abstraction significantly greater than rainfall, causing storage of aquifer to gradually decline. Where farmers are financiallyable,wellsaredeepened,but onlyasfarasthebaseoftheweathered zone.

1980s/1990s: still in groundwater development phase. Storage of the shallow aquifer still declining. Where farmers are financially able, boreholes drilled in base of large-diameter wells (dug-cum-borewells) in hope of intersecting fracture zones in the bedrock, but not always successful. Yieldsverydependent on recent years' rainfall.

1990s/2000s: farmers, or in some cases,groupsoffarmers,drillboreholes in search of groundwater, but with limited success.Agricultural production declining.

2.2.2 Institutional needs and the issue of political feasibility

In addition to the scientific and technical considerations discussed in the previous section, conventional approaches make assumptions about the ability of management organisations to influence demand and supply. More specifically, it is assumed that:

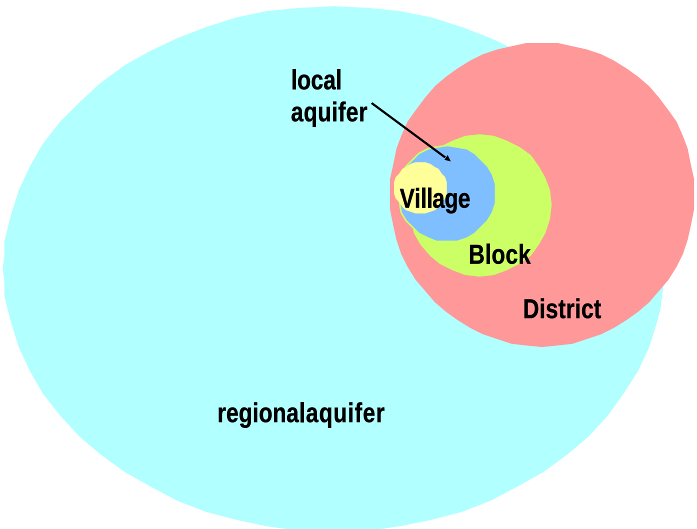
- Management organisations can be created with the authority and ability to directly influence supply and extraction at the level of hydrological units;
- Mechanisms exist for financing the activities of such management organisations;
- Related to this, the necessary technical, legal and economic levers are in-place to manipulate supply and demand.

The above issues are absolutely central in the Indian context. Let us take each in turn.

Firstly, the development of Management Organisations. As a substantial literature over the past decade makes clear, organisations capable of functioning at the intermediate geographical scale required for aquifer management are not common (Moench 1994a; Moench 1996). Even in hard-rock areas where groundwater flow regimes can be relatively localised, hydrologically interconnected zones often extend under multiple villages. In alluvial aquifers, such as the Mahesana Basin in Gujarat, the area overlying a single aquifer may contain thousands of villages. As a result, the question of whether management organisations can be created at the level of aquifers is a significant one (Figure 2.6).

Given the necessary political will, governmental organisations for groundwater management can be established in high-priority locations. The Central Ground Water Authority has already done this in Delhi and authorities have assumed a monitoring role over some aquifers near Chennai. This authority has the ability to notify areas for management based upon criteria such as the emergence of clear overdraft concerns. Once an area has been notified, the authority has the formal power to regulate activities such as well drilling and to mandate registration of all wells. However, as far as the authors are aware, the monitoring and enforcement of new controls has yet to begin. As a result, the verdict is not yet in on whether enforcement is viable, even in high-priority areas with relatively homogeneous aquifers and widely shared interests.

Figure 2.6 Aquifer versus institutional scale



It remains uncertain whether notification of areas for intensive management through groundwater management authorities will prove viable away from major urban centres or other particularly high-priority locations. Similar state approaches across Gujarat, Rajasthan, or other states where aquifers are threatened, appear unrealistic. Many of the activities underpinning conventional approaches are regulatory and involve restrictions on wells or water uses. Such interventions are bound to be politically unpopular. More than 60 per cent of India's population depends on agriculture and rural voters are central to the political stability of governments at the state and central levels. Since relations between rural residents and the state bureaucracy are often characterised by mistrust and conflict, politicians may be reluctant to create new regulatory organisations unless demand for them is sufficiently high among those subject to regulation. As a result, *it seems highly unlikely that governmental organisations can be formed for groundwater management in many of the rural areas where overdraft problems are now emerging.*

A tanker collects water from a farmer for use in the textile factories of Coimbatore

Secondly, the administrative burden associated with groundwater management organisations should not be underestimated. At present most states in India are running budget deficits and there is tremendous pressure to reduce the size of the bureaucracy. As a result, the creation and staffing of new governmental management organisations finds little support from those in charge of state budgets. Obtaining governmental financing for local management organisations faces similar problems. While donor financing could be obtained for pilot initiatives, there are currently no alternative models for financing groundwater management activities on a long-term basis. In locations such as the western USA, water districts are generally governed through user-elected boards of directors and have quasi-governmental powers of taxation, which they use as their main source of revenue. Such mechanisms are not common in India and the financing of management organisations remains to be worked out.

Thirdly, conventional approaches to groundwater management rely heavily on *the ability to influence, or regulate groundwater demand*. This can be achieved directly by establishing legal or administrative controls over use. Alternatively, it can be achieved indirectly by manipulating the wider economic signals to which groundwater users respond. Both approaches have been widely discussed in India in relation to groundwater legislation, power supply and pricing policies. The limitations facing groundwater management through power supply and pricing policies are discussed in Box 2.5. In short, the types of changes required to significantly reduce groundwater extraction have proved politically impossible to implement. This is also the case with groundwater legislation. Proposals for state regulation of groundwater have been present in India since the mid-1970s (Box 2.5). Despite the powers such proposals would confer on existing government departments, resistance from the public and analysts has beensubstantial.Inthecontextofsurfaceirrigationmanagement, regulation has proved problematic. As Vaidynathan stated over a decade ago, often "system managers ... have no effective power to enforce the rules or the penalties for violating those rules" (Vaidyanathan, 1991, p. 19). Furthermore, as B.D. Dhawan commented on groundwater regulations when they were passed in Gujarat in the 1980s: "there is little hope for effective implementation of such laws which are inherently difficult to enforce in the Indian conditions of small land holdings, inadequate administrative set-up in thecountryside,andanerodedstateof ethics."(Dhawan1989,p.9).

Twodieselenginespumpingoutwaterfromadugwellinthe Arwaribasin,Rajasthan

The comments above do not just reflect the perspectives of those outside the state.Resistancetothecreationofsuchregulatorybodieshasbeensubstantial even within the state and central groundwater bureaucracies, which would stand to assume new powers. Asmanyindividualsin such organisations have pointed out to the authors over the last decade, existing state and central groundwater organisations were set up to develop the resource base, not directly manage it. The Central Ground Water Board-Central Ground Water Authority has a small scientific staff in Delhi and a limited number of regional offices. State groundwater departments, or their equivalents, generally have a construction wing specialised in groundwater drilling and a small staff of hydrologists whose task has been to evaluate and monitor the resource base. The groundwater bureaucracy has little if any physical presence even at the district to say nothing of block, village or ultimate farm levels where groundwaterisactuallyused.Simply surveying thenumberofoperationalwells would be a mammoth task for the present bureaucracy. Actually monitoring groundwater usefromthemillionsofwellsscatteredamong India's fragmented landholdings is far beyond its capacity. Realigning the groundwater bureaucracies from a development-centred approach to a management-focussedonehasbegunbutthisisalong-terminitiative.

While the limitations discussed above on conventional groundwater management through the existing bureaucracy are clear, it is far from certain how thesemightchangewithcommunity-basedapproaches.Thisisexploredin detailinthenextchapter.

Box 2.5 Indirect influences on groundwater use: debates around power pricing

Policies governing the pricing of power and electricity supply offer a powerful means of indirectly managing groundwater and energy use, especially considering that Indian farmers have access to subsidised electricity amounting to US$ 4.5-5 billion/year to pump 1.5×10^{11} m^3 of water for irrigation (Shah et al., 2003a). The linkages between power pricing policies and over-development of groundwater have been widely discussed for over a decade in India (Arora & Kumar, 1993; Malik, 1993; Nagaraj & Chandrakanth, 1993). While it is beyond the scope of this document to summarise the extensive debates on power pricing, they are of direct relevance for conventional approaches to groundwater management and so are highlighted here.

Most states extract a low, flat-rate fee for irrigation power based on pump horsepower. This tariff structure has long been recognised as a strong incentive for inefficient water use and over-development (Moench, 1991). Many groups, including the World Bank, have advocated shifting to a consumption-based structure and removing or reducing subsidies as essential first steps toward addressing groundwater over-development problems and cutting the massive losses incurred by state electricity boards (World Bank and Ministry of Water Resources-Government of India 1998; World Bank Study Team 2001).

While price reforms have been widely advocated for over a decade, actual reforms have proved politically difficult to implement. Some states have made some progress in charging farmers for powering their irrigation pumps. However, the positive impacts on environmentally sensitive groundwater development and the negative impacts on the profitability of crop production are as yet unclear. In this context, while pricing reform may occur, it is unlikely to be tailored to potential opportunities for indirect regulation of groundwater extraction.

Despite the clear relationship between subsidies and groundwater development, it is far from clear that indirect regulation via changes in power pricing would result in more sustainable levels of groundwater use. Analyses over the past decade indicate that the returns from groundwater irrigation often outweigh the disincentives resulting from changes in power pricing and such changes therefore have a limited impact on the overall volume extracted (Moench 1995; Kumar and Singh 2001). In addition, it is difficult to tailor pricing policies to meet groundwater management needs in specific areas. Groundwater levels have been rising in canal command areas, increasing the risk of waterlogging. Yet overdraft occurs in nearby areas. Pricing policies may therefore help to reduce groundwater overdraft in certain areas only to exacerbate the risks of waterlogging in others.

The experience in virtually all case study areas suggests that subsidies are not the only, or even the main, factor contributing to over-abstraction. The amount of water pumped from a well depends not only on the cost of pumping but on the number of hours of electricity available over the period of a week or even longer. As Shah et al. (2000) admit, sustaining a prosperous groundwater economy would depend as much on proactive and imaginative rationing of electric supply to agriculture as on the reliability of this supply.

Finally, pricing policies for power affect all agricultural power use, not just groundwater pumping. Changing the pricing structure to manipulate groundwater demand would simultaneously affect many other agricultural activities, especially when the question of whether to charge a price or a tax for electricity remains unanswered.

Overall, major limitations exist for indirect regulation of groundwater extraction through economic mechanisms. Although it is beyond the scope of this study to discuss in detail the energy-groundwater nexus, it is clear that a wide variety of factors influence the economics of groundwater extraction. It is difficult to tailor these to meet the specific needs emerging in any given management area.

2.3 Summarising the limitations of conventional management

Conventional approaches to groundwater management face formidable challenges.

Firstly is the fact that policy operates in a climate of scientific uncertainty due to the fundamental gaps that remain in hydrogeological data and our understanding of aquifer systems. Hydrological data exist only for short periods of record and, although monitoring continues, the gaps in data will take decades to rectify. The relevance of historical data as a tool for predicting future conditions is uncertain and is made more so by the climatic variability and change that the world is now experiencing, thus further weakening the confidence we have in our ability to manage resources sustainably.

Extracting the juice from sugarcane

Available aquifer-based information, at this stage, is too generic to be useful in effective decision making. Scientists are as yet unable to quantify flows through groundwater systems or estimate key elements of the mass balance equation determining water availability. These gaps in scientific information limit our ability to define volumetric water rights, for example, in a way that directly relates to aquifer conditions - even assuming that users could be first registered and metered.

Secondly, state-regulatory or command and control approaches face major institutional and political obstacles that limit their applicability. State organisations have few practical levers at their disposal to influence groundwater demand directly. Devising and implementing a new suite of economic and regulatory remedies at the scale required is a long-term goal rather than a short- or medium-term solution. Moreover, while rural livelihoods are still intimately bound-up in groundwater-based economies, politicians will remain reluctant to introduce reforms which threaten, or are perceived to challenge, long-established use patterns.

Conventional groundwater management has limitations but windows of opportunity clearly exist

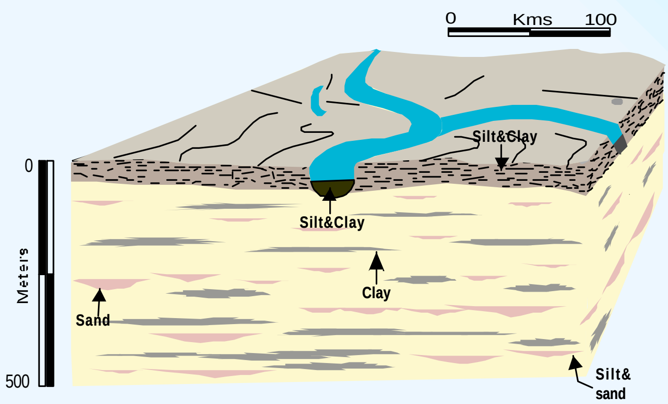
In summary then, the report clearly sees constraints in the application of conventional groundwater management approaches, but recognises windows of opportunity to pursue such approaches in controlled situations such as the following.

- At the aquifer scale: in strategic, relatively homogenous and well understood aquifers underlying urban areas, state management would be supported by politically influential populations and the tentative steps towards well registration and drilling control now taking place could be extended to volumetrically-defined licensing and other control measures.
- At watershed scale: in areas with enough information about aquifer heterogeneity, recharge and abstraction and where it is feasible to pilot further action on managing groundwater demand.

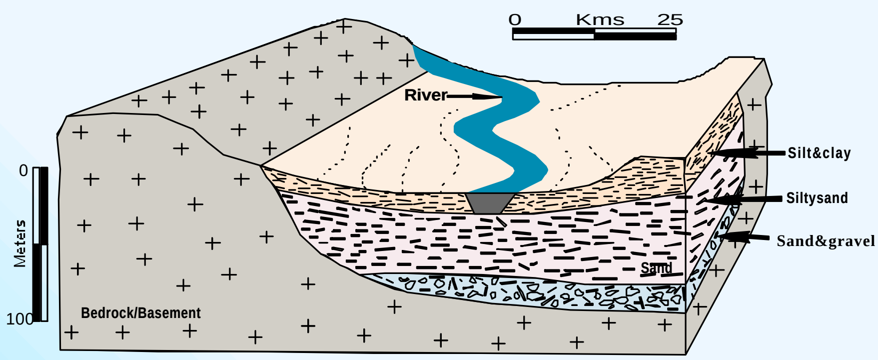
- In an extremely conducive energy environment where quality 'power' supply is balanced by a viable system of metering or rationing. Such a system ought to emphasise electricity use as much as groundwater use from the underlying aquifers.

Beyond such limited environments, direct influence over groundwater conditions is likely to be partial. Politically popular interventions (such as the construction of recharge structures) are likely to prove viable, while other interventions (typically those involving regulation or other initiatives to change demand) are difficult and unlikely to address the issue of groundwater overdraft directly. This all leaves large areas where conventional groundwater management approaches are unlikely to prove capable of addressing emerging overdraft problems. As a result, it is important to revisit the foundations on which conventional approaches to groundwater management are based. In particular, re-defining the objectives of management may help identify avenues for meeting core objectives when conventional management approaches prove difficult to implement.

Figure 2.7 Regional and local groundwater occurrence in alluvial sediments



Regional alluvial systems can extend for 10s of km and may be several hundred metres thick



Shallow alluvial systems overlying hardrock

3

Community-based responses

3. Community-based responses

It is often suggested that, where market and state are both inefficient, there is a strong case for strengthening community organisations by creating institutions that can manage common pool resources, or CPRs (Chopra et al., 1990). Specifically in favour of common property management is the argument that "...provided rules and regulations for monitoring and enforcement exist, common property regimes are efficient because they allow for economies of scale and access - unlike private property - and for ecologically sensitive management unlike state management, which is too distant" (Wade, 1988).

In this section of the report we explore whether community or user group management of groundwater can provide a practical alternative to conventional approaches. In other words, can self-regulation by groundwater users overcome the political, technical and institutional hurdles that make conventional approaches so difficult to implement. We begin by looking briefly at the political and institutional context in which community-based approaches have come to the fore, focusing particularly on the decentralisation agenda. Since 'the community' is at the centre of discussions about decentralised natural resource management, we then summarise - and question - some of the assumptions that underpin community-based approaches generally, and community-based collective action in particular. Drawing on these contextual insights and findings from the case studies, we then discuss the factors that appear important in initiating, shaping and sustaining groundwater management institutions.

3.1 Community-based management and the decentralisation agenda

A variety of approaches have been employed for implementing natural resource management activities in India, with varying degrees of responsibility resting with the state, local government, development agencies, NGOs and local people. A dominant institutional theme emerging over the past five years has been decentralisation, in tandem with efforts to promote a more 'bottom-up', participatory planning process (Carney and Farrington, 1998). As the poor are disproportionately dependent on common pool resources, so the argument goes, improvements in decentralised management - whether in equity of rights and responsibilities, in resource productivity, or in its sustainability - can contribute substantially to their livelihoods.

Cooling off in a check dam

The consensus which underpins this has been termed 'the community based sustainable development consensus' by Leach et al. (1997), and the 'new traditionalist discourse' by Singh a et al. (1997). In India, however, political and administrative decentralisation has been relatively recent (Box 3.1). The conventional view until the late 1980s was that rural communities lacked the necessary knowledge and self-restraint to be entrusted with the control of natural resources, and the administration of property rights.[4] The intervention of the state in these duties was therefore required, with government decision-making forming the practical basis and ideological justification for environmental policy.

Women collecting drinking water from a well in Samrapur village, Satlasana Taluka

Evidence of clear policy change in the *water sector* came about firstly in 1987, with the publication of the National Water Policy (NWP). The NWP aimed to develop a national consensus on a broad policy framework for water management. The NWP calls for a holistic, integrated and basin-orientated approach to water management, emphasising decentralisation and greater participation in water management decision-making. Concerning groundwater 'management', however, principles have been operationalised more through demand-led approaches to the provision of rural (domestic) water supplies, and through the 'Common Guidelines'[5] on watershed development, which emphasise decentralised partnership arrangements and user group participation in broad service provision. Management has not been interpreted in terms of developing locally agreed controls on groundwater access and abstraction through state/civil society/user group partnership arrangements, or through user groups alone.

Groundwater management is not interpreted in terms of developing locally agreed controls

Nonetheless, reform in all of these sub-sectors, and a renewed emphasis on collective action and user participation more generally, has highlighted the importance of common pool resource groups. It therefore seems vital that their strengths, weaknesses and the likely boundaries of their activity including the potential for self-regulation of groundwater use - should be well understood.

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[4] Property is usually defined as an exclusive right to possession, use or disposal of anything, and the social privilege to exclude others from use of the resource, or from deriving a benefit stream from the resource in question (Bromley, 1989).

[5] New Guidelines for Watershed Development (often referred to as 'the Common Guidelines') were issued in 1994 by the then Ministry of Rural Areas and Employment. They marked a significant shift in approach towards more participatory, decentralised decision making involving state/ civil society/community partnerships.

Box 3.1 The decentralisation context

Three distinct institutional approaches to decentralisation have varying legitimacy and potential capacity to contribute to livelihood 'improvements' (after Carney and Farrington, 1998; ODI, 2000).

***Administrative decentralisation**, involving the dispersal of tasks and responsibilities of higher levels of government to lower arenas. This includes the partial delegation of tasks formerly carried out by government to NGOs and the private sector at local (district and below) levels. In India, moves towards forming natural resource management partnerships with communities or 'user groups' for particular resources, are favoured. Administrative decentralisation is now the preferred institutional model for watershed development, for example, though local government involvement, through Panchayati Raj Institutions (PRI), is part of the mix.*

***Political decentralisation (devolution)**, or democratic decentralisation, refers to the transfer of resources, power and often tasks, to lower-level authorities, which are largely or wholly independent of higher levels of government and which are democratised in some way and to some degree. PRIs operate independently of government departments but draw on services from them. In India, where administrative decentralisation is now a core feature of watershed development, growing attention is focusing on the interface with political decentralisation through the Panchayati Raj local government reforms, and particularly the role of Gram Panchayats. Under the 73rd Amendment of the constitution, Panchayats have been assigned a wide array of shared functions with respect to economic development and social justice. These include the management of natural resources, such as water, and the provision of drinking water, although water supply and sanitation programmes are also heavily loaded with processes of administrative decentralisation, as described above. However, the emergence of Panchayats as actors in natural resource management is still at a nascent stage, and their ability to make a serious engagement would seem compromised by their limited technical capacity and financial autonomy. As a result, Panchayats have generally not moved beyond infrastructural targets (building roads, ponds and schools) to management.*

*Decentralised approaches also need to consider **'self'-initiated resource user groups that are local, rather than decentralised**. The Comman Project case studies highlight some of the tensions that can arise when such groups are seen to challenge the power or interests of the state, even when the state apparatus is supposed to facilitate, rather than control or undermine. In the Arwari River Basin, for example, tensions between local communities, their NGO 'supporter', Tarun Bharat Sangh (TBS), and the state government have boiled over on a number of occasions. Here, the activities of TBS in supporting community-based natural resource management, including efforts to conserve the benefits of groundwater recharge through restrictions on crop choice, have deliberately not included partnerships with administrative and political bodies.*

3.2 The community and collective action

Decentralisation and community-based management makes certain assumptions about the nature and interests of 'the community', and the nature of its dependency on natural resources such as groundwater. In particular, questions concern the role of natural resources in community livelihood strategies; the factors that influence - positively and negatively - collective action; the operation of social capital; and the ways in which local communities are integrated within wider political and economic structures (ODI, 2000).

What are these assumptions, and what is their rationale?

- *First*, the community is defined by physical, location-specific parameters. Specifically, it is often implicitly assumed to be a small, static, territorially-bound unit in which people have repeated face-to-face interactions, and in which shared norms and patterns of reciprocity and exchange promote shared understanding, and facilitate community action.
- *Second*, the connotation of community is generally of a small, harmonious group with internal mechanisms for fairly equitable conflict resolution. A positive relationship between the community and natural resource management is typically drawn. This traditionalist, or populist view, holds that the meeting of local subsistence needs should be sufficient motivation for community-level collective action.
- A *third* critical assumption is that the community has an identifiable relationship to a particular resource which excludes others outside of the community. In particular, the community is assumed to be mutually vulnerable, and mutually dependent, because of the centrality of resource use in supporting livelihoods (Mearns, 1995).

Starting from the assumption that people are not necessarily caught in a commons tragedy or a trap, the Comman Project research poses a key question: under what circumstances and conditions can groundwater users dynamically and positively shape economic and social institutions to arrive at local, cooperative solutions to problems of resource use and allocation?

An old tank near Pune now almost totally silted-up

Repeated attempts to compare and contrast collective action-common property (see Box 3.2) experiences from around the world suggest some indicators. Drawing on the international literature summarised on the Comman Project (Comman, 2005) and case study findings, we attempt to pinpoint the factors that appear relevant for groundwater management, drawing a distinction between:

- Factors affecting the initial feasibility of defining and establishing management groups with effective control over resources. These concern the resource-user interface, the characteristics of the community itself and the wider socio-economic and political arena in which it operates. These are termed *first order conditions*.
- Factors affecting the operationalisation of collective management, including the ability to define and operate rules and norms, monitoring arrangements and sanctions for non-compliance. These are termed *second order*

conditions. They are clearly influencedbythefirstorderconditions, but relate moretothewayinwhichgroupmanagementoperates.

Thesefactorsarediscussedfurtherbelow,andcomparedacrosscasestudiesin summary forminTable3.2.

Box 3.2 Common property defined: local management structures forcommonpoolresources

A common property regime is constituted by a well-defined group of users, a well defined resource that the group will use and manage, and a set of institutionalarrangementsthatdefineeachoftheabove.Thereshouldberules of use for the resource in question, rules for conflict resolution and the distributionofbenefitstreams,andfinallymechanismsforchangingtherules ofuse(Bromley,1989).

Common property should thereforebeviewedasaparticulartypeof socially constructed property relationship. It has been variously defined but essentiallyconsistsofa'distributionofrightsinresources,inwhichanumber of owners are co-equal in their rights to use the resource' (Ciriacy-Wantrup andBishop, 1975).Thisimpliesthatpotentialusersareexcluded.Indeedthe wholeconcept of property is rendered empty without the featureofexclusion hencethedistinctionbetweencommonpropertyregimesandsituationsofopen access,inwhichthereisnoexclusion,andhencenoproperty.Thefeasibilityof excluding orlimiting use bypotential beneficiaries is derived both from the physical attributesofthe resource, and fromthepropertyrightsdefined for it (BeckerandOstrom,1995).

3.3 Lessons from the case studies

3.3.1Initialobservations

The locations and research questions addressed by the Comman Project case studies are described in Section 1.1. Table 3.1 summarises aspects of the settingsforeachofthedetailedcasestudies.

Beforeexaminingspecificfactorsthat shape the opportunities and constraints usersfaceindevelopingandsustaininggroupmanagementinitiatives,wemake some more general observations. Below we compare groundwater management experiences across the case studies, drawing out important similarities and differences. In addition to the three detailed case studies, experiences from the Pani Panchayat reconnaissancecasestudyareincluded.

Symptomsand responsesto groundwater overdraftvary despiteunderlying commoncauses

First, while the underlying causes of groundwater overdraft are commonbetweencasestudies,symptomsandresponsesvary.Inall cases, well yields have declined to varying degrees, according to (a) thedegreeofgroundwaterdevelopmentthathastakenplace,(b)thestorageand transmission capacitiesoftheaquiferand(c)therainfallpattern,these factors having a degree of interdependence. For example, two villages were studied as partoftheCommanProjectintheCoimbatoreareaofTamilNadu.Thedepthof weathering of the underlying hard-rock is quite different in each village (see Section 3.3.2). Although well yields are declining, one of the villages is underlain by a more deeply weathered aquifer, which has a higher storage and permeability. Farmers there are still exploring for and developing groundwater. In the village with the shallower weathered profile, well yields have declined from unsustainable levels in the 1990s. There is little point to further exploration due to the limited storage of the aquifer.

The owners of this brick-making business no longer use agriculture as their main source of income.

These changes in hydrogeological conditions can be traced through to their impacts on livelihoods, though cause-effect relationships are not always clear-cut. In the case study villages of Satlasana Taluka, for example, the incomes of many households have declined as returns from groundwater-based agriculture have fallen with falling water levels (Box 3.3). People have coped by diversifying agriculture and livelihoods. In Coimbatore, on the other hand, the diversification is not merely a coping strategy (Box 3.4). Shifts out of agriculture are occurring not just as a result of the 'push' of a declining groundwater economy but because of the 'pull' of higher, more secure, incomes on offer in the rural non-farm and urban economies.

Secondly, community-*level* initiatives in watershed development and related activities are being conducted in each of the case study areas, based in part on the establishment of user groups, with and without the involvement of administrative and Panchayat Raj Institutions. Watershed development initiatives all emphasise enhanced recharge of groundwater, and a range of other farm and non-farm interventions. The local benefits that watershed development programmes can bring are not in dispute here; what is less clear is the extent to which they are attributable to changes in groundwater conditions, as opposed to enhanced soil moisture retention and farming practices. Only in the Arwari River Basin and Pani Panchayat schemes has *group* mobilisation around *demand-management objectives* been attempted, and then as a complement to supply-side activities. In the case study villages of Satlasana, there is rich experience of community-mobilisation around various natural resource management and harvesting objectives, including joint forestry management. These now extend to consider watershed treatment and irrigation practices, but not (yet) *group* controls on groundwater *access, abstraction and use* to agreed management objectives (Box 3.5). The case study villages in Coimbatore are similar in this respect, though here there is no embedded NGO, and no experience of group management beyond that needed for government-financed watershed development.

Thirdly, in both the Pani Panchayat and Arwari cases, the role of an external civil society organisation has been instrumental in catalysing and sustaining collective action. In Satlasana too, VIKSAT (a local NGO) has played a fundamental role in building community awareness of, and interest in, natural resource management. In both the Satlasana and Arwari cases, village-level institutions are embedded in higher-level, federated institutions that help

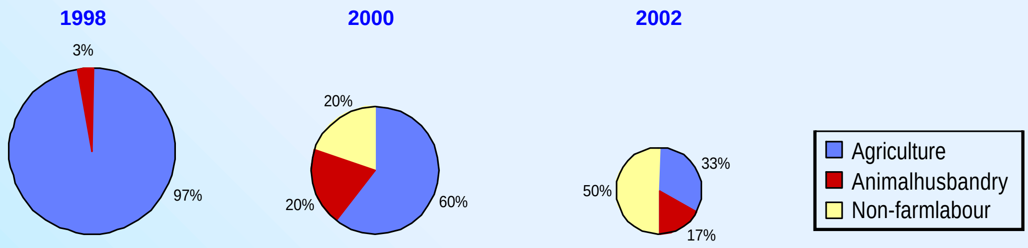
Box 3.3 Responses to groundwater overdraft and drought: a household story from the village of Bhanavas, Satlasana Taluka, Gujarat*

Vijesinh's story is typical of many in the Satlasana area of Gujarat, where households have had to come to terms with successive drought years, and a longer-term decline in groundwater availability and access.

Vijesinh has a family of five, including his mother, wife and two small children. He lives in a house with concrete roof, brick walls and cement floor, built six years ago when times were easier. The family owns 5 ha of land, which used to be cultivated and irrigated with a dug well. The well was deepened to 80 feet in 2000, when the water level dipped and could provide enough water only for 3-4 months and not enough to irrigate all five hectares. In 2001, Vijesinh excavated a 120-foot borehole in the dug well (creating a dug-cum-borewell), with Rs 35,000 borrowed from a local moneylender at 3 per cent interest/month. He has yet to repay the loan.

Prior to 1998 the first year of drought the household followed the general cropping pattern of the village: groundnut, bajra and castor during the monsoon; castor, wheat and fodder crops in winter; and bajra during the summer. From 1998, however, the family had to reduce the area under cultivation because of groundwater scarcity. The area under water-intensive wheat was cut back first. By 2002, the household was only able to grow 1.2 ha of wheat, 2.5 ha of castor and 1.2 ha of fodder (rajko). Vijesinh used to keep eight animals, including four buffaloes, two bullocks and two calves. In 2001, he sold two bullocks for Rs 5000, using the money to buy fodder for the remaining animals. However, the severe shortage of fodder that developed later in the year prompted further distress sales, and the calves were eventually sold for a token Rs500 just to ensure the survival of the cows. At the same time, Vijesinh attempted to supplement household income, and spread risk, by engaging in a variety of non-farm labouring activities, including construction work in nearby towns. Changes in family income over time are illustrated below.

Source of Income



Source: Mudrakartha et al., 2003. Note: the decreasing size of the pie charts illustrates a decline in the family's total income since 1998.

The charts indicate how, in the period since 1998, (a) overall household income has declined, (b) returns from agriculture have decreased significantly, and (c) dependence on animal husbandry (principally milk sales) and the non-farm economy has increased. What such charts do not show are the more subtle impacts on household welfare recorded during field work, including (particularly for poorer households) postponement of marriages and other important social functions and, for some caste groups, 'mass marriages' to reduce household expenditure.

These trends - agricultural contraction, shifts within agriculture, and shifts between the farm and non-farm economy - are seen across wealth groups within villages and across villages in Satlasana more generally. However, incentives and outcomes vary between different types of household. In Vijesinh's case, diversification has been adopted as a coping strategy to reduce risk and increase labour days. In other cases, although in the minority, diversification into non-farm activities has occurred because of the 'pull' of higher, more secure incomes on offer in the diamond-polishing industry and service sector, rather than 'push' factors related to changing groundwater conditions.

* *The collection of this information was partly supported by the project 'Adaptive strategies for responding to floods and droughts' www.i-s-e-t.org/asproject.*

of groundwater recharge structures; and (b) empower people by connecting them with a wider circle of allies with whom they can mount a more effective lobby.

Fourthly, while collective action on water conservation objectives is found in two of the case studies (see above), common property management is not. What is the distinction? The essence of common property is the power to exclude outsiders, such that CPRs become, in effect, private property for the group (Box 3.2). Yet in each case study, groundwater continues to be exploited under conditions of open access, with controls only on use. Hence in the Arwari Basin and Satlasana, informal norms restricting crop choice, and, indirectly, groundwater use, occur in a context of unrestricted groundwater access, with users continuing to drill new boreholes and deepen existing ones. Exclusion (to those outside the basin) operates solely through physical boundaries and is therefore 'leaky' - not through negotiated rights or norms defining who has, or does not have, 'property'.

Finally, it is difficult to identify and 'weight' the factors that are important in making group management feasible. For example, how does one gauge the relative importance of 'charismatic leadership' and 'enabling external conditions'? And to what extent can an abundance of one positive influence compensate for the absence of others? Below, we attempt to draw some conclusions, but note the importance of underlying principles, or issues, rather than specific institutional-resource models that 'work' or 'don't work'. Table 3.2 summarises these in relation to each of the case studies.

Table 3.1 Summary of the settings for the detailed case studies

Case study location	Lead partner organisation	Case study setting	Geology	Climate	No. households within study villages	Specific issues of interest
Satlasana, Gujarat	VIKSAT	Three remote villages in the foothills of the Aravalli Hills	Fractured and weathered granites	Single monsoon season average annual rainfall 603mm	475	Role of village federation in natural resource management, and potential for extension into groundwater management
Coimbatore District, Tamil Nadu	Tamil Nadu Agricultural University	Two villages ~30km to the east and north-west of the industrial city of Coimbatore	Basement rocks with differing thicknesses of weathering	Bimodal rainfall season -average annual rainfall 702mm	1850	Growth of the non-farm economy causes and outcomes
Arwari River Basin, Rajasthan	Institute of Development Studies	Six remote villages, located in the upper, middle and lower reaches of a well-defined river catchment of 1,055km^2	High relief basement rocks with varying thicknesses of sediment within valley bottoms	Single monsoon season -average annual rainfall ~500mm	1490	Effectiveness of Village Water Councils and Arwari River Parliament in controlling abstraction

Table 3.2 Factors affecting opportunities and constraints for group management of groundwater in the case study areas

First order conditions	Coimb	Satlas	Pani Panch	Arwari Basin
Interface between resource and management group influences who receives benefits and pays costs of group action				
Clearly defined boundaries	** to ***	**	**	***
Congruence between hydraulic unit and management group	* to ***	*	*	* to ***
Management group characteristics - affects ability to define groups of interest, management objectives and criteria for 'success'				
Similar technologies and investment in groundwater assets	*	*	**	*
Similar livelihood strategies and interests in resource conservation	*	*	**	**
Consensus on problem causes	*	**	**	**
Similar social-cultural characteristics	*	*	**	**
Prior experience of collective action	*	***	***	***
Nested institutions - helps ensure larger scale problems are addressed; helps absorb some of the transaction costs of group organisation				
Management groups nested within higher levels of organisation	*	***	***	***
Involvement of trusted civil society organisations	*	***	***	***
Strong leadership	*	***	***	***
External environment (policies, institutions, processes) defines the wider influences and constraints on group management				
Recognition of right to organise	?	**	**	*
Enabling legal framework	*	*	*	*
Wider economic signals encourage groundwater conservation	*	*	*	*
Second order conditions (applies only to existing group management schemes, i.e. Pani Panchayat and VWCs-AWP in Alwar)				
Rules/norms defining groundwater access and/or use entitlements defined and agreed	NA	NA	***	**
Monitoring and sanction arrangements exist for checking and enforcing compliance	NA	NA	**	***
Mechanisms/arenas exist for modifying rules/norms	NA	NA	**	**

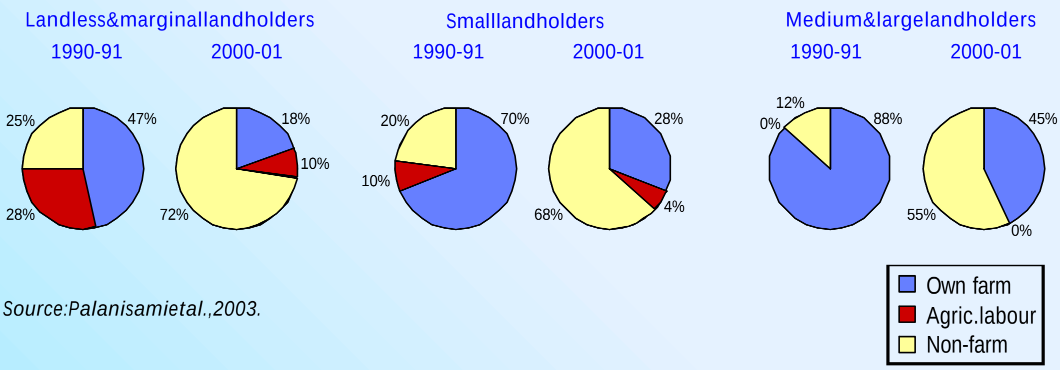
Notes: *** enabling/supportive; * disabling/unsupportive. Factors affecting the viability of collective action (first order conditions) helps shape the ability of users to define and agree rules/norms influencing user behaviour, monitor such rules/norms, apply sanctions and re-define rules/norms (second order conditions). In practice, the distinction is not clear-cut.

Box 3.4. Livelihood diversification in Coimbatore, Tamil Nadu

Understanding the range and dynamics of livelihood options, and the choices made by different groups within communities, is an essential starting point for any evaluation of community interest in groundwater management. The Comman Project case studies highlight a diversity of livelihood strategies that are shifting in response to declining groundwater access and independently of it as new opportunities develop in the non-farm economy. These 'push' and 'pull' factors can create increasingly divergent interests in groundwater conservation, rather than a collective incentive to preserve stocks for shared, long-term livelihood strategies.

Evidence from Coimbatore illustrates how household and wider regional economies can change rapidly as urban-rural links and communications improve. Here, we see some of the positive drivers and outcomes of diversification, and how diversification and specialisation can occur at the same time but at different levels. In the villages of Kattampatti and Kodangipalayam, for example, many wealthy households have specialised in textile manufacture as congested urban centres out-source production. Poorer households - the landless and marginal farmers also appear to have benefited, with new labouring opportunities in the powerloom sheds providing a way of increasing household labour days and incomes and spreading risk. At the same time, the proportion of income derived from agriculture has declined. Poorer groups shift to cultivating less water-intensive crops, increasing rainfed agriculture and land left fallow. In summary then, the range of economic options has increased, with a shift away from employment and income dependence on agriculture across wealth groups:

Changes in household income over time: Kodangipalayam village, Coimbatore



Source: Palanisami et al., 2003.

In Satlasana (Box 3.3), on the other hand, the 'push' factors are more obvious, as some households are forced from irrigated agriculture (as land-holders and labourers) into animal husbandry and seasonal, and longer term, migration. At the same time, opportunities in the rural non-farm economy are 'pulling' others into diamond polishing and the service sector.

Box 3.5 Community institutions and household perceptions in Satlasana, Gujarat

The Comman Project studied the villages of Bhanavas, Nana Kothasana and Samrapur, in Satlasana Taluka, which sit in the foothills of the Aravalli Hills in the north-east of Gujarat. Farmers in this area traditionally practised rainfed agriculture, but changed to groundwater-irrigated agriculture in the 1980s and 1990s. However, the level of groundwater abstraction required to maintain the boom in irrigated agriculture was not sustainable and, since the mid-1990s, agricultural production has declined. The problems associated with reduced groundwater availability have been exacerbated by the drought of recent years. In response to declining agricultural production, people became more dependent on animal husbandry; this itself has become difficult during the drought due to the lack of fodder. With the loss of agriculture-based livelihoods, many have been forced to migrate to nearby districts for sharecropping and further, in search of non-farm employment.

VIKSAT has pioneered natural resource management through collective action in Gujarat since 1985, initially through joint forest management in Sabarkantha District. In 1993, VIKSAT moved into water resources, working with the Tree Grower's Cooperative Societies in 32 villages in the Gadhwada region of Mahesana District. In 1995 these 32 Societies joined to form a federation named the Gadhwada Jal Jamin Sanrakshan Sangh, which sets out to protect water and land in the Gadhwada region. The Gadhwada Sangh's initiatives in water initially focussed on individual economic decisions that impinged on sustainability of water resources but has recently, with the support of VIKSAT, been pushing an integrated approach to water resource management. The activities it promotes are those commonly undertaken in watershed development, including improved irrigation techniques, changing cropping patterns, the use of field bunds and the installation of check dams. However, even with two decades of involvement in the region, VIKSAT has made little progress in developing, with the community, norms that would limit access and withdrawal of groundwater. Some of the underlying reasons can be understood with reference to the table below, summarising household views on potential solutions to groundwater scarcity in the villages of Bhanavas, Nana Kothasana and Samrapur:

Household views on potential solutions to water shortage	*Number (%) N=29*	
Provision of community wells for irrigation	*13*	*(45%)*
Improvement in irrigation technology (sprinklers; drip etc)	*11*	*(38%)*
Further changes to cropping pattern (less water-intensive crops)	*9*	*(31%)*
Watershed treatment e.g. increasing no. of anicuts and med bandi	*5*	*(17%)*
Community (village)-level irrigation systems	*4*	*(14%)*
Community restrictions on groundwater pumping	*4*	*(14%)*
Secure water from outside sources	*4*	*(14%)*
Revival of traditional, communal irrigation systems e.g. tanks	*0*	*(0%)*

Source: Mudrakartha et al., 2003. Note: water shortage relates to groundwater for irrigation use only; drinking water supplies are piped in under the Dharoi Group Water Supply Scheme (Gujarat Water Supply and Sewerage Board)

Drawing on these results and the findings of more open-ended household and group discussions, several points emerge.

- *Firstly, the most popular, community-based option is the provision (by an external actor) of shared irrigation wells. However, these are viewed as additional to, rather than a substitute for, existing (private) wells. In other words an extension of groundwater access rather than a reallocation of existing supply.*
- *Secondly, community self-regulation is widely perceived as unrealistic in the absence of any regulatory framework, and certainly not favoured by those with most to lose in the short term particularly larger landholders with substantial 'sunk' investments in groundwater infra-structure. Indeed, the prevailing entitlement regime, in which landholders are free to draw as much water as they need, or can afford, is viewed as legitimate by those with and without access. Nonetheless, broad support for enabling regulation by the government was articulated (well spacing; well depths), under which the community could then take on some management control through a Samiti a village water council or cooperative.*
- *Thirdly, prior experience of new micro-irrigation technologies in the area (promoted by VIKSAT), and the fact that technological change does not involve painful water reallocation, helps explain the popularity of this option. However, VIKSAT recognises that conservation gains here are by no means assured: with no cap on pumping, farmers will not necessarily abstract less water (irrigated area may increase; crops may change).*

3.3.2 The interface between resource and management group

At the beginning of the project, a distinction was drawn between aquifer management and groundwater management. At a local, community level, therefore, a critical question is whether small parts of an aquifer (beneath the management group) can be effectively 'closed off' to outsiders, such that the groundwater conserved is largely accessible to the group alone. Case study findings and groundwater modelling suggests that the ability to exclude non-participants from management initiatives is difficult. Hydrogeological boundaries are not easy to define and, even in hard-rock environments where groundwater flows are limited, the likelihood that users will be able to capture the benefits that issue from their collective efforts, over limited geographical scales, is not assured.

Chapter 2 described the varying characteristics of aquifers: whereas some span many hundreds of kilometres in the case of the deep sedimentary basins; others, the result of the weathering of crystalline rocks such as granites or basalts, may span little more than a few hundred metres. This scale issue (Figure 3.1) has great relevance to the feasibility of local management of groundwater.

The need for congruence between natural resources and user group boundaries is generally recognised as a key component of common property regimes. Groundwater raises particular challenges in this respect: it is very difficult to know where the boundaries occur as groundwater is a hidden resource, and hydrogeological information - especially at a local level - is limited. We can say, however, that in most hydrogeological environments, aquifer boundaries encompass many communities, particularly in the case of large regional aquifers. A key question explored by the ComMan Project is whether small parts of an aquifer (beneath the user group) can be effectively 'closed off' to outsiders, such that the groundwater resources, *augmented and/or conserved*, are largely accessible to the user group alone.

Measures to augment groundwater resources are present across the case studies, and form a key component of most watershed development programmes in India. Recharge structures are designed to retard the flow of water over the land surface, with the aim of increasing infiltration. These structures range from field bunds and small check dams to major percolation ponds. Measures to conserve groundwater through less pumping for crop irrigation are less common. Measures include reducing the area and number of seasons of cropping; cultivating crops with lower water requirements and implementing more water-efficient irrigation methods, such as drip-irrigation. Within the case study areas, group restrictions on groundwater use (though not the right to abstract) are limited to the Arwari Basin and Pani Panchayat initiatives (see Boxes 3.6 and 3.7). The hypothesis is that by enhancing water recharge during the monsoon season, and/or by reducing abstraction during the growing seasons, an increased stock of groundwater (a

A check dam in a narrow steep-sided valley in the Arwari River Basin 'mound') can be created beneath the land of a group of users. This 'mound' can then be accessed later, perhaps to enable drinking water supplies to be maintained during the latter part of the dry season or as a buffer for subsequent years, when the rains could potentially fail. A key question, then, is whether this stock will remain in the control of the user group, or whether a significant proportion will simply flow away, moving off down the natural regional groundwater gradient, or be pumped away by those outside the group.

A Pani Panchayat scheme based on a surface water irrigation source. Boundaries to the resource are clear and to-date the scheme is successful

Some simple computer modelling was undertaken as part of the Comman Project to gain further insight into this question, using a simplified conceptual model of aquifer systems in India. The model simulates an aquifer with uniform hydraulic properties and depth. Modelling indicated that even under the most favourable conditions, a *significant proportion* of the water conserved at the scale of a village or group of villages would flow away from its control. The implication is that there must be some physical boundary to the flow of groundwater to ensure the water conserved by the user group is not lost and, therefore, that the user group boundary must be similar in scale to that of the boundary of the aquifer(s) underlying it.

Illustrations of this are given by two of the case studies (see Figure 3.*2*): the Arwari River Basin and the Pani Panchayats of Maharashtra. In the former case, an enclosed basin comprising a series of enclosed village-scale watersheds with well-defined geologies, creates natural and clearly identifiable hydraulic boundaries. These provide some degree of 'natural' exclusion. As a result individual villages, and the villages within the basin, are able to capture *some* of the benefits of both groundwater recharge and conservation, even though landowners are still able to drill new wells and deepen existing ones. No restrictions apply to accessing and pumping groundwater, so open access within the basin remains. In the Pani Panchayat area, however, physical exclusion is more difficult. The so-called user group (Pani Panchayat scheme) is small as compared to the aquifer it taps. As a result, those outside the scheme and not bound by group norms are able to 'free ride', pumping for themselves the conservation gains of others.

Measures to augment groundwater are more acceptable than those to conserve it

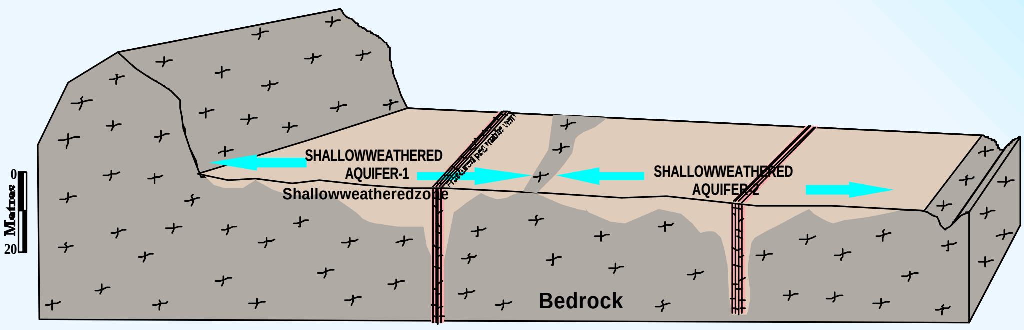
Clearly the simplifications made within the conceptual model used are great. Aquifers, in particular shallow, hard-rock, weathered-zone aquifers are not uniform in nature. In these geological environments, the lateral variability in the degree of weathering may be significant. Here, enhanced zones of weathering may exist that create relatively isolated pockets of aquifer, when the water-level falls below a certain depth. As a result, in these situations, individual farmers may be able to benefit to a degree from the measures they undertake to conserve water.

However, the variability of weathering within hard-rock aquifers is very difficult to predict or assess. For example, the two Comman Project case study sites in the Coimbatore area of Tamil Nadu, located 20 km apart, are both underlain by crystalline basement rocks. Due to the different mineralogy, grain size and structure of the rocks, the shallow weathered layer is quite different in nature at the two locations (see Figure 3.3). In Kodangipalayam the weathering is limited; the shallow aquifer is typically 10 m deep. In Kattampatty, it is typically 35 m deep. In Kodangipalayam, the aquifer is very patchy with outcrops seen in many locations; in Kattampatty, the aquifer extends laterally for up to kilometres and could be described as regional. The potential to ring-fence the water conserved would appear to be greater in Kodangipalayam, but even with detailed hydrogeological investigation, it would be difficult to assess to what degree.

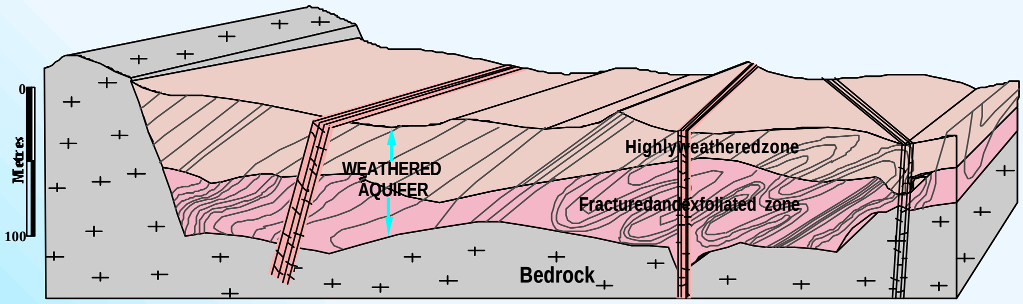
A high dam built across a steep valley in the Arwari River Basin

So, to summarise, the scale at which groundwater management must take place to be effective is highly dependent on the geology. Groundwater management requires that the boundaries of the resource be known. Even where this is possible, resource and institutional boundaries may not match. Where resource boundaries are large, it is challenging to scale-up user group initiatives to match, as the transactions costs of collective action increase with group size.

Figure 3.1 Local and regional aquifers in weathered basement rocks

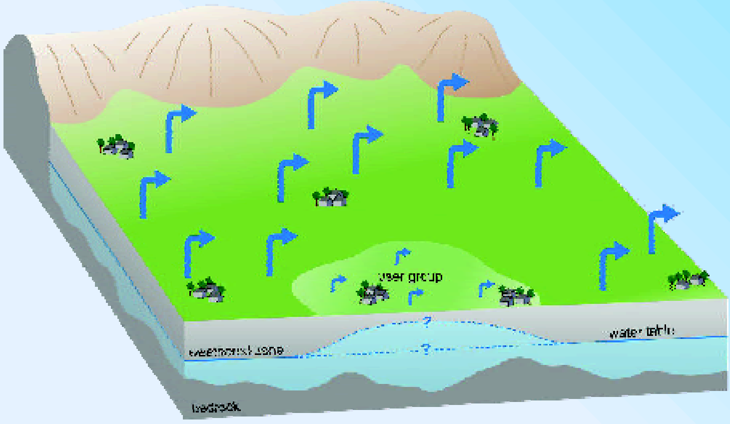


Conceptual diagram of localized groundwater occurrence: Kodangipalayam village, Coimbatore District

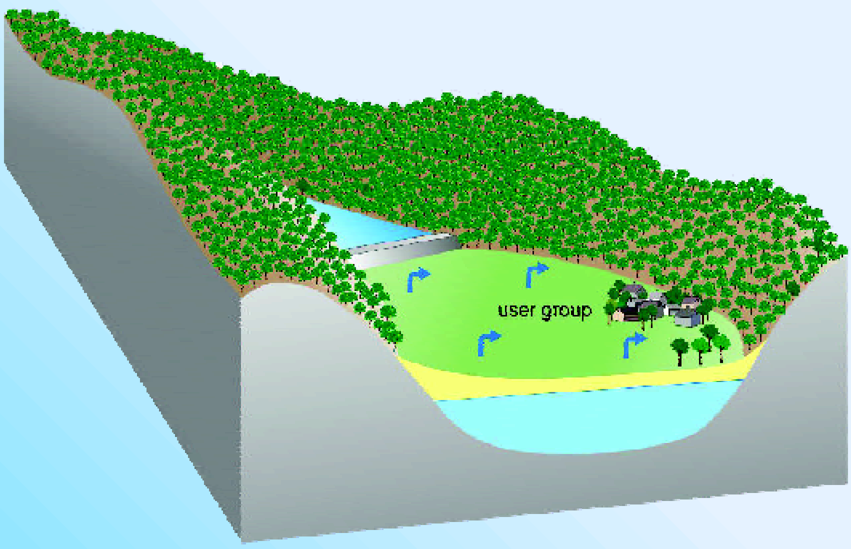


Conceptual diagram of regionalized groundwater occurrence: Kattampatty village, Coimbatore District

Figure 3.2 User group control of conserved groundwater resources

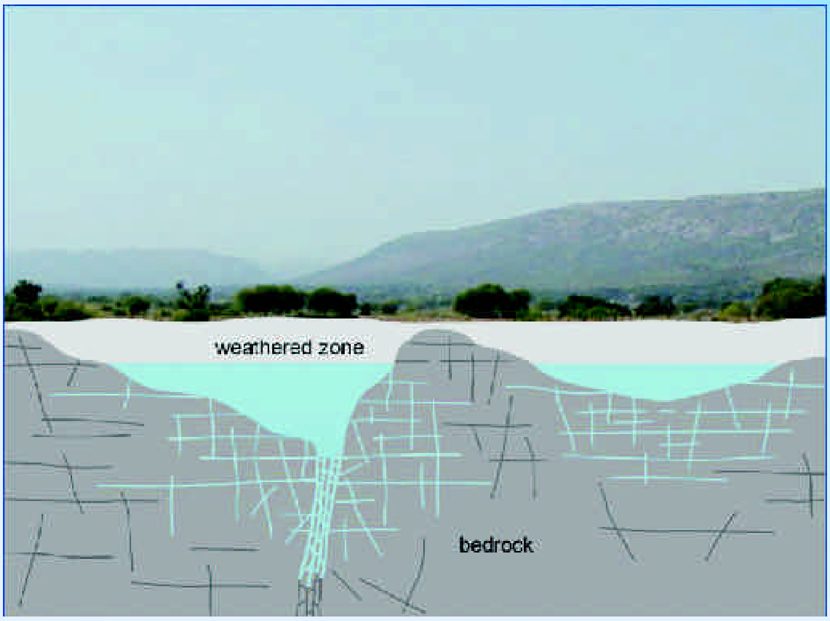


Havingdeveloped a set of norms to reduce groundwater abstraction and implemented measures to increase recharge, can one groundwater user group remain in control of the water they have conserved while those around continuetopumpheavily?Willa'mound'ofwaterdevelopbeneath the land for their future use, or willthiswatersimplyflowaway, becoming accessible to surroundingoutsiders? The results of the Comman Project suggest that in many geological settings it would be impossible for the group to retain exclusive control over the benefits of their conservation efforts(seethePaniPanchayatcasestudyvillageinBox3.7).



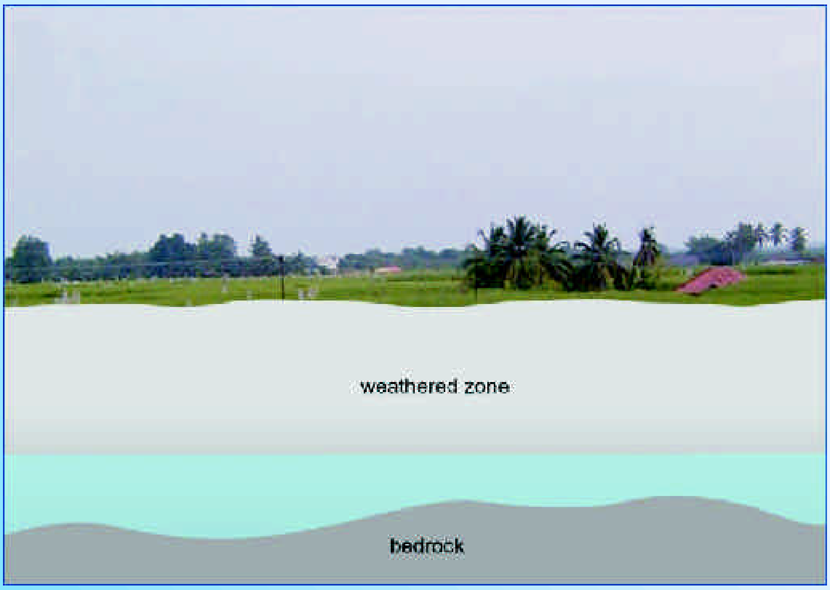
In the Arwari River Basin, the incised valleys in the upper reaches have natural boundaries to groundwater flow. They also form good sites for constructinghigh capacitycheck dams. Although groundwater islostfrom the village catchment by lateral flow down-gradient, the influence of abstractionbeyondthevillageboundaryisnotlikelytobesignificant.

Figure 3.3 Variability in the nature of the shallow weathered zone in hard-rock aquifers



Kodangipalayam area

Schematicdiagrams to illustrate the variability in the nature of the shallow weathered zone in hard-rock aquifers within tens of kilometres, as with the two case study villages in Coimbatore District



Kattampattyarea

3.3.3 Management group characteristics

The viability of user group management of groundwater ultimately depends on whether individuals within defined groups have a strong incentive to co-operate to achieve shared objectives. Individuals are more likely to switch from independent strategies to coordinated strategies when they are mutually vulnerable, and mutually dependent. The Comman Project case study findings suggest that communities consist of numerous configurations of interest, and that defining groups and management objectives is likely to be increasingly difficult as household economies and wider regional economies diversify.

The evolution of user-based solutions to common resource problems is often attributed to the existence of a community sharing a common goal or interest that cannot be reached or satisfied by individual action. International experience suggests that collective action is most likely when the community is *mutually vulnerable*, and *mutually dependent*. In other words, the more a group is dependent on groundwater to support shared livelihood strategies, and thus the greater the risk of non-cooperation, the greater the likelihood of collective action.

Our case study findings support this argument, providing a rough continuum of dependence and vulnerability. In the Arwari Basin, for example, livelihoods are still heavily dependent on groundwater. Most households own land and irrigate. The larger land-holders are increasingly commercial in their outlook, growing cash crops for nearby towns and cities - including Delhi - as transport and communication links improve. In the Pani Panchayat area agriculture similarly provides the mainstay of the local economy though, here too, shifts out of agriculture are occurring. In both cases, groups have succeeded in managing groundwater around broadly defined conservation objectives that support similar livelihood strategies. In the Arwari Basin, the NGO Tarun Bharat Sangh (TBS) defines *preconditions* for community support. These include the election of a Village Water Committee (VWC) to oversee construction activities and organise fund raising. Representatives from the VWC are then entitled to join the Arwari Water Parliament (AWP), where protocols on basin-wide natural resource management, including cropping restrictions indirectly limiting water use, are agreed (Box 3.6). In the Pani Panchayat case, a single, nodal institution (the NGO Gram Gourav Pratisthan GGP) also responds to community requests for assistance and sets preconditions for such assistance. However, conditionality does not extend to the establishment of village water councils or committees. Instead, individual households within a scheme agree to abide by a set of water allocation and cropping norms defined by GGP according to local hydrological and agro-economic conditions (Box 3.7).

A meeting of Gadhwada Jal Jamin Sanrakshan Sangh

In contrast to Arwari and, to a lesser extent the Pani Panchayat areas, significant livelihood shifts have occurred in the case study villages of

Box 3.6 Conserving the benefits of watershed treatment in the Arwari RiverBasin

The activities of the NGO, Tarun Bharat Sangh (TBS) in the Arwari River Basin, Rajasthan, have received a great deal of attention over recent years. TBS began working in the basin in 1985, supporting the construction and rehabilitation of traditional water harvesting structures called Johads (small check dams), as well as field bunding and other watershed 'treatment' activities. Around 300 structures have now been constructed or rehabilitated within a basin of approximately 1050 km^2. Specific impacts reported include: the return of perennial flows in the Arwari River; positive outcomes for rural livelihoods across wealth groups; a reversal of out-migration, and a new sense of intra and inter-community empowerment, following the formation of village water councils (VWCs) and, at the basin level, the Arwari Water Parliament (AWP) in 1998.

The Arwari Water Parliament

The AWP is an informal, non-government forum set up in 1998 (with the support of TBS) to address wider inter-village issues arising from watershed development in the basin, and to promote community control and management of water, land and forest resources more generally (Rathore, 2003). The full parliament meets twice yearly, with representation from the basin's 70 villages (through village water committees - VWCs), and a limited external membership of 'experts' and academics. The parliament discusses, and then agrees, informal rules restricting individual behaviour, which are then conveyed downwards to individual villages through elected VWC representatives. These are then discussed and implemented at village level entirely through social or moral pressure. Informal norms are discussed, and if necessary revised, at each parliamentary meeting. They currently include:

- *A ban on the sale of fish produced in the water stored behind anicuts or johads*
- *A ban on the use of pumps to lift surface water stored in anicuts*
- *Agreement not to sell land for industrial activity that might compromise collective water resource management efforts*
- *Restrictions on the use of chemical fertiliser*
- *Restrictions on crop choice, specifically limiting production of cotton and sugarcane to household use only, not commercial sale. Field work suggests this restriction is adhered to widely.*

Demand management lessons

TBS has worked in the Arwari basin area for many years, supporting and encouraging community self-help. It is a trusted organisation, with a legitimate and charismatic leadership. Importantly, watershed activities began with support for the building of treatment structures, creating a tangible entry point for community mobilisation. Moreover, the hydrogeological and topographic characteristics of the basin, and the micro-watersheds within it, created conditions in which the benefits of group action around recharge could be quickly appreciated. Only once these activities were firmly established was the issue of demand raised, and then through a higher level organisation the AWP ensuring that VWC members were involved, and consulted, in decision-making. This has helped create a climate of mutual assurance: users feel confident that if they abide by the rules, others will do likewise.

It needs to be emphasised that, thus far, the groundwater restrictions agreed extend only as far as crop choice. Crops are visible, and it is easy to see whether other users are abiding by the parliament's code. Neither the VWCs, the AWP nor TBS has yet sought to extend these voluntary codes to include direct restrictions on well drilling and pumping. These would be much more contentious, and difficult to monitor. So, in spite of the well-publicised benefits of TBS's work in the area, investment in groundwater infrastructure and pumping is still increasing. Indeed firm conclusions about the impact of watershed development on groundwater conditions remain difficult to draw in the absence of systematic, long-term monitoring. A tentative conclusion is that benefits may be attributable more to improvements in soil moisture retention and land improvement, rather than a balancing of groundwater demand and supply. This has led some to conclude that, without further restrictions on groundwater pumping, the benefits of watershed treatment in the area may not be sustainable (Rathore, 2003).

Box 3.7 The Pani Panchayat initiative: decoupling land and water rights

In the early 1970s, Naigaon village, located in a drought-prone area of Pune District, Maharashtra, saw the beginning of an initiative in water rights and distribution, called Pani Panchayat. It was initiated by the late Mr Vilasrao Salunkhe, and has since been carried forward through the NGO Gram Gaurav Pratisthan (GGP). It originally involved some 40 participants. Water security for every family, including the landless, was the goal of the experiment. Mr. Salunkhe believed that watershed planning can only be successful within low rainfall environments if drinking water is prioritised and agricultural uses restricted to the cultivation of less water-intensive crops.

There are currently 25 schemes in place (Kulkarni et al, 2003). These schemes are based on either a groundwater or surface water communal source. Within a Pani Panchayat village, typically a third of the land area is brought under the control of the scheme. The purchase of land and the subsequent development of the scheme (e.g. well construction, terracing and bunding, purchase of pumps and pipework) is usually funded by GPP with 20 percent of the cost borne by the community. Hydrological parameters, such as groundwater level, surface water level and/or rainfall are used to assess the amount of water that can be distributed during the year for crop irrigation. At least in some schemes, external monitors are used to operate pumps and ensure the agreed norms are followed. GGP provides the role of external auditor and arbitrator.

The scheme is then managed on the following principles:

- *Land and water is distributed based on the number in each family involved, including the landless. Typically 1.2 ha of irrigated land is apportioned to each family member, and an upper limit of 1000 m^3 per capita per annum is provided (although the actual limit is decided upon the availability of water for a particular year).*
- *Only seasonal crops are irrigated. Water-intensive crops such as sugarcane are not permitted and irrigation is allowed only for 8 months.*
- *Water and land rights are not linked. Water rights rest with the scheme members' community and are not transferred with land sale.*

Notably the surface water schemes, which predominate in the higher rainfall zones are proving more successful. This may be partly because they are based on a source which is visible, making it easier to estimate the optimum distribution of water. The Naigaon model scheme, located in a very low rainfall zone of ~400 mm/a, is based on a single groundwater source. The Naigaon watershed is located on the Deccan basalts that occupy approximately 500,000 km^2 of India. The aquifer underlying Naigaon has relatively high storage and permeability for this type of hard rock. The scheme has survived several droughts successfully but is currently endangered by gradual deterioration of the surrounding environment. Although no major demographic changes are reported, there has been an enormous technical change, i.e. wells being deepened, converted to dug-cum-borewells and the introduction of deep borewells, and the conversion from diesel engines to electric pumpsets. This has meant a progressive increase in groundwater abstraction in the area surrounding Naigaon village, resulting in significant groundwater depletion effects being felt in the area and a decline in the water levels in the main Pani Panchayat communal well. The scheme clearly cannot operate in isolation from the surrounding communities.

Pani Panchayat schemes are initiated and operated under a range of other limitations, in particular the lack of official backing from the Government. This makes it difficult to obtain Government subsidies for the scheme (normally available for small and marginal farmers) and to obtain Government permission to dig community open or borewells (Kulkarni et al, 2003).

Coimbatore with the result that a broadly felt interest in groundwater conservationismoredifficulttodetect. Here,household incomes across wealth groups are increasingly drawn from activities in the non-farm economy which are less groundwater dependent, such as textiles, quarrying and brick production (see Box 3.4). The 'stake' that households have in the condition of groundwaterresourcesisthereforechanging,andwaning,astheabilitytobuild assets and incomes becomes less dependent on local groundwater. Note that such transitions do not necessarily result in lower groundwater use, as those remaining within the groundwater irrigation economy may be able to 'capture' more. In Coimbatore the positionisunclear: ontheonehand,theproportion of rainfed and fallow land is increasing; on the other, some larger landholders are increasing the proportion of water-intensive, commercial crops such as sugarcane. Overall, however, there is clearlyalong-termshiftintoamoremixedeconomy,lessconstrained by limited, local water budgets. In these circumstances, the long-term incentives for collective action around groundwater conservationobjectivesaremuchlessobvious.

Externalcatalysts areoften responsiblefor collective management

Drawing together insights from all of the case studies, but particularly those from Coimbatore and Satlasana, we would therefore argue that communities consist of members with (increasingly) different interests in groundwater conditions, and that numerous *configurations of interest* are possible. The particular constellation of interests or dependencies may include, or be based on:

- Different endowments of land and other assets (e.g. wells, pumps)affecting the type,intensityandscaleofirrigationneeds-andperceivedentitlements -forownconsumption,forincomegenerationand forwagelabour.
- The time horizons, or discount rates, of different groups: those who view groundwater conservation as an investment in future productivity; those whoviewconservationasameansof(indirectly)increasingopportunitiesfor wage labour intheagricultural sector; and those who have little interest in conservation (beyond perhaps assured drinking water supplies) because they have diversified into non-farm livelihoods that are less directly dependentonthenaturalresourcebase.
- Variability in access to different sources of drinking water: those with their own private groundwater sources; those dependent on communaldrinking water sources; those with a reliable externally-sourced piped alternative; and those with an intermittent externally-sourced water supply who may still be partially dependent on groundwater during periods in which piped waterisnotavailable.

The key point here is that the potential range of different interests can lead in different directions, making collective management arrangements difficult to negotiate and sustain. Difficulties are compounded by the prevailing entitlement regime, inwhichcustomarygroundwater rights (linked toland) are both entrenched and perceived as legitimate across wealth groups. Moreover, fragmentation of inherited land has resulted in more wells being constructed and the complication of the 'water rights' regime. Where limited collective management does occur (in the Arwari Basin, and under the Pani Panchayat initiatives), the catalyst has been external: *groups have not 'self-organised' in* the face of shared threats, or opportunities, and the *primary* objective of organisation has not been groundwater conservation.

3.3.4 Nested institutions and the external environment

Case study findings support the view that the 'nesting' of local institutions into a broader framework of larger-scale institutions can help reduce the transaction costs of collective action. Nesting can bring other benefits too, helping to empower groups in an environment that offers little support for demand management.

It is not only group-level characteristics, or group-resource interfaces, which affect management capability. Chapter 2 of this report discussed in some detail the constraints on groundwater management posed by the lack of clearly defined property rights to groundwater, and the resultant 'rule of capture' that prevails. This undermines both state-led approaches to groundwater management, based on regulatory control, and the community-based approaches discussed in this section.

To be effective, the ability to physically exclude potential beneficiaries (users) from 'mining' group-conserved groundwater should ideally be backed up by property rights that are legally defendable. This is clearly not the case in India at present, nor is it likely to be in the foreseeable future. So any demand management gains within the Arwari Basin, for example, depend on physical exclusion only. At the same time, however, landowners within the basin continue their investment in groundwater development. In the Pani Panchayat case, management gains are being undermined through 'leaky' physical boundaries as those outside the scattered schemes sink new wells and deepen existing ones. At the same time, cheap energy and credit (see Chapter 2) provide users with additional incentives to exploit, rather than conserve.

A Pani Panchayat well, where water levels have dropped due to groundwater overabstraction in surrounding areas

Within this 'disabling' external environment, the institutional arrangements developed in both the Pani Panchayat and Arwari areas have provided some much needed cement to group management. In both cases, the role of external civil society actors has been instrumental in catalysing and sustaining collective action. In Satlasana too, VIKSAT has played a vital role in building community awareness of and interest in natural resource management. In both the Arwari and Satlasana cases, village-level institutions are embedded in higher-level, federated institutions that serve a number of functions:

- They provide arenas through which the operational norms governing groundwater access and/or use at lower levels are set (Pani Panchayat and Arwari River Basin).

- They provide a mechanism for harmonising upstream-downstream conflicts arising from watershed development activities. So in the Arwari Basin, for example, the pumping of water pooled behind johads and anicuts - water which infiltrates to, and benefits, downstream users - has been prohibited by a basin-wide authority (the parliament), able to hear and reconcile the views of different users.
- They help empower people by connecting them with a wider circle of allies with whom they can mount a more effective lobby (Pani Panchayat, Arwari River Basin and Gadhwada Jal Jamin Sanrakshan Sangh in Satlasana case study).

3.3.5 Developing community based management in the case study areas

Drawing on the analysis above, key questions concern the viability of establishing group management initiatives in the case study areas where none currently exist, and the feasibility of strengthening and extending group management within and beyond those areas where limited self-regulation does exist. In Table 3.3 these questions are explored through an analysis of the potential or existing strengths and weaknesses of community-based initiatives in each area, and of the opportunities and constraints that might influence future development. This is termed a SWOT (strengths, weaknesses, opportunities, threats) analysis. In Chapter 4, arguments are developed further by widening the perspective beyond group management, to consider a range of both water and livelihoods-focussed responses to overdraft problems.

The preceding sections provide some explanation for why group management to address overdraft has not emerged in the Satlasana and Coimbatore areas. Linking this with the SWOT analysis, the *potential* for development of group management around resource conservation, and the likelihood that small-scale initiatives would bring tangible benefits to the group, also appears low. There are several reasons for this.

In the Satlasana case, aquifers may be in direct hydraulic connection with the deep alluvial system that underlies much of north-central Gujarat. If this is the case it would mean that local conservation gains would be undermined by wider (uncapped) abstraction and water level declines. In spite of many enabling conditions then prior experience of collective action, the presence of a coordinating NGO amongst others there may be a fundamental scale constraint. In the Coimbatore area, this has a rather different dimension. Here, local variability of weathering within the hard-rock aquifer would make it very difficult to predict whether, and to what extent, it would be possible to capture conserved water, even with hydrogeological investigation. Moreover, other fundamental obstacles to group management exist in the form of diversification by households, and of the economy, that mitigate against collective agreement.

Excavation to provide storage upstream of a check dam. Households are paid by the volume of material removed: small earth walls show the boundaries between where different households have been digging.

In both cases, we would argue that it may not be possible to overcome the constraints on group management. This is not to say, however, that other group-individual initiatives aimed at increasing the efficiency of water use, enhancing the availability of water in wells within the command areas of recharge structures, or increasing soil moisture retention, should not be supported or could not be improved, as Chapter 4 makes clear. Rather, the argument is that group management of groundwater, based around a collectively agreed conservation goal, may not be viable as a means of solving local - or regional overdraft problems.

Turning to the Arwari and Pani Panchayat initiatives, key questions relate to their development potential, and whether either approach could be promoted as a 'model' for addressing overdraft concerns. In both cases, there are many positive features to build on: resident NGOs and established community support structures; secure funding; and prior experience of collective action and community self-help, for example. As the preceding discussion makes clear, however, neither initiative currently appears able to solve local, or regional, groundwater overdraft. What, then, for the future?

Hydrogeological advice may help assess the risk of losing conservation gains

In the Pani Panchayat region, both domestic and agricultural water supplies are threatened by regional over-exploitation, despite substantial investment in community-based water harvesting and conservation. Within the Pani Panchayat initiatives themselves the benefits of self-regulation are also threatened, in part because each initiative is relatively small and abstraction cannot be controlled beyond the scheme's community wells. One option being explored to address this problem amounts to the scaling-up of scheme protocols on the back of large watershed development projects planned for Pani Panchayat areas. In other words, watershed projects would introduce an element of conditionality: to become eligible for a project, communities within a watershed would undertake to share groundwater equitably, and according to availability, attempting to balance demand with supply. Hydrogeological advice would be sought to define (roughly) the latter, and to indicate locations for projects where conservation gains would at least be *less* likely to be lost to surrounding watersheds or to deeper, heavily exploited aquifer systems, given the nature of regional aquifers and hydraulic connectivity.

While intuitively attractive, 'piggy-backing' Pani Panchayat principles on watershed development initiatives presents some major challenges. First, the scale issue: finding watersheds where conservation gains could be retained within the basin (like Arwari) immediately limits applicability and implies a level of situational knowledge (“how do we know which hydrogeological situation we're in?”) that is not currently employed within watershed development programmes. Secondly, Pani Panchayat principles, which decouple land and water rights, would be highly contentious in watersheds where prior customary rights are already established, i.e. where private groundwater development has already occurred. Thirdly, there is the challenge of securing agreement amongst a larger number of households and villages within a watershed, not just between households using single community wells. A preliminary conclusion is that Pani Panchayat principles could only be effectively integrated within watershed

Table 3.3. The potential for community-based management of groundwater in the case study areas: strengths, weaknesses, opportunities, threats (SWOT)

	Arwari* (Rajasthan)	Pani Panchayat* (Maharashtra)	Satlasana (Gujarat)	Coimbatore (Tamil Nadu)
STRENGTHS	• Watershed treatment scaled up over 1000 km² river basin • Sequencing of activities: began with those that were relatively easy with more tangible benefits before more difficult activities • Slow incremental build-up: start small, generate demand, scale-up • Village committees nested within AWP • Upstream-downstream externalities internalised through AWP consultations and protocols • Restrictions on water-intensive crops complement treatment activities • Protocols defined at basin scale (AWP), implemented at village level wide consultation and therefore adoption • Well-defined basin boundaries help residents 'protect' forest and water resources • Resident NGO (TBS) with charismatic and high profile leadership • Activities coordinated through single, trusted NGO providing long-term support	• Many PP initiatives still survive and operate after several decades • Land and water rights decoupled • Water rights volumetrically defined, and allocated equitably - by GGP • Water rights define variable rather than absolute shares - flexibility • External auditors monitor allocations, create assurance • Restrictions on crop choice negotiated through higher level organisation - GGP • Resident NGO (GGP) with charismatic and high-profile leadership • Activities coordinated through single, trusted NGO (GGP) providing long-term support • Formal registration of GGP as society	No existing group management of groundwater but: • Prior experience of community organisation around NRM through cooperative societies, self-help groups • Community groups federated at taluka (block) level through Sangh - opportunity for wide consultation and adoption of new initiatives • Some experience with watershed treatment initiatives and promotion of low cost drip and sprinkler systems • Resident NGO (VIKSAT) offering long-term support • NR activities coordinated through single, trusted NGO (VIKSAT) • Formal registration of federal Sangh as society	No existing group management of groundwater but: • Some recent experience with more participatory, user group approaches to watershed development through GoI-DPAP programme • Long history of collective organisation around maintenance of irrigation tanks and water allocations in this area
WEAKNESSES	• No restrictions on groundwater access within, or outside, the basin • 'Private' rights of landholders to develop new wells and deepen existing ones perceived as legitimate • Further checks on demand (beyond crop restrictions) contentious, unlikely • Understanding of groundwater conditions limited; information on long-term trends anecdotal, ambiguous • Despite protocols on water use, groundwater potential still viewed as unlimited • Requires permanent NGO oversight - TBS still present after >15 years • AWP has no formal, legal status actions have no legal backing	• Blunderbuss approach to site selection makes each scheme vulnerable to outside influence • Inability to limit abstraction beyond PP community wells • Small size of individual initiatives • Rights defined by GGP have no legal backing within, or outside, initiatives - difficult to defend • Requires permanent NGO oversight - GGP still provides support to old and new schemes	• No restrictions on groundwater access or abstraction, either direct or indirect • 'Private' rights of landholders to develop new wells and deepen existing ones perceived as legitimate • Without checks on water abstraction or use, conservation gains from new irrigation technologies may be negligible • Interconnectivity of aquifers may lessen impact of local recharge and conservation initiatives • Sustainability of village cooperative groups and federal Sangh still dependent on VIKSAT support	• No restrictions on groundwater access or abstraction, either direct or indirect • 'Private' rights of landholders to develop new wells and deepen existing ones perceived as legitimate • Group-village management of irrigation tanks undermined in recent years by (subsidised) private investment in wells • No resident NGOs involved in community mobilisation around NRM objectives (NGO work with communities restricted to short-term projects) • Understanding of groundwater conditions and trends limited, especially awareness of the concept of community-based demand management

	Arwari* (Rajasthan)	Pani Panchayat* (Maharashtra)	Satlasana (Gujarat)	Coimbatore (Tamil Nadu)
OPPORTUNITIES	• Source of outside professional advice on hydrogeology identified • Better understanding of resource may inform future treatment choices and design of more flexible demand protocols • Continued support from TBS and increase in funding • Extension to surrounding basins with similar characteristics mooted • Groundwater abstraction still quite limited as compared to that in other areas of India - better placed for community action around groundwater	• Source of outside professional advice on hydrogeology identified • Better understanding of resource may inform future treatment choices and design of more flexible demand protocols and groundwater rights • Continued support from GGP • Attempts to revitalise older, fragile schemes • Piggy-back PP water use-allocation protocols on current demand for watershed development projects, especially where communities have exhausted GW development options • In this area potential to invoke existing legislation to protect drinking water supplies from deep aquifers	• Source of outside professional advice on hydrogeology identified • Better understanding of resource may inform future watershed treatment choices and define limits to water conservation gains through e.g. changes in irrigation technologies • Continuing support for local self-help and institution-building from VIKSAT	• A better understanding of resource conditions - especially local variability - would help inform targeting of watershed treatment initiatives • Power pricing • Livelihood diversification strongly apparent - could be examined as an option for reducing groundwater abstraction
THREATS	• Investment in new wells, and deepening of existing ones, continues • Access to new markets may increase demand for water-intensive cash crops and threaten existing protocols • Potential for serious overdraft in 5-10 years with no further limits on groundwater abstraction-use	• Regional acceleration in groundwater abstraction continues, with impacts already felt within PP initiatives. • In some areas, initiatives are looking increasingly fragile, with high risk of closure • Shifts in rural economy beginning to emerge may undermine group incentives	• Livelihood diversification (from both push and pull factors) may undermine collective efforts • Without aquifer-wide scaling up of recharge and conservation initiatives, impacts on local groundwater conditions limited	• Rapid transformation of rural economy over last decade undermines long-term interest in resource conservation (though at same time reduces dependency-vulnerability) • Increasing capture of resource by rural elite engaged in short-term mining of resource

Note: in the SWOT analysis above, strengths and weaknesses relate to conditions within a resource management initiative (Arwari, Pani Panchayat, Satlasana) or, where none currently exists, that shape the potential for such initiatives within an area (Coimbatore). Opportunities and threats relate more to conditions outside the initiative or immediate area.

*Areas where group organisation around groundwater conservation objectives has already occurred.

development projects in two types of area. In the first, there is some prospect of retaining conserved water within the selected watershed. In the second, there is either no prior groundwater development, or the groundwater development options of all participating households and villages have been exhausted and there is broad consensus on collective strategies.

In the Arwari Basin, watershed development already provides the backdrop to limited demand management, agreed and authorised through the basin parliament and village water committees. Key questions here relate to the ability to (a) deepen existing restrictions on demand, which are currently restricted to crop choice; and (b) extend the initiative to other areas. In contrast to Pani Panchayat schemes, which link novel water use-allocation protocols to new community wells, groundwater development in Arwari has been in full swing for over three decades. Challenging existing rights, for example to limit well digging, or ban new wells or the deepening of existing ones, would therefore be contentious, especially given the prevailing view that groundwater potential is unlimited.[6] There are, however, circumstances in which views might change:

Firstly, TBS is now seeking hydrogeological advice out of concern that (a) variations in groundwater potential and constraints exist across the basin but are not factored into current protocols; and (b) the role it could play in raising conservation awareness.

Secondly, clear evidence that existing patterns of groundwater development are unsustainable may be necessary, for example with the costs of new drilling becoming uneconomic for most households. In conjunction with awareness raising and explanation, and with lobbying through the basin parliament, further restrictions on demand might be feasible.

Watershed development in the Arwari basin provides a platform for limited demand management

There are plans to extend Arwari principles to surrounding (similar) basins, though these have not been developed in any detail. In all likelihood, new basin activities would follow a similar (Arwari) sequence, beginning with community mobilisation around measures to increase groundwater recharge and then moving on to the more difficult demand aspects. It should be emphasised, however, that neither Arwari nor Pani Panchayat initiatives are viewed as 'models' by their NGO champions, with guidelines and checklists that are easily transferable to other areas, and contexts. So, while both NGOs stress the need for community self-help and self-reliance, and take this message to many other areas, *they do not welcome the idea of prescriptive replication*.

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[6] A view widely held across case study areas. In this respect, the well-publicised success of watershed development in places such as Arwari may generate its own problems, with demand management viewed as both unnecessary and as an infringement of basic rights.

3.4 Wider Lessons: the limits of collective action

The question ofwheregroundwatermanagementcurrently'fits'inthecontextof administrativeandpoliticaldecentralisationbringsusbacktointerpretationsof 'management' and the political economy of sector reform. There has been a fundamental change in beliefs about the appropriate role of the state over the pastdecade.Ratherthanbeingtheexecutorofastate-leddevelopmentprocess, thestateisbecomingafacilitatorinafarmoreheterogeneousprocessinwhicha coalition of different actors and institutions is involved. However, although incipientpartnerships areemerging(includingthosewithPRIs)concerned with the 'management' of watershed development projects water supply infrastructure, management of groundwaterresources, inawaythatcombines *both supply and demand-side* activities, is not part of the agenda. In Chapter 4 of this report, we argue that it should be. The argument, though, is for the development of new coalitions of management interest between the administrative and political system, between NGOs and the state, andbetween all of these and localcommunities. Within thisspacethereisno'correct'institutional model. As thecase study discussion above illustrates, group management of groundwater eveninthosecircumstanceswherestrictpreconditions can be met, can offer only partial and rather fragile remedies to groundwateroverdraft.

"Scale"and "exclusion"pose thecentral challenges to developmentof community-based organizations forgroundwater management

Why is group management of groundwater a difficult and partial response to the problems identified in this and previous sections? In many areas, we would arguethatusershavelittleincentivetoinvestin managing the resource base. As documented in the Coimbatore case study,forexample (see also Box4.1), economicsystemscan changerapidly. Althoughindividualsmay fully recognise the impacts that declining water levels are likely to have on agriculture, they may not view these as primary threats to their long-term livelihoods.A 'broadly feltneedformanagement'maythereforenotexist.Where rights and 'rules in use' are concerned, existing rights systems with the rare exception of thePani Panchayat schemes - are rules of capture that effectively allocate all power to individual landowners. As a result, they create strong disincentives for collective management based on the ability to exclude non-participants. Moreover, the rights of landholders to pump as muchwateras theywant are not contested by those without land, and without direct access to groundwater.

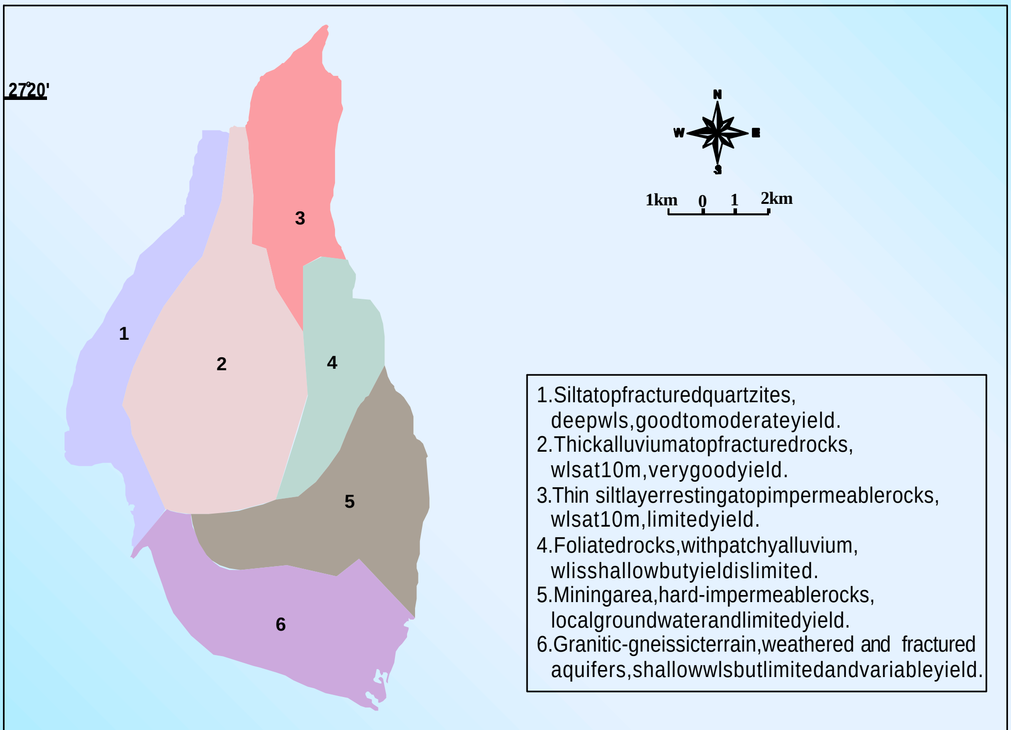
ApercolationpondinCoimbatoreDistrict

Defining resource and user group boundaries is also pertinent here. It is a technically complex task to identify hydrological system boundaries for management in both hard-rock and alluvial areas. Mechanismstocontrol free riders arealsoproblematic. Wells aregenerallyownedbyindividualsandlocatedon private lands.Individualcooperationwithmanagement initiatives cannot be assumed even within individual villages. And in many locations, particularly in large aquifer systems, reductions in extraction or increases in recharge may not result in rapid or even observable changes in water levels. As a result, it may be difficult to convince individual users that more costly, cooperative strategies will bring tangible benefits.

A dug well deepened as groundwater levels decline

The above list of limitations on collective action could be extended further to include the need for long term support from external civil society organisations, and strong leadership. Of all the above points, scale and the related issue of exclusion present perhaps the central challenges to the development of community-based organisations for groundwater management. The existence of a 'broadly felt need for management' or the challenge of defining boundaries, rule enforcement, controlling 'free-riders', maintaining group homogeneity and so on, are all likely to increase with the geographical scale of management and the number of individuals that need to be involved. As a result, community-based or representative management approaches appear to have the greatest chance of success in areas where hydrological systems are highly localised. Even within these environments, however, the Pani Panchayat and Arwari River Basin Parliament management experiences suggest that institutions will have difficulty controlling groundwater abstraction, let alone groundwater access, through social pressure alone.

Figure 3.4 The Arwari basin can be sub-divided into 6 distinct areas, based on hydrogeological observations



Source: Compiled by ACWADAM for Rathore, 2003

4

Research findings and recommendations on the way forward

4. Research Findings and Recommendations on the Way Forward

"The mark of effective research, advice and policy making is thecapacityof those involved to know the difference between what 'should' be done, and what'can'bedone."(J.A.Allan,2001)

4.1 Core Findings

1. Community-based strategies are unlikely to be effective as a primary responsestrategy *foraddressingmostcasesofgroundwateroverdraft.*

   In some circumstances, communities can mobilise around demand-side management, limiting resource access and/or use in pursuit of agreed objectives. However, circumstances are restricted, and the benefits generated do not add up to a primary strategy for balancing demand and supply. In general, small groups are unlikely to be able to retain the water they conserve, even if agreements on abstraction and use can be reached and monitored; the range of interests within communities - in many cases growing with livelihood diversification - makes objective setting around conservationgoalsmoredifficult; andtheperceivedlegitimacyofcustomary groundwater rights continues to create strong disincentives for collective management.

2. The ineffectivenessofcommunity-based strategies as a primary solutionto groundwateroverdraftatalocalscale *doesnotimply* thatsuchstrategiesare withoutbenefit,however.

   Community-based strategies, combined with community-level watershed interventions to improve the productivity of land and water, can generate importantbenefitsforlocal peopleby:

   a. Increasing the social and economic returns to limited available water resources (increasing crop yields, livelihoods and social assets per drop);

   b. Increasing the retention of moisture in the soil, enabling rural households to grow crops where none wouldotherwisebepossible;

   c. Enhancing the availability of water in wells within the command areas of recharge structures, providing a critical buffer of water supply that rural communities can use to meet essential requirements fordrinking,livestockand, in some cases, irrigation during droughts.

Avillagehandpumpdowngradientofa check damintheArwariRiverBasin

In conjunction with other watershed interventions, therefore, community-based approaches aimed at restricting demand may help mitigate the adverse impacts of groundwater overdraft on livelihoods. They therefore deserve continued support. Attributing changes in groundwater conditions to different types of intervention remains difficult though. A tentative conclusion is that even at a local level, livelihood improvements may have more to do with soil moisture conservation and better land management than with positive and sustainable impacts on local-regional water balances.

3. Conventional management strategies are also unlikely to be effective in reducing groundwater extraction to sustainable levels across the large aquifers at risk in many rural areas.

This finding is not unique to our study. As Tushaar Shah and others comment: "The direct management of the groundwater economy is... an impractical idea in South Asia" (Shah et al. 2003a). This is because such approaches are based on technical, institutional and political preconditions that are difficult to meet, and cannot be easily applied to situations where groundwater is being abstracted by many thousands of small-scale users. However, we argue that such strategies could be implemented on key urban aquifers where widely shared services are threatened, and political support for action is more readily mobilised.

A well located in a pocket of shallow weathered hard-rock, down-gradient of a check dam, Coimbatore District

4. The shortcomings of both conventional and community-based approaches suggest that more attention should be devoted to processes that:

    a. Increase the efficiency of groundwater use (i.e. ensure that the social benefits derived from groundwater use are maximized);

    b. Anticipate and proactively support the adaptation of households, communities and regions to other forms of livelihood as intensive irrigated agriculture becomes increasingly less viable in locations where overdraft is severe;

    c. Ensure domestic water supply security (since this represents the minimum requirement for households to remain in a region and undertake any form of economic activity); and

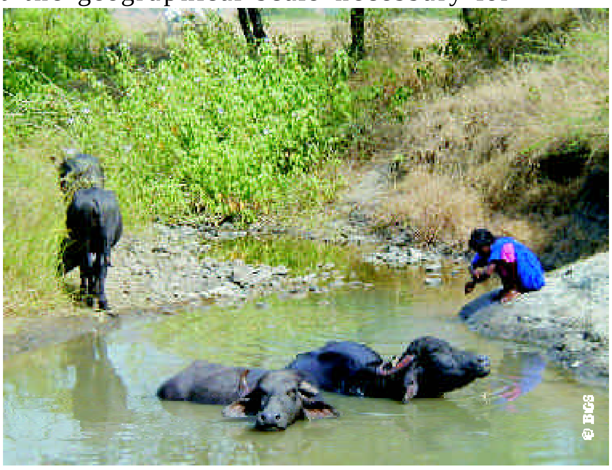
    d. Increase the effectiveness of community actions to harvest water and conserve soil moisture.

4.2 Discussion of findings

The quote from J. A. Allan at the beginning of this section highlights a dilemma that professionals in many fields face: in attempting to meet professional or society's expectations, what *should be done* often *can not be done*. Groundwater overdraft is one small problem area within the universe of groundwater management needs. Saying that groundwater 'should' be managed on a sustainable basis does not mean it 'can' be managed on a sustainable basis.

There is abundant evidence of the important and substantial benefits that community-based initiatives can generate for local communities coping with the impacts of groundwater overdraft. In undertaking the Comman Project, our initial objective was to identify the factors contributing to successful management through community-based institutions. It is with reluctance, therefore, that we report that such initiatives unfortunately do not add up to a *primary strategy* for the sustainable management of groundwater resources.

With the exception of a few isolated cases, community-based water management initiatives do not even attempt to restrict demand. Instead, virtually all involve efforts to increase supply through water harvesting. Although such efforts do generate benefits, they do not represent an effective strategy for groundwater management in areas where overdraft levels are high. As VIKSAT has shown in a separate project in the Sabarmati Basin, water harvesting alone can only reduce the gap between water demand and supply in that basin by a few per cent (Kumar et al. 1999). Without controlling or substantially reducing extraction the groundwater resource base cannot be managed on a large scale. Furthermore, there are sound reasons why it is unlikely that community-based institutions capable of controlling groundwater demand would be able to organise at the geographical scale necessary for effective management of the groundwater resource base.



Waterbuffalowateringandcoolingoffinacheckdam

Despite their minimal impact on the balance between extraction and recharge at an aquifer level, community-based initiatives to harvest water and increase the efficiency of water use generate important and substantial benefits, as described in Section 4.1. Finding that community-based initiatives for sustainable management of the groundwater resource base are unlikely to be fully effective *in no way reduces the value of the above benefits*. This observation underlies our second core finding: *continued support for community based initiatives to harvest water and increase the efficiency of groundwater use is of fundamental importance*. While they do not add up to an effective strategy for managing the resource base, such initiatives may, particularly in conjunction with other forms of intervention, help to mitigate the help to mitigate the impact of groundwater overdraft. The costs and benefits of such approaches should continue to be evaluated. There are substantial unresolved debates within the scientific community over the impact of water harvesting on groundwater conditions and upstream-downstream water availability. The research from case study areas has shed little light on the impact of water-harvesting activities on groundwater conditions. While preliminary field data from studies in Satlasana suggest that recharge may sometimes result in localised groundwater mounds, modelling results indicate that such benefits are likely to be short-lived. Furthermore, such benefits may not be cost-free to other regions; for example, it has been found that upstream water harvesting can sometimes deplete downstream users of their expected endowments, but such relationships await further scientific study (Batchelor et al., 2000).

Community-based waterharvesting andincreasing groundwater-use efficiency areimportant

Our third finding confirms earlier work suggesting that, on their own, conventional command and control strategies are unlikely to reduce groundwater extraction to sustainable levels in most regions of groundwater overdraft. An IWMI publication referring to the effectiveness of the Central Ground Water Authority recently stated that: “The direct management of the groundwater economy is, therefore, an impractical idea in South Asia” (Shah et al. 2003a p.6). *We have explored the reasons for this in some detail in order to emphasise the critical importance of identifying alternative strategies for responding to groundwater problems and to clearly indicate what we mean by 'groundwater management'.*

Our finding concerning the shortcomings of conventional groundwater management in this context does not suggest that conventional management approaches are always inappropriate. Given the relative ease of concentrating political and technical capital in cities, we believe that conventional management strategies to protect aquifers supplying urban domestic needs have a greater chance of success. These reasons are not explored in detail because they were not the primary focus of research under the project.

The fact that neither conventional nor community-based management approaches, on their own, can generally solve the problems of groundwater overdraft leads us to advocate greater attention to processes that encourage efficient water use and which enable households, communities and regions to adapt to the livelihood constraints imposed by water availability (Box 4.1). Tushaar Shah and others (Shah et al. 2003b p. 134) suggest that, in areas where recharge is limited and extraction high, agricultural economies based on intensive groundwater use are bubble economies (Section 1.2). While indirect measures such as energy price reform will probably increase the efficiency of groundwater use, *efficiency and long-term sustainability are not necessarily equivalent* (Moench and Kumar 1995). Recognition of this is nothing new. Similarly, while power sector reforms have been receiving substantial attention in recent years, and policies may emerge in some states that reduce incentives for inefficient groundwater use, it is far from clear that such indirect measures will result in a balancing of extraction and recharge. Metering of power consumption, while widely advocated, faces substantial obstacles and may not be practicable (Shah et al. 2003a). While approaches based on power rationing have been proposed (Shah et al. 2003a) these have yet to be implemented or tested. More to the point, even if indirect measures do reduce extraction it will be through their role in catalysing structural changes in the intensity of water use for rural livelihoods. The extent of this structural adaptation is not yet clear. For example, some change can occur within livelihoods by increasing the efficiency of water use while allowing households to maintain agricultural livelihoods based on groundwater irrigation, but change may also involve shifts to livelihoods that are non-farm based and less dependent on groundwater availability. This is an important research area. The bottom line is that structural adaptation to water scarcity will occur whether as a result of indirect measures or in response to increasing groundwater overdraft.

Our research suggests the need for devoting greater attention to processes that: increase the efficiency of groundwater use; support the adaptation of households, communities and regions to less water-intensive forms of livelihood; ensure domestic water supply security; and increase the effectiveness of community-based activities to conserve soil moisture and harvest water.

This leads us to recommend expanding the management perspective, emphasising diagnostic and other processes and the development of programmatic approaches that are adaptive and enable adaptation. What such processes might consist of and the key questions related to them are explored in detail in the following sections.

Old irrigation wells are now used to supply water to large estates that combine horticultural plantations and week-end resorts: one such well, located west of Pune

Box 4.1 Livelihood diversification, water-use and water management

In a growing and increasingly interconnected economy, the structure of employment and income can change rapidly. Key features of transition include growing numbers of functionally landless people, increasing dependence on non-agricultural incomes (though with some links to agriculture), and diversification in both the type and geographical sources of income. These long-term structural changes of the kind seen in the Coimbatore area, outlined in Table 4.1 below, have important implications for groundwater use and groundwater management.

First, shifting to less water-intensive livelihoods can reduce economic dependence on local water resources and reduce local abstraction. Of course food is still needed, but more can be purchased rather than grown locally. Water for domestic uses must, in most circumstances, be sourced locally but shifts towards lower water-use activities can liberate ample quantities to meet basic needs. Secondly, economic shifts can influence water policy. Government and civil society perspectives on water and management needs can begin to align, and the voice of agricultural users can be challenged. In short, livelihood diversification can help to create the political space needed to introduce more testing reforms, in particular those promoting the reallocation of water. Such reforms are much more difficult to implement when livelihoods are still heavily dependent on irrigated agriculture.

What are the policy lessons? Although diversification is a 'natural' outcome of economic transition it can also be promoted at various levels as a means of reducing vulnerability and (indirectly) easing pressure on the groundwater resource base. Take a watershed development project in an arid area, for example, with a growing problem of groundwater overdraft. Rebalancing priorities away from the building of recharge structures towards non-farm elements (support for cottage industries, local infrastructure) could help support sustainable livelihoods, rather than cement dependence on unsustainable, groundwater-dependent irrigation. At the district or state level, a wide range of 'non-water' policies could be reviewed in relation to their ability to generate growth in the rural non-farm economy, and their knock-on effects on water use.

Such 'adaptive' remedies are not suggested as a long-term substitute for water policy reform. However, they may provide interim, indirect and feasible means of supporting incomes and reducing vulnerabilities. They suggest a need for water policy makers and programme/project staff to look beyond conventional sector boundaries in addressing the causes, and symptoms, of intensive groundwater use.

Characteristic	'Traditional' view	Emerging reality
Rural jobs	Mostly agricultural	Increasingly non-agricultural: rural non-farm economy and urban
Rural incomes	Dependent on agriculture	Increasingly diverse and geographically dispersed
Dependence on CPRs such as groundwater	High, especially for poorer households	Decreasing, though pattern mixed. Growing numbers of 'functionally landless'
Socio-economic change	Static: subsistence based agriculture	Dynamic: push and pull factors drawing people into the rural non-farm economy
Economic integration	Little	Increasingly integrated
Food insecure	Peasants	Rural and urban poor-varied
Main sources of household vulnerability/food shocks	Poor rainfall and other production 'shocks'	Income shocks causing food insecurity
Nature of community	Place-based, single occupancy and dependency	Interest-based, multi-occupancy
Policies, institutions	Traditional	Emerging needs
Remedies for household food insecurity	Food-based relief, safety nets	Income transfers, economic diversification?
Rural development narrative	Increase the productivity of natural resources	Employment generation, income diversification, reduced dependence on natural resources
Key institutions	Ministries of Agriculture, Irrigation, Forestry, Water, Rural Development	New coalitions. Natural resource plus infrastructure, commerce, industry, tourism etc
Water policies	Surface water and irrigation related aspects dominant	Focus on groundwater needed, and management of water demand

Sources: based on case study findings, and wider evaluations of rural transition in India (e.g. Saxena and Farrington, 2003) and internationally (e.g. Ashley and Maxwell, 2001).

4.3 Potential Courses of action in case study areas

Our recommendations on the way forward are designed to address critical questions first in the case study areas and, secondly, on a more general level. Suggestionsonwaysforwardinthecasestudyareasarepresentedfirstbecause the diverse conditions andthetypes of actions that webelieveare appropriate, serve as a lead into, andillustration of, the wider recommendations thatfollow. It is important to recognize that the potential opportunities and limitations discussed in each of the case study areas are just that: *potential opportunities and limitations*. The diversity of these and the fact that many are not directly relatedtothemanagement of the groundwaterresource base are precisely the reason we recommend expanding the management perspective, the development of diagnostic processes, and much more adaptive programme design. Furthermore, while community or conventional approaches to groundwatermanagementappearinadequateinthemselves,approachesbased on regionally tailored *combinations* of interventions through community initiatives, conventional command and control strategies, indirect measures and livelihood-based adaptation may have a much greater chance of both reducing the impactofgroundwateroverdraftonlivelihoodsand,insomecases, reducing theoverdraftitself.

4.3.1SpecificSites

Satlasana,Gujarat

Our incomplete understanding of the connectivity between the aquifer underlyingSatlasanaandregionalsystemsmakesitdifficulttopredictthelikely impacts of community-level interventions on groundwater availability. The aquifersystemhereisformedprimarilyofweatheredandfracturedgranites.Itis likelythereforethat itwillbegenerallylowinstoragebutwithlocallyproductive zones. This low storage means that water levels will recover quickly following good wet seasons. However, it is also the reason why water levels have fallen significantly in response to increased abstraction. The benefits to individual farmers of reducing their abstraction will depend on the degree of connectivity between the aquifer in thevicinity of their well and the regional aquifer. Where there are no physical barriers to the flow of groundwater, water that is not pumped maysimplyflowawaydown-gradient over the period ofthedryseason. However, if an individual well or small group of wells is tapping an isolated pocket of the aquifer, formed by weathering and fracturing, a reduction in abstraction may result in a sustained yield over a period of low rainfall. At present there is insufficient information in the Satlasana area to predict the likelyoutcome.

Local water-harvesting activities could significantly increase soil moisture retention and help to create localised groundwater mounds, benefiting wells within limited zones adjacent to recharge structures. Activitiestoincrease the economicreturntolimitedavailablewatersuppliesmayalsogenerateimportant benefitsinthisregion.However,investmentsindripirrigationorother groundwater dependent irrigation systems would be undermined if water levels continue to decline and wells continued to fail. Such activities should therefore be undertaken with caution. Given the risk, improvements in rainfed cropping systems and techniques for storing water to provide protective irrigation may have greater impact.

In addition to direct water-related interventions, the development of agricultural livelihood systems that enable effective use of short-lived groundwater supplies (i.e. water available in wells during the pulse of recharge that occurs following the monsoon) may have substantial benefit. An example would be livelihoods becoming more reliant on livestock. Irrigated fodder could be produced locally, when water is available, and purchased when water supplies are insufficient to support local production. This pattern is already occurring in Satlasana, spawning other livelihood activities to support it. It could also involve the development of markets or processing facilities that enable villagers to increase the value of agricultural production in relation to water use. The development of oil seeds processing facilities by regional cooperatives was, for example, a critical factor in other parts of Gujarat that enabled farmers to shift into high-value / low-water intensity oilseed crops. The importance of such shifts in relation to groundwater management has already been recognised by organisations such as the World Bank (World Bank and Ministry of Water Resources - Government of India 1998 p. 44). Such indirect interventions could help mitigate the impact of groundwater overdraft.

Beyond this, investigation of opportunities for supporting expansion of the non-farm economy is extremely important. Shifting to an economy based on livestock and rainfed agriculture may not be a viable option for many families in the Satlasana area and, as documented in the case studies, many families seem to be diversifying their livelihood strategies away from agriculture. Villagers are engaging more in regional wage-labour markets and activities such as diamond polishing, a major regional industry. As a result, supporting development of the non-farm economy would also build on existing trends at the household and village level.

Digging for decorative stones for use in jewellery making

Regional piped water supply schemes to meet domestic water requirements have been implemented in the Satlasana region. As a result, access to domestic water supplies is not currently a factor limiting the ability of populations to remain in the region.

Long-term strategies for mitigating the impact of groundwater overdraft on livelihoods in the Satlasana region probably require a combination of the following:

1. Continued reliance on large-scale drinking water supply systems to meet domestic water needs. Such systems have generally been built and operated by the government, but there is no inherent requirement for this.

2. Community and household-level initiatives to increase the efficiency of agricultural water use and to supplement soil moisture through water harvesting;
3. Indirect interventions such as power sector reform and the development of marketing facilities that encourage more efficient water use; and
4. Livelihood interventions that encourage the development of non-farm sources of income.

Coimbatore

Regional patterns of groundwater overdraft have been well recognised in the Coimbatore region for more than a decade (Palanasami and Balasubramanian 1993). As Comman Project case studies indicate, decreasing availability of groundwater coupled with increasing economic opportunities in other sectors has catalysed a major shift toward non-farm based livelihoods. This shift appears to have occurred across the income spectrum.

The impact of groundwater management activities - whether demand or supply side - is likely to vary greatly in this region and at the micro level. In some sites, wells in the hard-rock basement may operate more as cisterns which are isolated from regional groundwater systems. At other sites, wells intersect substantial fractures in the bedrock or occur in deeply weathered materials and, as a result, are likely to be directly influenced by patterns of extraction occurring at a regional scale. In the first case, recharge activities and efficient use of water contained in the well cistern would directly benefit the well owner. In the second case, it could be difficult to determine whether or not groundwater-focussed interventions had any observable impact.

A deep irrigation borehole, Coimbatore District

Indirect interventions such as price reforms for electricity are unlikely to have much impact on groundwater conditions. The limited storage capacity of wells already effectively rations water and only the highest-value crops are irrigated.

Given the shift away from irrigated agriculture, activities to ensure equitable access to the larger non-farm economy may have greater economic impact than water-focussed interventions. Indeed, many of the remaining wells in use are owned by large landowners, who typically operate family businesses that have already diversified into non-farm activities, such as textile production and brick making. It is likely, therefore, that the return from investments in groundwater management would accrue primarily to those sections of the community that are already well off. Because of this, the basis for community action is unclear even where physical conditions may be conducive to management of the resource base and its use.

In addition to livelihood diversification, activities to increase soil moisture for retention and the efficiency of on-farm water use could generate major benefits for small farmers. As in the Satlasana case, the security of domestic water supplies is less of a problem, as large-scale systems pipe water to households. The reliability of these systems is, however, unknown and actions that strengthen them or ensure backup could be important.

Pani Panchayats

In this region both domestic and agricultural water supply security are endangered despite the presence of substantial community-based efforts for water harvesting and conservation. This appears to be due to regional patterns of groundwater over-abstraction.

Safeguarding the security of domestic water supplies is the priority for ensuring the long-term sustainability of livelihoods in the Pani Panchayat region. Secondly, livelihood systems should be independent of intensive groundwater irrigation. Further investigation is required to determine whether community-based activities would be effective in protecting groundwater sources for domestic water supply. Other avenues for ensuring domestic water supply security are also essential to investigate. Such avenues could include government regulation of groundwater extraction from deep aquifers using authority provided under existing or new laws (Maharashtra Groundwater Regulation for Drinking Water Purposes Act, 1993; Maharashtra Water Resources Regulatory Bill, 2003) but with support from local communities. Points of leverage for this may lie less with attempts to regulate extraction at the farm and community level and more in higher-level courses of action such as regulation of the drilling industry.

Horticulture promotion in Purandar Taluka

As in other regions, the reliance of many households on non-farm activities, particularly those involving commuting and migration, appears to have increased substantially over recent decades (Comman, 2005). However, access to alternative livelihood sources appears to be limited by educational levels and external competition among many other constraints. Increasing access to such sources of income could make a major difference. In addition, activities to increase the productivity of rainfed agriculture and other land-based income sources through soil moisture conservation appear important from an income perspective although they are unlikely to have much, if any, effect on groundwater resource conditions. Existing Pani Panchayat institutions could play a major role in the development and implementation of such courses of action. In addition, it is expected that major watershed development projects will be implemented in the region, and it may be possible to utilise these programmes to finance initiatives tailored to specific opportunities for enhancing soil moisture conservation or developing non-agricultural livelihoods in the Pani Panchayat areas.

The opportunities for mitigating the impacts of groundwater overdraft in the Pani Panchayat areas appear to depend on a combination of high-level (probably state-led) initiatives to protect deeper aquifers and more localised initiatives aimed at reducing economic dependence on agriculture while increasing the productivity of that agriculture which it is possible to sustain. More specifically:

1. State-led legislative and community-level measures to protect drinking water sources;
2. Processes to strengthen and improve access for all inhabitants to non-farm income activities;
3. New directions for agricultural productivity which would include strengthening of rainfed agriculture and animal husbandry along with the establishment of reliable market links to ensure security of agricultural income;
4. A combination of conventional (indirect) and community efforts (watershed development and Pani Panchayat) activities to enhance supply and, where possible, reduce demand.

Arwari

Available information on groundwater conditions in the Arwari area is contradictory. As a result, it is not clear whether the area is suffering from extensive groundwater overdraft. In addition, the region has higher rainfall than other parts of Rajasthan and intensive groundwater irrigated agriculture is, for a variety of physiographic and other reasons, currently limited. Geologically, most groundwater is contained in shallow alluvial aquifers along valley bottoms that are underlain by bedrock.

A goat-herder, Arwari River Basin

In this context, activities to harvest water at a basin scale are more likely to influence local groundwater conditions than they are in many other regions of India. Ongoing community efforts to harvest water appear to be generating substantial local benefits in terms of soil moisture retention, re-vegetation and possibly also groundwater recharge.

Given the above, effective responses to the long-term probability of groundwater overdraft do not appear to require reductions in current use - merely the capping of future growth in demand. This could be achieved through a combination of community and governmental interventions such as:

1. continuing efforts to harvest additional water supplies and improve soil moisture;
2. exploring the establishment of indirect (energy-related, crop-market related, crop-processing related) or direct (banning of new wells, especially deep bore wells) measures to restrict the growth of groundwater extraction in the future;
3. increasing the efficiency of water use within agriculture; and
4. a much longer-term strategy of encouraging increasing dependence on non-

farm activities as population grows in emerging and future generations through education, improvements in communication and transport systems, etc.

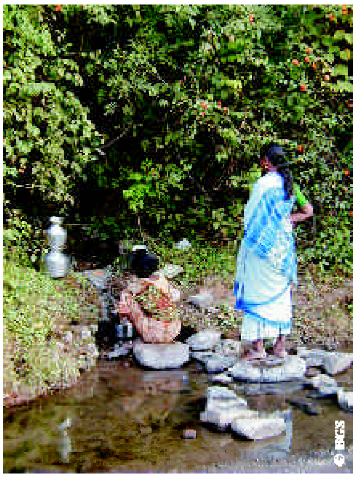
4.3.2 Process Implications in the Case Study Areas

The list of potential responses to groundwater overdraft in each of the case study areas has broad areas of similarity, which differ in detail. This underlies our emphasis on the need for diagnostic processes and adaptive programmes as central to any effective response to the impacts of groundwater overdraft.

What this means is best explained by contrasting the potential ways forward identified in each of the case study areas. In the Pani Panchayat area of Maharashtra, for example, we have raised the possibility of establishing regulatory mechanisms to protect deep sources of drinking water. This of course pre-supposes the presence of such deep sources and assumes that existing Pani Panchayat organisations might support the government in regulating companies that are able to drill to such depths. The possibility of regulating a small group of organisations and protecting a specific and discrete water source that would benefit all inhabitants is unique to this area. In Coimbatore, for example, the same strategy would probably benefit a very narrow and already wealthy section of the population while having little if any impact on regional groundwater conditions. In the Arwari case, water harvesting is clearly having significant, although as yet unevaluated, benefits.

Ability to diversify livelihoods depends upon tangible assets

Equally important differences between these areas become apparent when opportunities for livelihood change within and beyond agriculture are considered. In the Arwari region, irrigated agriculture is still viable and there is time enough for any process of economic transition to occur. Providing individuals and households a basic education could equip them with the social capital they need in order to make the transition. This is fundamentally different from the Satlasana region where the drying up of wells has already led to the abrupt decline of irrigated agriculture, forcing families to seek alternative livelihoods. In Satlasana, specific opportunities in animal husbandry and wage labour, for example in the regional diamond business, appear most promising in the short term. Not so for Coimbatore and the Pani Panchayat areas. There, involvement in non-agricultural work is already widespread and much of the regional economy relies on commuting wage labourers. The bubble of intensive irrigated agriculture has already popped and for much of the population, livelihood questions probably concern their position in, and access to, wider economic activities, rather than on agriculture. Empowerment has occurred for some, impoverishment for others. It is critical to understand and address the new forms of vulnerability likely to be associated with the transition. We also believe that recommendations to support the development of non-agricultural based livelihoods can lead to tangible rather than hopelessly broad and complicated courses of action. In many areas, the ability of households and communities to diversify livelihoods depends on tangible assets such as education, transport, credit, communications or access to them. Facilitating the shift to non-farm livelihoods could call for relatively straightforward investments in education, communications, transport, finance, marketing and other relevant infrastructure. The same is true for attempts to increase the efficiency of water communications, transport, finance, marketing and other relevant infrastructure. Thesameistrueforattemptstoincreasetheefficiencyofwater use within existing agricultural and livestock-based livelihoodsystems.


Collectingwater from anunprotected spring

The differences between our case study areas are probably representative of the differences between communities across much of India. Constraints and opportunities for responding to the livelihood impacts associated with emerging groundwater problems are highly localised and site specific. Addressing them therefore requires solid participatory processes that diagnose the problems and identify site-specific opportunities for interventions. In addition, programme support approaches (whether community based, governmental, NGO or other) must beadaptive. That is, they need to be capable of providing different forms of support at different levels of intervention (household, community, state) according to the needs, opportunities and constraints present in different areas. Furthermore, thesupport programmes themselves need tobeflexible enough to adapt to changing needs and conditions. These arguments have been developed fromspecificobservationsmadeineach of the casestudyareas.

4.4 Wider recommendations: strategies for responding to groundwater problems

From our perspective, at least five factors are central to designing an effective national strategy for catalysing community-based responses to the impact of groundwaterproblemsonthesustainabilityofrurallivelihoods:

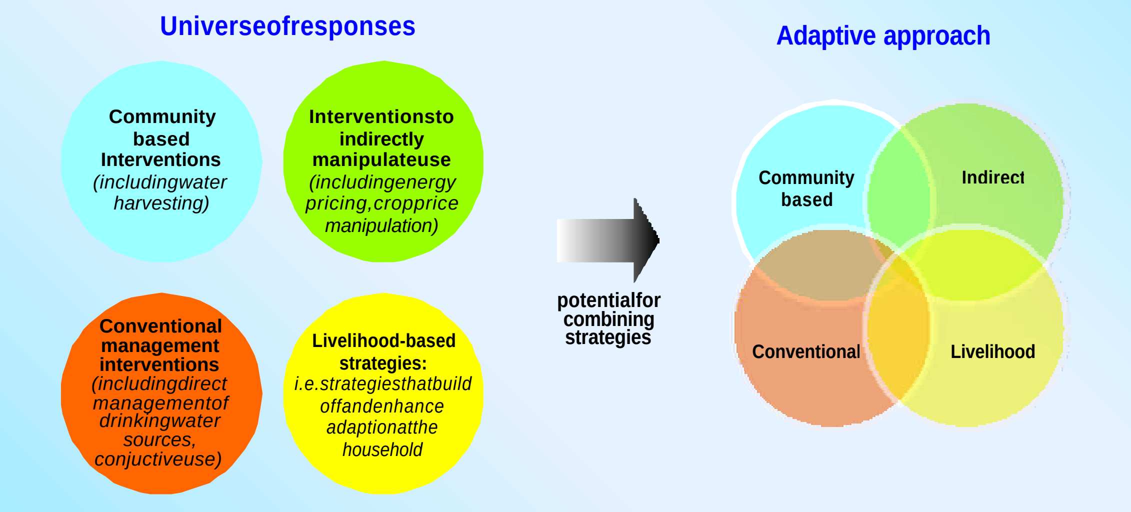
- Local and regional capacity to diagnose emerging groundwater problems and identify potential interventions. These interventions must be technically and socially feasible given the scale at which the concerned hydrologicalandsocio-economicsystemsfunction;
- Clear processes for external organisations (NGOs, government and others) to collaborate with local communities in order to explore and identify the appropriate mix of community-based, conventional management and indirectinterventionsthatcanmakearealdifference;
- Regional and state-level frameworks to support clear diagnostic and decision-makingprocessesamongdepartmentsandthepoliticalleadership whereverstrategiesrequirestateinputs;
- National-level mechanisms through which economicsystems may adaptto exploit regional groundwater-related opportunities and overcome constraints, including high-level policy decisions regarding indirect points ofleverage;
- Governmentanddonorsupportprogrammesthatare flexible enoughto

embrace multi-sectoral approaches to diverse problems at all levels;

- Specific programmes to protect and enhance domestic water supply sources, where these are threatened.

Each of these elements needs further conceptual development through targeted research and, we believe, through practical attempts to expand the management perspective in case study areas. Before this, however, it is important to recognise the overall structure of the approach we are suggesting. In this report, groundwater management is discussed largely in isolation from wider processes of socio-economic change. Even within the 'groundwater field', conventional, community-based and indirect strategies are generally discussed separately. IWRM based approaches, which are widely advocated, attempt to bring many of the water-specific factors together but rarely go beyond that. A core message here is that groundwater management activities on their own are unlikely to be effective, therefore society needs to also explore avenues for adapting livelihoods and economies to evolving water resource conditions. This is not to imply that

Figure 4.1 The adaptive approach to addressing deteriorating water resource conditions

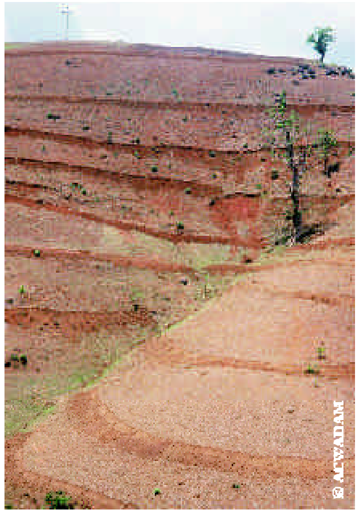


In summary, we believe that an appropriate response to the problems of groundwater overdraft will rely on a context-specific combination of interventions. These interventions may fall within the broad realm of 'water management', may be 'livelihood focussed' and may even fall well outside conventional strategies for responding to groundwater overdraft. Such an approach will require interventions at multiple levels (community, regional, state and national) and will need to adapt as conditions change. Developing such an approach, conceptually and practically, relies on further targeted research. We believe this approach may be developed by following a strategy similar to that for Joint Forest Management during the late 1980s and early 1990s. Such a strategy would involve a series of field projects guided at the state level by regional working groups comprising representatives from project areas, the government, NGOs and donor organisations. Avenues to do this are outlined in the next section on *The Way Forward*.

4.5 The Way Forward

The recommendations made here part company from the narrowly-defined strategies for 'community-based groundwater management' which the Comman Project was originally designed to address. The vision has grown to draw on conventional, community-based, indirect and livelihood-focussed approachesinacombinationdeterminedbylocalconditions.

The development of strategies for responding to groundwater overdraft should be phased and themselves subject to adaptation and refinement as experience isgained.Thefirst phase inthis process would combine experimentation (pilot implementation), research, monitoring, evaluation and clear opportunities for course corrections. This would, ultimately lead to further phases where the balance between elements would shift toward wider implementation; research, monitoring and evaluation would,however,remainessentialtoenableapproachesto be adapted or refined in response to larger change processesandtheinherentvariabilitybetweenareas.



Soilconservationformsandimportant aspectofwatersheddevelopmentprojects

The remainderofthissectionfocusesonthenatureofthe interactive implementation, research and policy developmentprocessthatweviewasessential,alongwith the working group framework in which it can be actualised.

The first step in our proposed strategy is to develop processes of implementation, research and policy development leading to actual pilot activities that test and document strategies. This should build on existing community-based initiatives such as the Pani Panchayats of Maharastra and the Arwari River Basin Parliament supported by Tarun Bharat Sangh in Rajasthan and o n efforts to decentralise and strengthen the formal panchayat system. As a result, the process and pilot activities would be undertaken in cooperation with local NGOs and panchayats at locations experiencing groundwateroverdraftproblems.

What might this process look like? Many development approaches have used pilot projects totestanapproach which, if found to beeffective, is then scaled up. However, this is probably inappropriate giventheCommanProjectresults, which highlight the site-specific nature of groundwater overdraft problems. Replication depends on *diagnostic processes* and *frameworks* for decision making rather than location-specific activities they are intended to catalyse. Whatdoesthismean?

We propose that the initial phase of any response programme should start by undertaking a seriesofcollaborative diagnostic activities at pilot sitestoreach common agreement regarding the natureofgroundwaterproblems in the area and the types of activities that could address them. This could be initiated through basin-level multi-stakeholder dialogue meetings of the type VIKSAT hasinitiatedintheSabarmatiBasin(Mudrakartha2002,Moenchetal.2003).

Participants in this diagnostic process should include community members, governmental organisations dealing with groundwater and other aspects of rural development, NGOs and other support organisations.

This initial diagnostic process would aim to produce three sets of outcomes:

1. A preliminary evaluation of the potential 'points of leverage' for addressing groundwater problems within each of the four potential arenas of intervention; and
2. A clear identification of the organisations and types of decision makers that need to contribute to the development and implementation of actions designed to address the identified 'points of leverage'.
3. Facilitating a network of individuals, groups, organisations and levels of society that ultimately need to interact.

The above outcomes will outline *what* might be done and who needs to be involved. This should then be used to create the initial agenda and membership list for a working group. This working group will develop ideas for action and take decisions. Its membership should reflect the array of decision makers in communities, state and local government, NGOs and the private sector who are essential for moving an interactive implementation, research and policy development process forward. The working group should also have access to funding sources required to implement the identified agenda.

It is important that the nature of the working group and the specific activities it may undertake should not be pre-defined they should be the outcome of the diagnostic process. The discussion in this report regarding potential courses of action in the Comman Project case study areas is an example of what such a diagnostic process might yield. As already discussed, strategies will be site-specific, but they will share certain generic characteristics:

1. Diagnostic processes are likely to result in the identification of some points of leverage that have little or nothing to do with groundwater management *per se*;
2. The diagnostic process itself will raise many questions that can only be answered through a combination of research, policy dialogue and implementation activities. All three components will need to go hand in hand in order to enable the evolution of effective strategies.
3. The types of analyses and approaches required are interdisciplinary. Since interdisciplinary processes of this type are complex, *substantial capacity building and support will be required*. Programmes should ensure that:
    a. capacity-development activities are not just focussed on implementation or formal management organisations but also occur in the private sector and in analytical, advocacy and political organisations that often challenge established perspectives;
    b. flexibility is built in from the start; while clear starting points are needed, it is essential that funding can be reallocated and objectives retargeted as experience accrues; and

c. they have identified evaluation milestones where they can adjust or changecourseasneeded.

4. Processes of the type proposed are inherently political. As a result, care must betaken in designing them to ensure all stakeholders have equitable access to problem definition, approach identification anddecision-making processes. Ensuring this occurs would be assisted by *harvesting lessons from existing stakeholder and other processesforcommunity-government or community-NGO interaction*. This research should address a series of key questionsincluding:

   a. Whattypesofprocessenablea **balanced** dialogue betweenindividuals, communitiesandhigherlevelsofgovernment/socialorganisation?

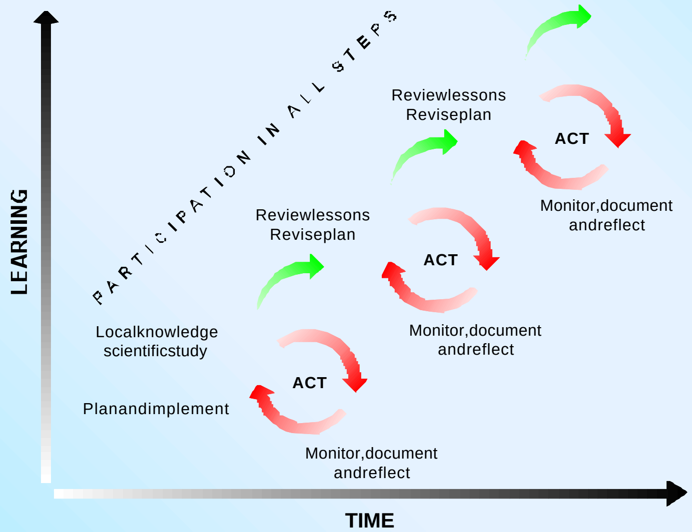
   b. Do different process approaches influence the balance of power both withincommunitiesand betweencommunities and externalactors, i.e. whataretheequityimplicationsofdifferentprocesses?

   c. How effective and efficient are different processes with respect to the identification of specific courses of action that actually address core problemareas?Itisessentialtorecognisethatprocessesarenotendsin themselves...theyneedtoresultinspecific,tangiblecoursesofaction.

   d. Do different approaches enable or restrict an on-going process of adaptation as conditions change? Many processes result in specific 'one-shot' plansor implementationstrategies. Asargued here,however, conditionsareoftenchangingrapidlyinwaysthatnecessitateon-going adjustmentsin approach.Asaresult,theprocessitself needstoenable adaptation.

5. Movingforwardwill initself be a process of adaptive learning, guided bythe workinggroup framework and the experience it accumulates. This process isillustratedintheFigure4.2.

Figure 4.2 Learning by doing (adapted fromPO'Hara,International Institute of Rural Reconstruction, 2003)



5

Conclusions

5. Conclusions

The development of effective responses to emerging groundwater problems is now a serious challenge for many countries. Groundwater related problems threaten livelihoods and affect basic humanitarian objectives, such as the elimination of poverty. As a result, the development of effective responses should be a central concern for governments, donors and other actors.

Effective solutions are unlikely to emerge from strategies that focus exclusively on the resource base itself. Neither conventional state-led, indirect, nor community-based management approaches are likely to be sufficient if implemented as a primary response strategy. Substantial opportunities for mitigating the impact of overdraft do, however, exist. Research undertaken by the Comman Project indicates that such strategies need to combine activities intended to influence the demand and supply of groundwater directly *with* activities that change the vulnerability of livelihoods to overdraft while safeguarding the securityof domestic water supplies. In many cases, activities focusing on livelihoods and domestic water supply security are likely to outweigh those focusing solely on groundwater management.

Developing effective strategies for responding to groundwater overdraft is challenging, due to the variety of problems, the scale of problems and responses and the pace of social and economic change. Standardised approaches are therefore inappropriate. To be effective, responses need to be closely tailored to local conditions and capable of adapting to changing conditions. For this reason, we propose the development of strategies that draw on the interaction between research, policy development and implementation. This interactive process should be guided by broad-based, participatory, working groups. For this to be effective, governmental and donor support programmes need to be designed in as flexible a manner as possible. They also need to emphasise locally grounded process, capacity building, research, experimentation, monitoring and evaluation as inherent parts of an overall response strategy.

References

REFERENCES

ALLAN J A 2001 TheMiddle East Water Question: Hydropolitics and the Global Economy,I.B.Tauris,LondonandNewYork.

ARORA H and KUMAR A 1993. Use of Correct Pricing as a Fiscal Instrument in Sustainable Use of Groundwater.Workshop on Water Management:India's GroundwaterChallenge,VIKSAT,Ahmedabad,India.,VIKSAT.

ASHLEY C and MAXWELL S (eds) 2001. Rethinking Rural Development. DevelopmentPolicyReview,Vol.19,No.4,December2001.

BATCHELOR C, RAMA MOHAN RAO M S and JAMES A J 2000.Karnataka Watershed Development Project : Water Resources Audit. KAWAD Report 17, KAWAD SocietyNo.2501stMain,Indiranagar,Bangalore,India,90.

BECKER C D and OSTROM E 1995. Human ecology and resource sustainability: the importance of institutional diversity. Annual Review of Ecology and Systematics26:113-33.

BROMLEY DW1989.PropertyRelations and Economic Development:The Other LandReform.WorldDevelopment17(6):867-871.

CARNEY D and FARRINGTON J 1998. Natural Resource Management and Institutional Change. Routledge Research/ODI Development Policy Studies,RoutledgePress.

CENTRAL GROUND WATER BOARD (CGWB) 1991. Special Issue on Ground Water Statistics. Bhu-JalNews6(1):1162.

CENTRAL GROUND WATER BOARD (CGWB) 1995. Groundwater Resources of India. Faridabad: MinistryofWaterResources,GovernmentofIndia.

CHOPRA K, KADEKODI G K and MURTY M N. 1990. Participatory Development: PeopleandCommonPropertyResources.NewDelhi:SagePublicationsLtd.

CIRIACY-WANTRUP S U and BISHOP R C 1975. 'CommonProperty' asaConceptin Natural ResourcesPolicy.NaturalResourcesJournal,15:713-727.

COMMAN 2005. Community Management of Groundwater Resources in Rural India: Research Report. British Geological Survey Commissioned Report, CR/05/36N

DHAWAN B D 1988. Inter-Source Differences in Productivity of Irrigated Agriculture. Irrigation in India's Agricultural Development: Productivity, Stability,Equity.B.D.Dhawan.NewDelhi,Sage:114133.

GALE IN, NEUMANN I, CALOW R C, MOENCH M 2002.Theeffectivenessofartificial recharge of groundwater: a review. British Geological Survey Commercial ReportCR/02/108N.

GALE I N, MACDONALD D M J, NEUMANN I and CALOW R C 2003. Augmenting Groundwater Resources by Artificial Recharge AGRAR Phase 2 Inception Report. British Geological Survey Commissioned Research Report CR/03/028C.

KERR J, PANGARE G, PANGARE V L, GEORGE P J and KOLAVALLI S 1999. Introduction to: Participatory Watershed Development: Challenges for the Twenty-First Century, edited by John Farrington, Cathryn Turton and A J James.OUP.

KULKARNI H 1998. Watershed development and management a movement seekinginputsinearthsciences. Journal, Geological SocietyofIndia:52(2), 239-241.

KULKARNI H, DEOLANKAR S B, LALWANI A, JOSEPH B and PAWAR S 2000. Hydrogeological framework for the Deccan basalt groundwater systems, west-centralIndia.HydrogeologyJournal:8,368-378.

KULKARNI H, SHARMA S, BADARAYANI U, MUDRAKARTHA S, PALANISAMI K, RATHORE M S, MADHUSOODHANAN M P, and SRINATH J 2003. CommunityManagement of Groundwater Resources in Rural India: Reconnaissance Case Studies. AdvancedCenterforWaterResourcesDevelopmentandManagement.

KUMAR MD, CHOPDE S, MUDRAKARTHA S and PRAKASH A 1999. Addressing Water Scarcity: Local Strategies for Water Supply and Conservation Management in the Sabarmati Basin, Gujarat. In, Rethinking theMosaic: Investigations intoLocalWaterManagement.EditedbyMarcusMoench,ElisabethCaspari andAjayaDixit.ISET,Colorado,USA.

KUMAR M D and SINGH O P 2001."Marketinstrumentsfor demandmanagement inthefaceofscarcityandoveruseofwaterinGujarat,WesternIndia."Water Policy,3:387403.

LEACH M, MEARNS R and SCOONES I 1997. Challenges to community-based sustainable development: dynamics, entitlements, institutions. In: Community-based sustainable development: consensus or conflict? IDS Bulletin 28(4),October1997.

LOBO C and PALGHADMAL 1999. In fertile ground: the impacts of participatory watershed management(Eds. Hinchcliffe F, ThompsonJ,Pretty J,GuijtI& Shah P).ITPublications,London.

MACDONALD D M J, KULKARNI H, LAWRENCE A R, DEOLANKAR S B, BARKER J A and LALWANI A B 1995. Sustainable Groundwater Development of hard-rock aquifers : the possible conflict between irrigation and drinking water suppliesfromtheDeccanBasaltsofIndia.BritishGeologicalSurvey(NERC) TechnicalReportWC/95/52,54.

MALIK R P S 1993. Electricity Pricing and Sustainable Use of Groundwater: Evaluation of Some Alternatives for North-West Indian Agriculture. WorkshoponWaterManagement: India's GroundwaterChallenge,VIKAST, Ahmedabad,India.,VIKSAT.

MEARNS R1995.Community,CollectiveActionandCommonGrazing:TheCase of Post-Socialist Mongolia. IDS Discussion Paper 350. Brighton, University ofSussex.

MOENCH M 1991. Groundwater and Electricity Co-management: Generating new Options. Farmer Management of Groundwater Irrigation in Asia, Dhaka, Bangladesh, International Irrigation Management Institute, Colombo,SriLanka.

MOENCH M 1992. "Drawing Down the Buffer." Economic and Political Weekly, XXVII(13):A7A14.

MOENCH M 1992. "Chasing the Water Table." Economic and Political Weekly, XXVII(13):A171A177.

MOENCH M 1994. "Approaches to Groundwater Management: To Control or Enable."Economic&PoliticalWeekly(September24):A135A146.

MOENCH M 1994. "Hydrology Under Central Planning: Groundwater in India." WaterNepal,4(1):98112.

MOENCH M (Ed.) 1995. Electricity Prices: A Tool for Groundwater Management inIndia.Ahmedabad,VIKSAT.

MOENCH M and KUMAR D 1995. Distinctions between "Efficiency" and "Sustainability: The role of energy prices in groundwatermanagement. The Challenge of the Ballance: Environmental Economics in India. A. Agarwal. Centre for Science & Environment, New Delhi, Centre for Science & Environment:305-309.

MOENCH M 1996. Groundwater Policy: Issues and Alternatives in India. Colombo,InternationalIrrigationManagementInstitute.

MOENCH M, DIXIT A, JANAKARAJAN S, RATHORE M S and MUDRAKARTHA S 2003.The Fluid Mosaic: Water Governance in the Context of Variability, Uncertainty and Change. Kathmandu, Nepal Water Conservation Foundation and the InstituteforSocialandEnvironmentalTransition.

MUDRAKARTHA S 2002. Negotiating a People-Based Governance Institution for Sabarmati Management: The Gujarat Experience. Paper presented at International Workshop on Deliberative Democracy-Negotiated Development: Prospects for Multi-Stakeholder Platforms in Water ResourcesManagementinIndia.Hyderabad,India.February.

MUDRAKARTHA S, MADHUSOODHANAN M P and SRINATH J 2003. Community Management of Groundwater: A Study of Bhanavas, Samrapur and Nana Kothasana Villages of Satlasana Taluka, Mahesana District, Gujarat. VikramSarabhaiCentreforDevelopmentInteraction.

NAGARAJ N and CHANDRAKANTH M G 1993. Irrigation in Hard Rock Areas of the Deccan Plateau: Estimation of Willingness to Pay. Workshop on Water Management:India'sGroundwaterChallenge,VIKSAT,Ahmedabad,India.

NARASIMHAN T N 1990. "Groundwater in the Peninsular Indian Shield: A Framework for Rational Assessment." Journal of the Geological Society of India,36:353363.

ODI 2000. Panchayat Raj and Natural Resources Management: How to DecentraliseManagementOverNaturalResources NationalLevelSituation Analysis and Literature Review. Overseas Development Institute, October 2000.

OIKOS and IIRR 2000. Social and Institutional Issues on Watershed ManagementinIndia.

PALANISAMI K and BALASUBRAMANIAN R 1993. Overexploitation of Groundwater Resources: Experiences from Tamil Nadu. Workshop on Water Management: India's Groundwater Challenge, VIKAST, Ahmedabad, India, VIKSAT.

PALANISAMI K, TIRUMOORTHY S and GANAPATHY L 2003.CommunityManagement of Groundwater Resources in Rural India: A Case Study of Kattampattiand Kodangipalayam Villages in Coimbatore District of Tamil Nadu. Water TechnologyCentre,TamilNaduAgriculturalUniversity.

RAMA MOHAN RAO M S, BATCHELOR C H, JAMES A J, NAGARAJA R, SEELEY J and BUTTERWORTH J A 2003. Andhra Pradesh Rural Livelihoods Programme WaterAuditReport.APRLP,Rajendranagar,Hyderabad500030,India.

RATHORE MS2003.CommunityBasedManagementofGroundwaterResources: A Case Study of Arwari River Basin, Alwar District, Rajasthan. Institute of DevelopmentStudies,Jaipur.

SAXENA N C and FARRINGTON J 2003. Trends and Prospects for Poverty Alleviation in Rural India: Context and Options. ODI Working Paper 198, May2003.

SHAH M, BANERJI D, VIJAYSHANKAR P S and AMBASTA P 1998. India's drylands : Tribal Societies and Development through Environmental Regeneration. OxfordUniversityPress,NewDelhi.322.

SHAH T, ALAM M, KUMAR M D, NAGAR R K and SINGH M 2000.Pedalpump andthe poor: Social impact of a manual irrigation technology in South Asia. WorkshoponPoverty,Gender andWater inSouthAsia,Ahmedabad,India, 10-11August2000.38p.

SHAH T, SCOTT C, KISHORE A and SHARMA A 2003. Energy-Irrigation Nexus in South Asia: Improving Groundwater Conservation and Power Sector Viability.Colombo,InternationalWaterManagementInstitute:27.

SHAH T, ROY A D, WURESHI A S and WANG J 2003."SustainingAsia'sgroundwater boom: An overview of issues and Evidence." Natural Resources Forum 27: 130-141.

SINGHA S, GURURANI S and GREENBERG B 1997. The 'New Traditionalist' Discourse of Indian Environmentalism. Journal of Peasant Studies 24(1): 65-99.

VAIDYANATHAN A 1991. Critical Issues Facing Indian Irrigation pp 8-26: in Meinzen-Dick R. & Svendsen, M. (eds.), Future Directions For Indian Irrigation: Research and Policy Issues, International Food Policy Research Institute,Washington,D.C.pp333.

WADE R 1988. Village Republics: Economic Conditions for Collective ManagementinSouthIndia.Cambridge:CambridgeUniversityPress.

WORLD BANK and MINISTRY OF WATER RESOURCES - Government of India 1998. India - Water Resources Management Sector Review, Groundwater Regulation and Management Report. Washington D.C., New Delhi, World Bank,GovernmentofIndia.

WORLD BANK STUDY TEAM 2001. India Supply of PowertoAgriculture:Working Note.Delhi,WorldBank:28,7February2001.Appendix Projectoutputs

APPENDIX PROJECT OUTPUTS

Project reports

Comman 2002. Community Management of Groundwater Resources in Rural India: Project Inception Report. British Geological Survey Commissioned Report,CR/02/80C.

Comman 2005. Community Management of Groundwater Resources in Rural India: Research Report. British Geological Survey Commissioned Report, CR/05/36N

Working documents

KulkarniH,SharmaS,BadarayaniU,MudrakarthaS,PalanisamiK,RathoreM S, Madhusoodhanan M P, and Srinath J 2003. Community Management of Groundwater Resources in Rural India: Reconnaissance Case Studies. AdvancedCenterforWaterResourcesDevelopmentandManagement.

Mudrakartha S, Madhusoodhanan M P and Srinath J 2003. Community Management of Groundwater: A Study of Bhanavas, Samrapur and Nana Kothasana Villages of Satlasana Taluka, Mahesana District, Gujarat. Vikram SarabhaiCentreforDevelopmentInteraction.

Palanisami K,TirumoorthySandGanapathyL2003.CommunityManagement of Groundwater Resources in Rural India: A Case Study of Kattampatti and Kodangipalayam Villages in Coimbatore District of Tamil Nadu. Water Technology Centre,TamilNaduAgriculturalUniversity.

RathoreMS2003.CommunityManagementofGroundwaterResources:ACase StudyofArwariRiverBasin,AlwarDistrict,Rajasthan.InstituteofDevelopment Studies,Jaipur.

British Geological Survey 2005

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