

RETHINKING THE MOSAIC

Investigations into Local Water Management



Themes from Collaborative Research

- Institute of Development Studies, Jaipur
- Institute for Social and Environmental Transition, Boulder
 - Madras Institute of Development Studies, Chennai
 - Nepal Water Conservation Foundation, Kathmandu
- Vikram Sarabhai Centre for Development Interaction, Ahmedabad

Edited by
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1999

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Institute of Development Studies (IDS)
Institute for Social and Environmental Transition (ISET)
Madras Institute of Development Studies (MIDS)
Nepal Water Conservation Foundation (NWCF)
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Supported by International Development Research Centre (IDRC)
Ottawa, Canada and The Ford Foundation, New Delhi, India

First Edition: 1000
December, 1999.

Price
Nepal and India Rs 1000
Foreign US\$ 30
Other SAARC countries US\$ 25.
(Postage charges additional)

Published by: Nepal Water Conservation Foundation, Kathmandu,
and the Institute for Social and Environmental Transition, Boulder,
Colorado, U.S.A.

DESIGN AND TYPESETTING
GraphicFORMAT, PO Box 38, Naxal, Nepal.

PRINTED AT
Jagadamba Press PO Box 42, Patan Dhoka, Nepal.

Acknowledgments

The research programme was undertaken through grants from the International Development Research Centre (IDRC) and The Ford Foundation, New Delhi. Their support and patience is gratefully acknowledged. The Pacific Institute for Studies in Development, Environment, and Security provided much needed support. Special mention is also essential for the careful and detailed work on document layout and map design done by Anil Raj Shrestha and Sunil Shrestha of GraphicFORMAT. Ajaya Dixit supervised production of this publication. Opinions expressed in the papers are those of the authors, not the editors or the organizations supporting the research. Kanchan Dixit also provided much needed support. Thanks are also due to everyone who has contributed views and insights at different stages of the research programme. Photographs were contributed by Marcus Moench, Ajaya Dixit, Dipak Gyawali, Salil Subedi, S. Janakarajan and VIKSAT.

About the Study

This is the report of the first phase of the collaborative program on Local Supply and Conservation Responses to Water Scarcity supported by the International Development Research Centre (IDRC) and The Ford Foundation. The study investigated water management issues of four river basins: the Palar, the Sabarmati, and the Shekhawati in Tamil Nadu, Gujarat, and Rajasthan respectively as well as the Tinau in Nepal that joins the West Rapti in Uttar Pradesh. Water management challenges in the Noyyal and the Bhavani basins of Tamil Nadu were also investigated.

In the first three basins, water scarcity is an increasingly grim reality. The organizations and their principal investigators have extensive experience in analysing water management issues in scarcity situations. The fourth river basin was selected to capture the physical diversity of a Himalayan river and to analyse the water management concerns in an area of Nepal and India that is ostensibly rich in water resources but is beginning to confront a situation of stress.

Though collaborative, the study implementation did not provide scope for the kind of process envisaged in the design. As such, methodological differences are evident. While studies in India followed the social science research model, the study on the Tinau used an ethno-ecological approach. The collaborative exercise, however, did include series of meetings and sharing of research tools as well as ideas. Three major events were the April 1998 Writing Workshop in Kathmandu, the January 1999 Chennai Meeting and the May 1999 Ahmedabad Workshop where the findings of the study were reviewed, analysed and critiqued. There were regular interactions via email as well as joint field visits.

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LOCATION OF RIVER BASINS



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PREFACE

In many cases, local management seems to be approached as a small-scale version of larger levels of organization.

From the Ganga in the north to the Cauvery in the south, rivers of South Asia have carried the political, economic and social history of the region with them. As they flow from the highland ranges of the Himalaya, Western Ghats or the Aravallis towards the Bay of Bengal or Arabian Sea, these rivers have become intertwined with the hopes and aspirations of the people who live in their basins. Today, water systems in the region are under stress. Growing demands from agriculture, industry and urban growth stretch available supplies while pollution undermines the quality of the resource base. Addressing these problems will require a level of understanding and management far beyond that needed during the entire previous history of water development. Building the institutions and scientific understanding essential to enable management represents one of the most important challenges facing the region. In many ways, this challenge is one of understanding social change and its dynamics. Approaches to it stem from concepts – either implicit or explicit – regarding the role of different groups within society and of the state and also why individuals and groups behave the way they do. These underlying concepts, and the differing sets of assumptions social actors make based upon them, are rarely explicit in debates over water management. The set of papers in this volume represent an initial effort to clarify key elements in debates over the role of decentralized, “local” institutions and the participatory processes necessary to initiate effective water management.

“Local,” “participatory” approaches to water management are often proposed as alternatives to large scale centralized initiatives managed by the State. While centralized State initiatives draw on a long history of water resources development, relatively few data exist on the nature and limitations of more localized approaches. In addition, the terms “local” and “participatory” are vague. What “local” and “participatory” mean is unclear both in terms of physical scale and the social processes involved. In many cases, local management seems to be approached as simply a small-scale version of larger levels of organization. Local management organizations are expected to take on a similar array of functions (though scaled down and requiring less technical expertise) as their larger State cousins and are even characterized as operating through a similar analytical decision-making process. Where scale is concerned, they are intended to take responsibility for a hydrologic unit or water delivery system (aquifer, river basin, irrigation system or municipal supply facility). This “local” hydrologic unit or system is seen as a single element among an array of other similar local elements that are governed at some ultimate level by the State.

More often than not, the existence of such an “overall system” is itself an assumption, as is the belief at the central levels that local management units are

To force local water management systems into a unitary framework based on how they "should" work is unrealistic.

similar or guided by similar sets of management concerns. This hierarchic "rationalist" model is rarely explicitly spelled out but implicitly underlies many recent attempts to develop "local", "participatory" water management organizations. The development of water user associations in surface irrigation systems is, for example, a major case in point. In contrast to the model, local systems (as the cases in this volume show) are richly heterogeneous in their management styles and objectives. Attempting to force them into a unitary framework based on how they "should" work is unrealistic. Similarly, the "overall system" itself is a policy terrain that is contested at various levels.

The rationalist model of policy reform and management is implicitly based on concepts of social behaviour and the role of organizations that are far removed from local dynamics. In the assumed model, arguments for policy reform are developed from careful multi-disciplinary analysis and directed to high-level decision makers. These decision makers are assumed to be patriarchal rationalists who synthesize available information and make informed, objective decisions within the constraints imposed by an external unruly world. In practice, policy decisions are widely recognized as occurring within a complex environment in which numerous social actors cognize and strategize with varying degrees of certainty or objectivity. The lack of progress in developing effective water management approaches is often viewed as related to these inherent imperfections in decision-making. This is, however, often not seen as a fundamental flaw in the model. Instead, failures are generally attributed to "external" factors such as "lack of political will," "vested interests" or "imperfect information."

Initiating local management within this hierarchic framework is generally portrayed as a process of policy reform. Organizational models are developed and tested through policy research and pilot projects. Analysts evaluate pilot project results and recommend appropriate policy changes to higher-level decision-makers. Once decisions are made, policy reforms are assumed to take place enabling widespread formation of "improved" (that is more local and participatory) management organizations. These organizations are then assumed to be capable of "managing" local water resources through a relatively standard array of planning, regulatory, monitoring, technical and other techniques.

While the papers in this volume do not analyse policy reform models directly, taken together they suggest a fundamentally new approach to the evolution of effective management responses. All the case studies highlight the dynamic interlinkage between physical water resource systems and the larger social, economic and institutional context within which they are managed. The studies also highlight the wide variety of actors whose individual or collective decisions influence water use patterns and, ultimately, water management needs and options. Together they imply that, rather than the hierarchic and prescriptive top down reform model underlying most conventional policy analysis, reform must involve a much more open, non-linear and on-going process of social dialogue and debate. This flexible "bottom-up" approach is essential if complex water management systems are to be nudged toward less stressful and conflict ridden paths in the future.

The effectiveness of this process is dependent on recognizing three strands in an overall

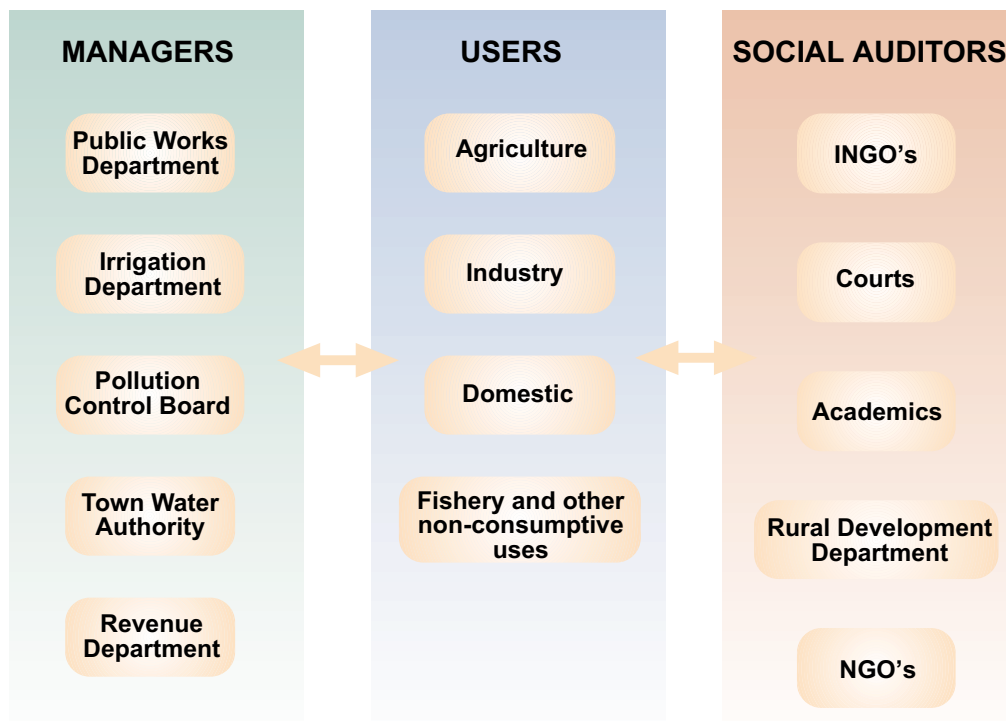
management triad that need to be in dynamic and creative engagement. The difference between the model of policy reform suggested here and the linear model assumed in most water management debates is outlined below. At the centre of this perspective lie water users in all their diversity. As the first strand in the triad, they are not mute, atomized and passive actors that will do as they are told. On the contrary, they actively cognize, strategize and make decisions – individually and collectively – to further what *they* perceive to be *their* advantage. These interests more often than not differ from those that water managers (the second strand in the triad) may prescribe. This discrepancy between what the users want and what the managers think they “should” want cannot be resolved within the hierarchic “rationalist”

model, which essentially upholds the principle of institutional monism.

The third strand consists of what we call “social auditors”. They are the “watch dog” social activists as well as various organs of the state that are responsible for assuring appropriate justice. They are not users or managers, and their concerns often stem from different callings – those of equity, sustainability and fair play. Linear policy models that account for the users at the bottom and the managers at the top are often at a loss when these actors enter the fray – often in the event that contradictions emerge between the avowed objectives of management and its practice. Except for extreme cases of bureaucratic rigidity, social auditors from the activist mould and from within

Reform must involve a much more open, non-linear and on-going process of social dialogue.

Figure 1:
Stakeholders' framework.



Actions that strengthen capability to engage in social dialogue are essential in order to create will necessary for effective implementation of management activities.

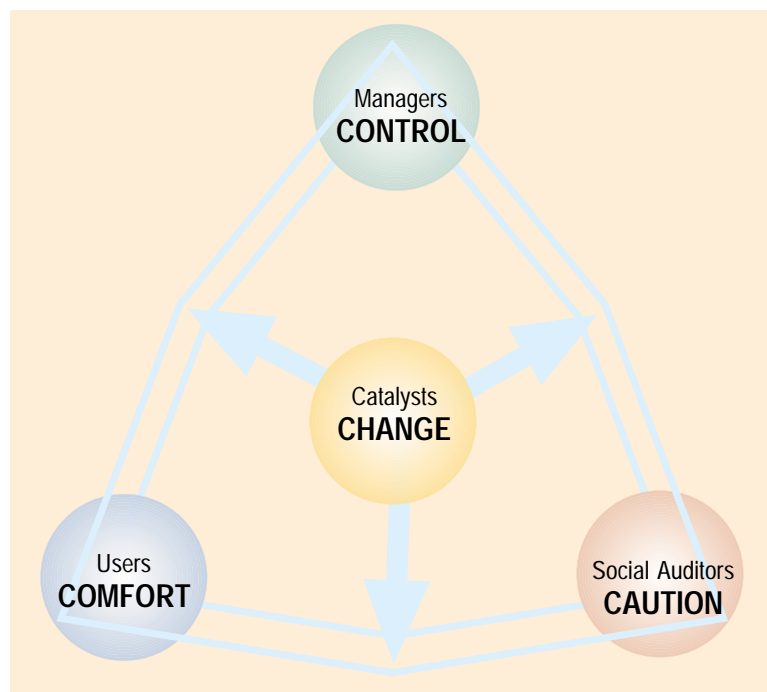
the government do often work together to assure proper functioning by the concerned water bureaucracy. They also often act as catalysts for change. Furthermore, even as the managers of a department may advocate hierarchical administrative approaches to water management, significant sections of the state machinery, including the judiciary and units of local governance, often assert themselves in upholding points of equity, democratic process and social justice. These catalyzing changes can thus come from any section.

The above approach to understanding and approaching water management is a dynamic one based on social process. In it, as with any democratic constitution or pluralistic scheme, the

question of the balance of power is central. It implies that the conventional emphasis placed in the past decades on “omniscient managers” engaged in new development or construction needs to be shifted to “cautious managers” operating in a context rife with uncertainties and where courses of action are contested by auditors and users.

The point for those seeking reform has to do with “where one hits it.” Does one attempt to address water problems through the planning and linear decision-making mode – or through approaches that seek to alter the complex interplay of different social groups and the balance of power within society. Taken together, the papers in this volume suggest that the second approach is of fundamental importance. Actions that strengthen organizations capable of engaging in social debate and provide them with the information essential to do so on an informed basis are needed in order to create the political will essential for the formation of effective institutions and the implementation of management activities. Changing water use and allocation patterns affects basic livelihoods and the value systems of many groups in society. As a result, water management is inherently a political process. In addition, in order to be effective, approaches must respond to the highly varied and dynamic nature of local contexts. Both of these depend on a broad base of social dialogue. Linear policy analysis directed toward formal decision makers represents an important counterpart to this social dialogue. It is, however, unlikely to be sufficient. While most efforts to develop approaches and institutions for local water management have implicitly assumed a linear model of policy reform, the papers in this volume suggest a wider process, in which catalysts and social auditors play major roles, is essential.

Figure 2:
Three strands of effective water use.



C H A P T E R

1

**Addressing Constraints in
Complex Systems**

***Meeting the Water Management Needs
of South Asia in the 21st Century***

Marcus Moench

Water management is inherently a question of governance. Water related issues ripple throughout society and affect basic livelihoods and deeply embedded social values. As a result they must be addressed at a societal level through the complex array of political, economic, institutional and social processes by which society governs itself. That is, perhaps, the single most important theme running throughout research by the collaborative group and, as a result, this paper:

Objectives

Water management represents one of the most fundamental challenges facing South Asia in the 21st century. Over the last century, increases in irrigation provided the foundation on which agricultural growth, poverty alleviation and ultimately the growth of national economies have rested. Progress has been substantial, but much of it may prove unsustainable. In many areas, pollution, groundwater overdraft, water scarcity and the unanticipated impacts of human actions on complex water systems threaten both the environment and the economic foundations of society. The problem is not just one of water scarcity or resource degradation. Land use changes and rapid increases in the population living within flood zones underlie major increases in both flooding and its impacts. Maintaining the environment while meeting the basic food, domestic and quality of life needs of growing populations in South Asia will require fundamental changes in the way water resources are used and managed. Furthermore, much of the physical and institutional infrastructure for water management created over recent decades is poorly designed and decaying. The costs of system reform and

rehabilitation strain national accounts. For investments to be effective, fundamental changes in physical and institutional infrastructure are needed.

Fundamental change is easy to recommend but hard to implement. Conditions and management needs evolve over time and the physical nature of water resource problems varies between locations and scales of management or analysis. Cultural, economic and political contexts also vary and with them the social viability of different management interventions. Furthermore, institutions – although often vibrant when new – rapidly become rigid and entrenched, unable to respond to changing conditions. In combination, the above factors necessitate water management strategies capable of producing effective action within socially complex and continuously evolving contexts. Strategies dominating current debates over water resource issues provide, at best, a partial basis for this.

The purpose of this report is to present preliminary results from a series of case studies undertaken by the collaborative project on

Conditions and management needs evolve over time.

Local Supply and Conservation Responses to Water Scarcity and to propose a research and action programme through which results can be confirmed, new insights gained and implementation catalysed. In addition, the report identifies conceptual insights that are practically and strategically central to addressing South Asia's water management challenges in the 21st century. These insights have been identified on the basis of case studies and a wider analysis of water management issues. They address key gaps in currently dominant approaches to water management and suggest new strategies for action and research.

Preliminary Implications for Policy and Implementation

The tremendous diversity of problems, contexts and opportunities for water management that exist in local areas is the primary initial result of the collaborative research project on Local Supply and Conservation Responses to Water Scarcity. This result is, in one sense, trivial – saying that conditions vary greatly between areas isn't a particularly profound insight. In another sense, however, the result is far from trivial. The history of water management is, in many ways, a history of searches for universally applicable solutions. The “development era” focused on construction of large-scale infrastructure projects – dams, municipal supply systems, irrigation systems and embankments – as the single most important set of interventions to meet water management needs. In a similar manner, many now advocate economic pricing, basin approaches, integrated planning, the development of participatory water management institutions and demand side management as “the” solution to management needs. The case studies presented

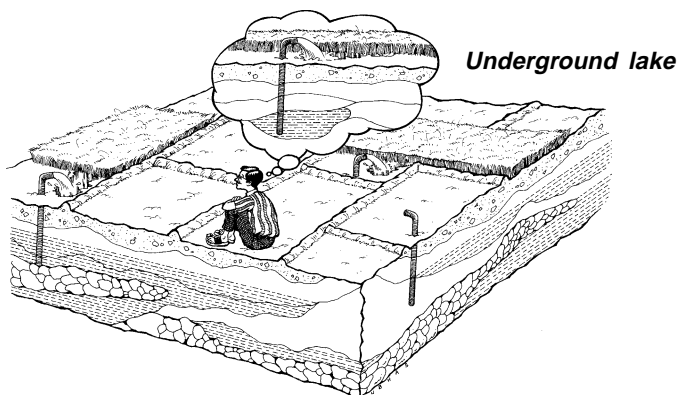
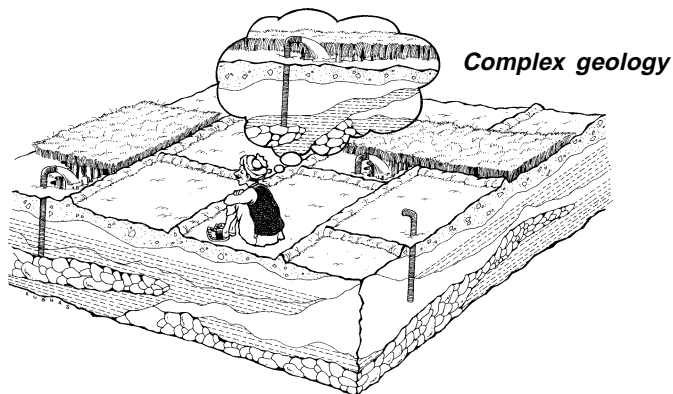
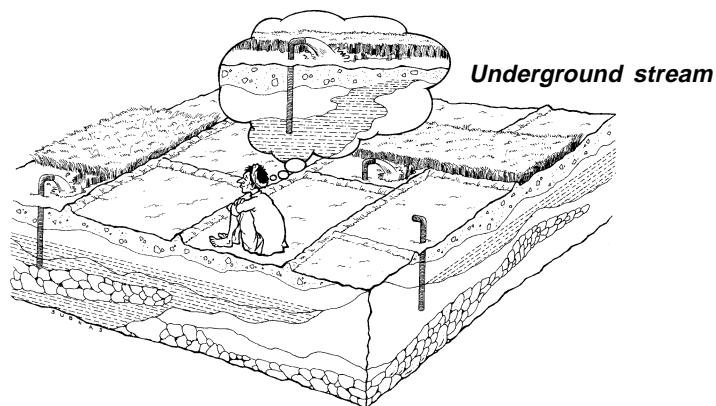
This chapter is organized in the following manner: Key initial results are presented briefly first. The focus then shifts to conceptual insights generated by the collaborative research. These conceptual insights are of equal importance as the more immediate policy results because they help to clarify key elements in the underlying frameworks that ultimately shape approaches to water management. Emerging physical and social issues are discussed next with particular reference to the conceptual elements. The final section identifies ways forward both for approaches to water management in general and for the collaborative project itself.

here, in contrast, highlight the potential role multiple sets of management actions at different levels of intervention might play in meeting management needs within different areas. We do not see any particular set of water management interventions *per se* as having universal applicability – too much depends on the local context.¹ Furthermore, socioeconomic and political considerations in all localities often dominate other considerations in determining the types of interventions that could, practically, be implemented.

The diversity of local contexts and the dominant role of social and political considerations leads to what we see as a broadly applicable and an important result for the study. Society's ability to respond to local water management needs depends on information and understanding of emerging problems. Beyond this, it is primarily an issue of governance, process and the structure of civil society.

Society's ability to respond to local water management needs is primarily an issue of information, governance processes and the structure of civil society.

**Aquifer conditions and human perceptions:
One reality, many visions**



Unless broad groups of stakeholders understand emerging problems and have an effective voice in the formulation of management approaches, solutions will not evolve, will be stymied by lack of support or will benefit only narrow elites. As the diagram on this page illustrates, perceptions of water resources often vary. Interventions that strengthen the ability of different groups to engage in *informed* dialogue within civil society are probably the single most important avenue for addressing water management needs at all levels.

The above results have major implications for water policy and implementation activities in India and Nepal. Instead of implementation policy reforms of the type often advocated, however, the results suggest that key points of leverage for addressing water management needs lie in:

1. systems that enable public access to key water resources information;
2. the location of administrative frameworks and processes for water management that enable wide-spread public involvement and give water users a clear role in decision-making processes; and
3. the development of analytical and advocacy organizations with public information mandates that are capable of addressing the socioeconomic dimensions of water management as well as the technical.

Conceptual Insights

“The proposed new approach to managing water resources builds on the lessons of experience. At its core is the adoption of a comprehensive policy framework and the treatment of water as an economic good, combined with decentralized management and delivery structures, greater reliance on pricing, and fuller participation by stakeholders.” (World Bank, 1993)

Conceptual frameworks are important. They form the basis for management initiatives implemented by NGOs, state and national governments and international donor agencies. They are also used as a basis for advocating policy and legal or legislative reforms. The conceptual frameworks that guide most current water management initiatives are, at best, partial. They capture or reflect important factors affecting society’s ability to manage water resource but also often obscure key issues or contain limitations. The World Bank’s Policy Paper on *Water Resources Management* (quoted above) reflects some of the conceptual themes that run through water management dialogues worldwide including:

Economics: The need to recognize the economic value of water and treat it as an economic good;

Integration: The need for integrated approaches to water management and the development of comprehensive policy frameworks that address the needs of multiple users including the environment;

Participation and Decentralization: The need to involve stakeholders in water management initiatives and decentralize delivery of water services for effective management;

Institution Building: The need to create organizations, rights structures and legislative

frameworks at local, regional, national and international levels that can provide a framework for implementing water management actions;

Basin Management: The need to manage water resources within natural units – generally river basins;

Sustainability: The need to manage the water resource base so that it is passed on undiminished in quantity and quality to other users and future generations.

Each of the above concepts reflects a history of research and practical experience. The concepts capture key insights important to effective water resource management. Yet each concept contains inherent limitations. These limitations – and the sometimes perverse results they generate in the context of management initiatives – are important to recognize. Of more importance, however, is the identification and development of new or under emphasized concepts that help address these limitations.

Field case studies and broader analysis by participants in the collaborative research programme have resulted in the identification of five broad conceptual elements that are, to greater or lesser degrees, under-represented in current water management debates and yet appear central

The conceptual frameworks that guide most current water management initiatives are, at best, partial. New concepts are essential.

to society's ability to address critical challenges. These are:

- the importance of an enabling civil environment;
- the process nature of management;
- integrated response sets;
- water service focus; and
- trend reflective management.

Political will reflects the balance of power in society. Well informed groups develop their own perspectives.

In many ways, the above concepts represent a fundamental divergence in world view between a static perspective in which water resource systems can be understood and optimized to meet society's needs and a dynamic perspective that emphasizes the dynamic interlinked nature of water resource and other systems and the limitations of human understanding. The first world view tends to lead to technically dominated planning approaches that attempt to comprehensively describe and manage systems through manipulation of stocks and flows. The second, which we articulate, emphasizes processes and frameworks for responding to uncertainty as needs arise. Water management issues are seen essentially as issues of governance within a larger civil society context. They cannot be addressed without both understanding and social dialogue.

Enabling Civil Environment

The concept of an enabling civil environment, while often implicit, has received little explicit attention in debates over water management. The core idea is that management can only occur if the institutions that define civil society are functioning in ways that enable management system evolution and implementation.

Water management plans developed by specialists and targeted at audiences of "key decision makers" often come to naught. In many cases, technical experts and policy analysts identify "lack of political will" as a key cause. Absence of "political will," however, generally does not reflect the characteristics of individual politicians but the larger balance of power within society. When large sections of society are disenfranchised or lack information and understanding, they are not in a position to identify, advocate or protect their interests. As a result, special interests (which are often better informed or represent elite groups of water users) are in a far better position to influence government actions in ways that benefit themselves. Furthermore, in many cases, lack of information and understanding leads the very groups most affected by problems to oppose actions intended to address those problems. This type of dynamic is implicitly recognized by most professionals and underlies public IEC (information-education-communication) components in water management projects or programmes.

The enabling civil environment concept, however, extends beyond the simple IEC approach common in water management. IEC elements are generally included in management programmes on the premise that, if the public understands what *we* (the specialists) are trying to do, then they will support *our* management recommendations. Society rarely works that way. Well-informed groups – groups with access to information and the capacity to analyse it – develop their own perspectives. These perspectives often differ from those of technical managers. In contrast to the standard IEC approach, the concept of an enabling civil environment focuses on the process of

negotiation within society. It emphasizes giving stakeholders the sets of analytical, legal, institutional and organizational tools essential to develop and advocate their perspectives rather than viewing the stakeholders as obstacles to “be convinced” through information, education and communication.

The concept of an enabling civil environment locates the foundations of management action in negotiations between groups and perspectives within civil society. When the balance of power within society is weighted against those most affected by water problems, effective approaches to management are unlikely to evolve. This is particularly true when essential management actions directly affect groups with substantial political, economic or social capital. In order to negotiate effectively, those affected by water problems must have information. Organizations must also exist that adequately represent affected groups, have the capacity to analyse information and develop management proposals, and are in a position to advocate the perspectives they develop within larger governmental frameworks. Appropriate legal and legislative frameworks are a further essential component. Unless legal frameworks give groups the basis and standing to catalyse action, the perspectives of those groups and the values they seek to protect will be at a comparative disadvantage to those of other groups. If no law against groundwater pollution exists, for example, or if the pollution law only empowers governmental action, groups affected by pollution will be excluded from legal courses of action. Similarly, where recognized legal frameworks limit organizational options, the evolution of advocacy and management organizations is constrained. The evolution of

pollution legislation in India provides some insights into the legal frameworks that can enable actions within civil society, (Box 1).

The significance of an enabling civil environment for the evolution of water management has immediate practical implications for those seeking to address emerging problems. It suggests that indirect actions to increase information availability, the capacity of non-government and grass roots advocacy organizations, and legal rights frameworks are at least as important as more direct management initiatives. In the absence of initiatives to create enabling civil environments, many technically viable management approaches will fail because the balance of power in society reduces their political or social viability. In addition, the enabling civil environment concept addresses gaps in two principles – participation and institutional capacity building – which are core components of many current water management initiatives.

The need to “involve” local users in initiatives is now central to most prescriptions for natural resource management. In many cases, however, there is little real “participation.” Information, problem identification, management approach development and decision-making functions remain within the government departments. These government departments operate within constraints imposed by the larger political-economic structures that define power relations in society. Because participatory approaches rarely involve actions or structural changes intended to influence those power relations, the scope for “real” participation by affected communities in the identification, development and implementation of management initiatives is limited. In the absence of an enabling

Indirect actions to increase information availability, the capacity of NGOs and reform legal rights frameworks are as important as direct management initiatives.

BOX 1: Enabling Civil Society, the Case of Pollution in India

Until the early 1970s, few legal avenues existed to address pollution problems in India except those implicit in certain constitutional provisions. Article 21 of the Constitution of India, for example, guarantees protection of life and personal liberty; Article 47 of the Constitution states that it is the primary duty of the State to raise the level of nutrition and of the standard of living and to improve public health; Article 48A indicates that the State shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country; and Article 51(A)g explicitly requires the State to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures. The above articles provided a potential basis for action to address pollution problems but, in the absence of action at the Supreme Court level, gave little basis for practical initiatives at local levels in the context of specific pollution problems.

After the United Nations conference on the Human Environment held in Stockholm in 1972, where India expressed strong environmental concerns, the 42nd amendment to the Constitution was passed. This enabled enactment of a series of environmental protection laws such as The Water (the prevention and control of pollution) Act, 1974, the Air (the prevention and control of pollution) Act 1981 and the Environment Protection Act, 1986. The Water

Act, 1974 enabled the formation of the Central Pollution Control Board and the formation of various State Pollution Control Boards. While the former functions directly under the control of the Government of India, the latter function under the control of the various state governments. The Water Act prohibits the use of streams and wells for disposal of polluting matters, puts restrictions on outlets and discharge of effluents without obtaining consent from the various pollution control boards. The Environment Protection Act of 1986 also contains very useful provisions. It enables the creation of an authority or authorities under Section 3(3) of the act with adequate powers to control pollution and protect environment. Some states have acted



Tannery wastes: Tamil Nadu

Access to improved information builds social capacity.

civil environment, participatory initiatives often become little more than window dressing.

Institutional capacity building is another key component of most water management programmes. In general it focuses on building the array of technical and analytical skills within government departments and the infrastructure they have available for their functions. The impact of institutional capacity building efforts is, however,

often limited. Improvements in the technical quality of a management plan or the database on which water resource analyses are made have little impact in themselves unless the social context enables utilization of the improved information. When information is not widely disseminated, when non-governmental and advocacy organizations lack analytical capacities and when legal frameworks limit avenues for action by social organizations, building the

on this. For example, the Tamil Nadu government issued Order (Ms) No 213 dated March 30, 1989, which prohibited setting up of polluting industries (including tanneries, and dyeing and bleaching units) within one kilometre of the embankments of rivers, streams or dams.

None of the constitutional provisions and acts, however, have had significant impact on the direct ability of the government to control pollution problems in Tamil Nadu. The government order issued in 1989 has not been enforced strictly and the Tamil Nadu Pollution Control Board which is supposed to monitor and control pollution remains more of a passive spectator than a powerful pollution controlling agency.

Despite the limitations of the above acts, it is primarily due to environmental laws that many NGOs have become active in affected regions. The laws gave NGOs a basis to create awareness among the people and represent their cases to the authorities and in courts of law. The presence of a legal structure also provided a strong reason for NGOs and communities to assess damage caused to the environment, to individuals and to communities by polluters. In some cases, public interest litigation enabled by the legal structure has resulted in significant actions. Public interest litigation filed by the Vellore Citizens' Forum in 1991, for example, sparked off a major judiciary intervention in Tamil Nadu. This has led to the closure of many tanneries and

dyeing and bleaching units as well as having put enormous pressure on them to install treatment plants. In addition, legal action led to a major judgement by the Supreme Court in 1996. Under this judgement the central government has been urged to constitute an authority headed by a retired judge of the High Court to deal with the situation created by the tanneries and other polluting industries in the state. The authority is intended to implement the "polluter pays" principle. It will also assess and help pay compensation to the families affected by tannery pollution. After the Supreme Court judgement, an NGO in the Kodaganar River basin identified 27 villages where land, houses, cattle, crops and the health of villagers have been severely affected and there have been major losses of employment due to pollution. For all these losses the total amount of damage claimed is about Rs. 104 million and the NGO is supporting the community in its pleas for compensation.

Despite the progress pollution legislation has enabled, political parties in the region are not willing to mobilize residents against the polluters. This would antagonize the industrial interests that represent an important source of financial support for political activities. In addition, workers in the industries and the labour unions representing them are a major support base for all political parties. These interests are more concerned with wage issues than organizing to address environmental problems.

S. Janakarajan

institutional capacity of governmental or scientific organizations has little impact on the social or political context. As a result, the impact of institutional capacity building on society's ability to identify and implement effective management actions remains rather limited.

The enabling civil environment concept presumes non-linear approaches to management. Management becomes a continuous process in

which natural resource problems emerge and are addressed – not through the implementation of comprehensive and integrated management plans – but through negotiation between sections of society affected by a given water resource problem and by the types of actions they proposed to address it. In many ways the approach is a pragmatic response to the fact that governmental capacity is extremely constrained. Particularly in the highly populated regions of South Asia, governments lack

**Water
management is
a continuous
process
governed by
non-linear
relationships.**

Constraint analysis can be used to identify management needs and potential points of leverage for addressing them.

the ability to impose management solutions on millions of individual water users. In other ways, however, the enabling civil environment concept reflects deeper beliefs about the importance of democratic institutions and processes. These beliefs are articulated in the constitutions of many states in the region. Emphasis here on the importance of an enabling civil environment for water management flows from this larger democratic framework.

The Process Nature of Management

The enabling civil environment concept reflects the *process* nature of management. From our perspective, management is a process by which institutions (and society as a whole) identify and respond to diverse complex challenges as they emerge within continuously evolving contexts. Although planning may be part of management, the process extends far beyond the preparation and implementation of discrete “plans.” The enabling civil environment is, in many ways, an underlying “framework” defining the boundaries within which management processes run. It also generates management goals and objectives. These goals and objectives will shift as specific needs emerge and the perspectives of different groups within society evolve.

Recognizing the process nature of management complicates definition of the underlying principles needed to give it structure. Without such principles, however, management could easily become “seat of the pants” responses to immediate concerns.

Discussions held between research collaborators on the *Local Supply and Conservation Responses*

to Water Scarcity project resulted in the identification of three basic principles for guiding management processes: (1) Systemic perspectives; (2) Constraint analysis; and (3) Context (scale, institution and trend) reflective responses. These basic principles are discussed briefly below. In addition, integrated resource planning processes are discussed briefly in Box 15 at the end of this chapter. This provides a practical example of the application of process considerations to energy and water planning in other countries.

Systemic Perspectives

Water management problems need to be approached from a systemic perspective but generally cannot be addressed through comprehensive systems analysis. A core distinction is being made here. A systemic perspective recognizes *both* the importance of interactions between systems *and* the limitations of knowledge regarding those interactions. It also emphasizes scale issues. Aquifers or watersheds are not discrete units but operate rather as systems within systems. The scale at which management needs to occur depends on the scale of system processes and interactions. Watershed approaches, when applied to the Gangetic basin at one extreme or a localized pollution problem at the other become meaningless. *Instead of focusing on “local management” or “basin management” the key is to identify the system scale at which different problems need to be addressed.* Furthermore, comprehensive systems analysis presumes an ability to identify and quantify the nature of interactions and to clearly define the boundaries of systems – or at least those of the greatest importance in relation to management needs. This is, however, often unachievable.

The fact that water management problems must be addressed as part of the larger hydrologic system in which they occur is widely recognized. The “systemic” nature of management issues, however, extends far beyond the hydrologic system. Many management issues are rooted in interactions between complex interdependent water resource, economic, environmental, cultural, institutional and social systems. The nature of these interactions, while often important, is extremely difficult to analyse in a systematic and comprehensive manner. In most parts of the world, key data required for comprehensive analysis are unavailable. Furthermore, in many cases the systems themselves are poorly understood. As a result, while the location of water problems within larger sets of interacting systems is widely recognized, the ability to analyse those systems is relatively weak.

The “comprehensive” policy framework recommended by the World Bank and the widespread emphasis given to integrated management approaches in the global water management literature have led to many massive data collection and planning exercises. These often run into fundamental problems due to the scale of the exercise, long lead and analysis times and lack of data. Furthermore, the exercises are difficult to focus and, while useful as mechanisms for compiling information, rarely result in the integrated vision or depth of information needed for a centralized approach to planning and management.

Approaching water management problems from a systemic perspective, rather than attempting comprehensive integrated analysis fits well with the process nature of management. The systemic

perspective encourages recognition of interlinked systems at different levels – within the hydrologic system, and between the hydrologic system and other environmental, economic or social systems. At the same time, by explicitly recognizing the limitations of knowledge concerning system interactions, the concept should encourage the development of mechanisms for responding to uncertainty – that is, the social frameworks needed to guide an ongoing management *process* forward.

Constraint Analysis

Constraint analysis represents a second key principle for guiding management processes. The core idea here is that *within a broader systemic perspective*, analysis of management problems at any given time should emphasize key constraints rather than systems as a whole. In many ways, this is already what people do. Society tends to focus on points where problems are perceived as occurring or imminent. As problems are addressed, attention shifts to new areas. Constraint analysis recognizes and formalizes the incremental “tinkering” nature of social responses to management needs.

The contrast between constraint analysis and integrated planning is fundamental. Approaches based on constraint analysis are problem focused. The principle is to identify problem areas (or potential problem areas) and then trace out the key factors causing those constraints to emerge within interlinked sets of systems. Integrated planning, on the other hand, presumes an ability to describe and understand the systems as a whole first and then to “manage” them in a way that optimizes water resource systems to minimize constraints.

Management issues are rooted in interactions between complex and interdependent water resource, economic, environmental, cultural, institutional and social systems.

Management initiatives need to reflect local contexts and adapt as conditions change.

Context Reflective or Adaptive Responses

Natural variability is a key theme running throughout the water management literature. Hydrologic characteristics vary greatly between locations and at different scales of analysis. This is also the case with social, cultural and economic systems. Management approaches, in contrast, have tended to cluster around individual themes or models. Participatory, “decentralized” approaches are, for example, now competing with centralized planning approaches. Similarly, sectoral “use-based” management structures (focused, for example, on individual irrigation or drinking water systems) are now competing with integrated structures (water resource departments or basin commissions) that focus on multiple uses within hydrologic units such as basins.

There is a disjuncture between the inherent variability of natural and social systems and the tendency for approaches to cluster around a few management models. New management paradigms emerge in response to limitations in earlier ones. When these new paradigms become dominant, their inherent limitations emerge and they are gradually discarded in favor of new “better” paradigms. In many cases, water management paradigms become “solutions” in search of problems.

The principle of context reflective responses is intended to address the above disjuncture. The basic idea is that management approaches need to reflect the characteristics of specific situations (problems, objectives and opportunities) rather than follow narrowly pre-defined models or

philosophies. Constraint analysis can be used to identify management needs and potential points of leverage for addressing them. Once leverage points have been identified an array of potential management responses will emerge through dialogue between civil society actors.² The characteristics of these responses will then determine the approaches appropriate for implementing them.

In many ways, the above principle turns current debates over management on their head. Instead of debating whether or not participatory, decentralized approaches are “better” than centralized approaches for water management in general, the principle suggests working from the specifics of a given problem outwards toward the best solution for addressing it. Some problems may be best addressed through decentralized “participatory” approaches; others may require much more centralized forms of intervention.³

Within the overall principle of context reflective responses proposed, three elements appear particularly important to consider: scale, institutions and trends.

- **Scale:** The scale at which management needs to occur varies greatly in specific situations. Current management philosophy emphasizes the importance of natural hydrologic units – watersheds and aquifers – as management units. While this does reflect essential characteristics of the natural system, many basins (such as the Ganga) are too large to be effectively managed as a single unit. Furthermore, basins rarely coincide with natural units of human organization. As a result, while basins and aquifers are convenient

units from a resource perspective, they are often complicated from a social management perspective.

Many management needs – such as localized overdraft or pollution problems – can be addressed effectively through actions at local or regional scales. Other needs – such as water allocation between upstream and downstream users or the impacts of upstream land use patterns on downstream flooding – have inherent implications at the basin scale. As a result, while the context of any given management need or set of responses within the larger basin system must be recognized, there is no inherent reason for management at a basin scale and there may be good reasons not to do so. Overall, rather than focusing on basins *per se*, the goal should be to ensure that management actions occur within hydrologically viable units. This argument suggests that the scale at which responses to management needs are targeted should depend on the specific context rather than a pre-defined basin or local management strategy. In many cases, nested sets of management approaches will probably be necessary. Some of these would address inherently local issues, others regional and others basin level.

■ **Institutions:** In addition to scale, the nature of existing institutions is a key factor defining the context of any given management need. Cultural groupings, economic institutions (such as markets), private and public sector organizations, and administrative units are critical factors determining the array of social management options. As a result, as in the case of approaches

defined on a watershed versus other basis, the existing institutional landscape should be a critical consideration in developing management approaches. In general, approaches that build off existing institutions and cultural patterns of behaviour wherever possible rather than attempting to develop new ones are likely to be more successful. The guiding principle might be termed “institutional evolution” as opposed to institutional superimposition.

This concept has particularly large implications for debates over local versus governmental and market versus regulatory institutions for management. Rather than start off with an ingrained philosophical perspective regarding one or the other approach, it suggests that the institutional mix appropriate in a given context should emerge based on analysis of options, existing institutions and the larger process of dialogue within civil society.

■ **Trends:** Finally, larger trends within society need to be recognized as part of the management context. In many cases, management approaches are developed with little sensitivity for larger trends within society. The local, village based, management approaches that are often advocated may, for example, conflict with increasing trends toward urbanization in many parts of the world. Similarly, management approaches that advocate, for example, crop shifting or specific types of irrigation technologies may run counter to global market trends. In general, management approaches that build off or are consistent with larger social trends are more likely to be successful than approaches that attempt to run counter to these trends.

The elements of context reflective response are

- Scale
- Institutions
- Trends.

Management approaches need to be developed with more sensitivity to the larger trends within society.

Water Service Focus

Water management debates are often clouded by a strong focus on the water resource system itself rather than on the core environmental and human services it provides. The conceptual distinction being made is of basic importance. Society and the natural environment depend on water resource systems to provide basic services such as access to clean water for basic needs, water for economic uses and instream flows and water quality conditions necessary to maintain biodiversity and ecosystem characteristics. Most people “care” about the maintenance of these basic services rather than about water resource characteristics *per se*.

In most parts of the world, efforts to monitor and analyse the functioning of water resource systems are, at best, loosely tied to the services we actually care about or depend on. Furthermore, the manner in which data (for example on groundwater extraction, surface water diversions, pollution and water quality) are analysed rarely conveys the threats to basic human or environmental services that may be implicit in them.

The case of groundwater in India is illustrative. In India, water levels in monitoring wells are the only groundwater data collected on a regular basis. These data are combined with estimates of other parameters such as pumping to estimate extraction/recharge ratios. These ratios are intended to reflect the sustainability of groundwater use patterns. If extraction increases to the point where it approaches or exceeds recharge, uses are presumed to be unsustainable, and management actions are triggered.

The above approach has a number of fundamental flaws. Data to accurately calculate the extraction/recharge ratio are unavailable and there is substantial uncertainty regarding the real meaning (if any) of published ratios (Moench, 1991). More importantly, however, the water balance estimates, even if accurate, are by themselves a very poor indicator of potential impacts on water services. Water level declines, for example, can affect base flows in streams, surface vegetation communities, pumping costs and access to groundwater by individuals owning shallow wells. They can, as a result, have major implications for environmental values, access equity and agricultural production costs. Water level changes are not linearly related to the extraction/recharge ratio. In many cases, recharge initially increases as water levels decline. Furthermore, the rate of water level decline with pumping depends far more on the characteristics of aquifers than it does on the balance of extraction and recharge. Beyond this it is important to recognize that, in some cases, the sustainability of extraction (as indicated by the extraction-recharge ratio) may not be an appropriate management objective. Groundwater mining may, for example, be appropriate during prolonged droughts or where substantial fossil water resources are available.

The core point in the above discussion is that the relationship between hydrological data and the water services society may care about is neither linear nor transparent. By focusing primarily on the ratio of extraction to recharge, attention is drawn to the water resource base itself and focused on relatively abstract sustainability issues. While the overall sustainability of use patterns is important, it is only one among many potential

management objectives. Furthermore, many key water services can be affected long before there is any real threat to sustainability of the resource base. The above situation is common in most parts of the world. Water resource monitoring systems have generally been devised by engineers and scientists concerned with resource dynamics but little appreciation for the water services that may be of wider importance.

If management is viewed as a process governed by prevailing perspectives within society, then information on hydrologic systems needs to relate to water services in a manner that is accurate and transparent. This “water service” focus should be a basic principle or starting point in the analysis of water resource systems and management needs. Emphasizing water services does not imply any reduction in the need for the basic hydrological data essential to understand water resource dynamics but may often imply a reorientation in the types of data collected, the way they are analysed and how they are presented.

Integrated Response Sets

The principle of integrated response sets stems from recognition that in virtually all cases meeting water management objectives requires multiple forms of intervention. Both the case studies undertaken through this project and the wider literature on water resources emphasize the broad array of environmental, economic and social factors influencing individual water use decisions. In many countries, however, management approaches rely on a very limited set of tools. Furthermore, even where multiple avenues are being tried, they are often applied in a piecemeal, fragmentary manner. India, for example, is

attempting to develop groundwater management approaches based primarily on regulation (Moench, 1994). This neglects the fact that water use decisions, particularly those in the agricultural sector, are dominated by economic, technical, access and system operation considerations. Similarly, in other areas, market based approaches are advocated as “the solution” to most water management and allocation needs. As with regulatory approaches, giving market mechanisms a pre-eminent position neglects the fact that many key water management services (poverty alleviation, environmental maintenance, cultural, and religious) are not reflected in market transactions. In general, integrated response sets should incorporate the following potential spheres of action:

- **Technical and Infrastructure:** Water use technologies and infrastructure have a tremendous impact on management options and needs. As a

The relationship between hydrological data and the water services society may care about is neither linear nor transparent.



Expanding urban sprawl: Rajasthan

result, the technological availability and options for creating or altering infrastructure are central pieces in any integrated set of responses to management needs.

- **Regulation:** Possibilities for regulation and issues regarding who and how regulation might be accomplished are a key part of integrated response sets.

- **Economic and Market:** As previously noted, economic factors are among the most major influencing water use patterns. As a result, avenues for influencing the economics of water use, in particular the price users pay for water, need to be a key component in any integrated set of responses to water management needs. Water prices can be influenced either indirectly (through energy prices, for example) or directly through the creation and functioning of water markets. It is important to recognize, however, that water prices established in either manner are unlikely to reflect the full value of the resource since many uses – such as the role water plays in maintaining

If water resource organizations are established primarily on technical lines, then the perspectives they will tend to promote will be dominated by technical considerations.



Groundwater recharge message: Gujarat

ecological systems – are not reflected in market transactions or easily incorporated in indirect approaches to pricing.

- **Education:** The social nature of the management process necessitates a broad-based understanding of issues and options. In addition, since many water management decisions are made at the level of individuals (how long to irrigate, whether or not to take a long shower, etc...) the degree to which individuals understand water related issues will greatly influence the viability of many management initiatives. Education should thus be a core piece in any integrated strategy.

- **Organization:** The nature and orientation of public and private sector organizations has a large impact on the types of management issues that emerge and how they are addressed. If water resource organizations, such as groundwater departments are organized primarily on technical lines, then the perspectives they will tend to promote will be dominated by technical considerations. Similarly, the structure of local management groups and the resources (technical and otherwise) they can draw on will influence their perspectives and spheres of action. As a result, organizational considerations need to be a central part of any integrated set of responses to water management needs.

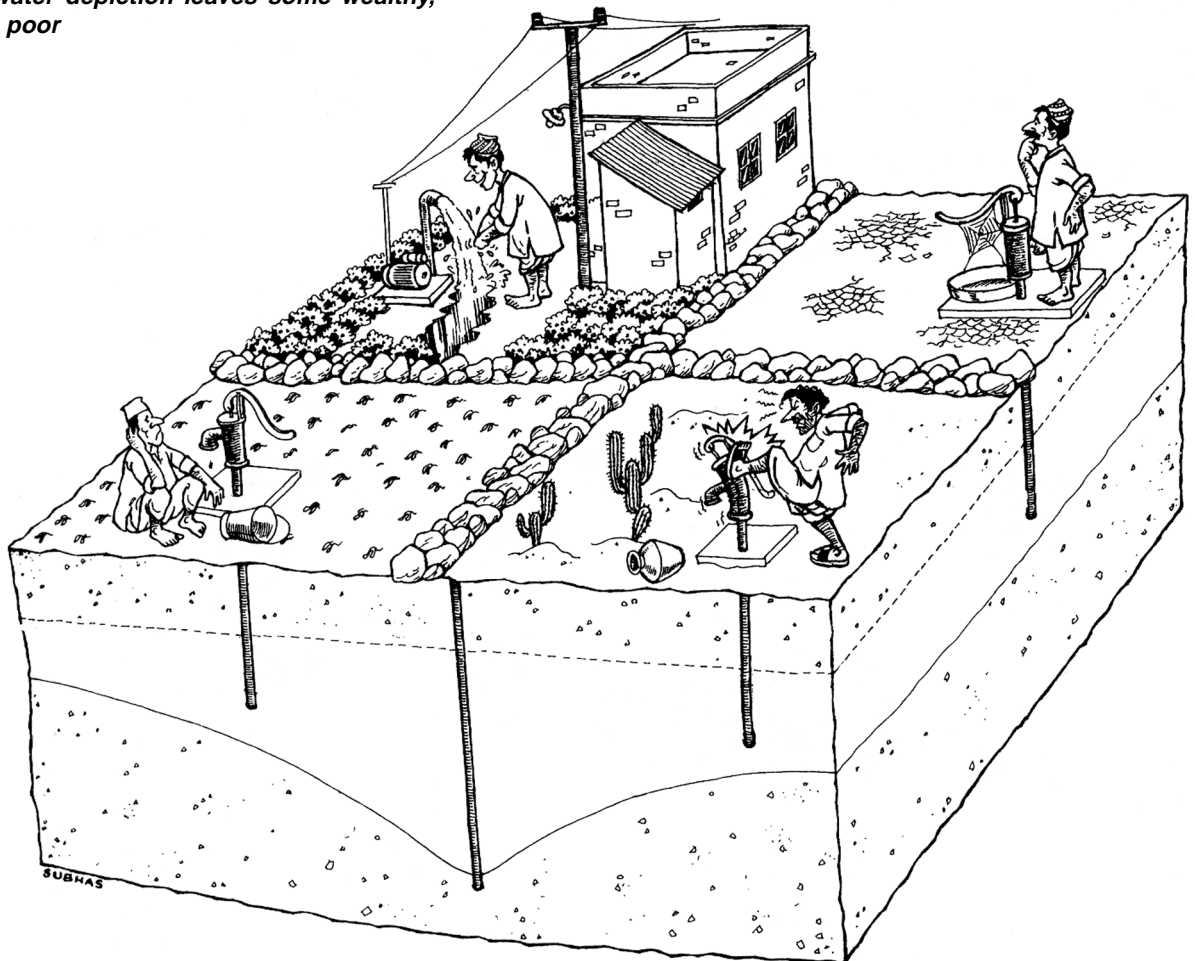
- **Enabling Legal and Rights Framework:** Legal and rights structures represent a final major sphere of action within integrated response sets. In many ways this arena is particularly important as the point where integration occurs. Regulatory and market arenas of management are, for example, directly dependent on the legal and rights

framework. Organizations also depend on this framework to define their structure and operational options. Overall, the enabling legal and rights framework plays a key role in shaping management options and the degree to which they enable different groups to voice their interests. As the diagram below illustrates, water problems affect social groups differently. Equitable legal and rights frameworks need, as a result, to be a core component in any integrated response strategy.

The importance of integrated response sets as a basic management principle leaves open the question of how those sets are developed and implemented. It is essential to recognize, however, that each element in the set is interdependent. As a result, approaches that emphasize one or another sphere without consideration of its links with other spheres may be ineffective and are likely to lead to unanticipated results.

An enabling legal and rights framework plays a key role in shaping management options.

Groundwater depletion leaves some wealthy, the rest poor



Source: *Pani ko Artha Rajniti*.

Key Emerging Issues

The focus of this paper now shifts from the broad conceptual insights generated in debates between participants to integration of the more direct results from field research within each case study location.

The poor and disenfranchised are the first to lose access to water when scarcity occurs.

The preliminary results of this study highlight some issues that are common in many situations globally. Water scarcity linked with groundwater overdraft and pollution are critical problems in all case sites except perhaps those in Nepal. Flooding is also an issue even in “water scarce” regions such as Gujarat. Beyond the resource itself, in many cases management systems that have functioned well for centuries have increasingly come under stress and are being destroyed. Where the social dimensions are concerned, competition is growing both within and between rural and urban areas. As a result, equity concerns are increasing. The poor and disenfranchised are the first to lose access to water when scarcity occurs. They also are the first to face the consequences of poor management or infrastructure development decisions. Legal frameworks and the capacity of institutions at all levels to develop effective responses to the above concerns are weak or nonexistent.

Beyond the above common issues, the case studies highlight a number of issues that have received less attention in the global literature. At the heart of management problems in all the case study areas lies the *interdependent* nature of water resource and water use systems. The sequential nature of flows and water uses implies that problems and the results of management interventions ripple through both the

hydrologic system and the water use and economic systems based upon them. Furthermore, the target of management is constantly shifting. Responding to natural variability (both floods and droughts) is a major issue – particularly in arid areas where inter and intra-annual fluctuations in precipitation are common. The issue of variability is, however, not dominated primarily by hydrologic or climatic dynamics. Rapid social, economic, land use and (in some cases) technical changes are occurring within each case study area. Some changes are due to long term demographic or other trends, others are driven by much shorter term economic or social fluctuations. These changes, rather than micro-level decisions based on water considerations *per se*, have a dominant impact on water use patterns. Perhaps the greatest challenges facing water management are not the physical problems themselves but devising systems capable of functioning and remaining relevant in the face of rapid patterns of social and economic change.

Water Resource

Interdependent Systems

The story of system interdependency starts in situations, such as that along the Tinnu River in Nepal and India, where local water use patterns evolve in directions that ignore both upstream dependencies and downstream effects. It is not a new story – but the story is of increasing importance as the scale of human action significantly alters hydrologic dynamics. The case of the Tinnu is outlined in detail in box number 2 in order to illustrate key issues in the interdependency story.

The situation found in the Tinau case is common. In most areas studied as part of this research, resource development or management activities have been initiated with little conception of the larger system into which they fit. As a result, major problems regularly emerge due to unanticipated interactions. Collection of the data required to fully characterize systems would be a major time consuming and expensive process – one unlikely to be undertaken rapidly in most medium watersheds of South Asia. It should be emphasized, however, that extremely valuable insights can be achieved through the partial data that is often available *if* it is analysed from a systemic perspective. The use of the WEAP modelling system to evaluate the potential impacts of groundwater recharge and demand side management activities in Gujarat (Box 3) is illustrative. The WEAP system enables evaluation of water demand and supply balances at a basin or regional level on the basis of relatively limited data. Using it, VIKSAT was able to determine that recharge – the primary focus of government and NGO water management activities in their study area – could address only a minor fraction of groundwater overdraft problems, while demand side management activities could have a far greater impact. Focusing on key constraints within a larger semi-quantitative or qualitative conceptualization of water resource systems allows development of more integrated management responses and the progressive refinement of systemic understanding.

Overall, a water resources systems approach to water management planning helps incorporate the inter-relationships between physical components of the water resource system (surface storage, stream flows and groundwater storage), and also between

supply and demand. It also helps prioritize different demands within basins, such as drinking water supplies, irrigation, urban and industrial uses, on the basis of consensus among the user groups. Finally, it can help identify the types of water management interventions that can have maximum impact in terms of reducing the overall gap between the goals of management and the limitations inherent in each intervention. A systems approach can also help stakeholders to understand the impact of various interventions.

Overdraft and Aquifer Disruption

In many parts of India, groundwater overdraft is emerging as a major point of concern (World Bank, 1998). Since the 1950s, government policies have emphasized groundwater development as an important mechanism for ensuring food security and as a catalyst for rural development. As a result, the number of wells and operational pumpsets has increased exponentially from a few thousand in the early 1950s to estimated numbers exceeding



Supply line abandoned due to groundwater overdraft in Rajasthan

Water resource development has often been initiated with little consideration for large systems. Unanticipated interactions are a direct result.

BOX 2:**Interdependent Systems: The Case of the Tinau in Nepal**

The Tinau starts in the Mahabharat middle hills of Palpa in Nepal. Throughout the hill region, traditional hill irrigation systems dominate water use patterns. Numerous individual small to medium scale diversions take water out of the river and channel it along hillside and valley bottom terraces. Most of these diversions are seasonal and the diversion structures are temporary – designed to be rebuilt following each monsoon.

Before it exits into the plains of the Nepal Tarai, the Tinau runs through a narrow gorge. There, below the lowest of the hill irrigation diversions, a small 1 MW run of the river hydropower plant has been constructed. This plant is currently not operational. A gauging station was, however, established at the plant. This station represents virtually the only fixed data point regarding flows in what is, at that point, a medium sized river. Just below the hydropower station, the river exits the hills at the small but fast growing town of Butwal. It is a typical Tarai town with a market and many consumer goods shops. It is also an engineering centre and ideally located to grow as a site for small to medium scale industries. The town now diverts more and more water for municipal uses and returns it untreated to the stream as an increasingly large and degraded waste flow.

Below Butwal, the Tinau is a braided stream whose shifting course wends its way across the coarse sediments at the base of the Himalayas and finally into the deeper, fine basin sediments of the main Gangetic basin along the India-Nepal border. The hydrology of this zone is poorly understood. Flow in the Tinau almost disappears as it crosses the Bhabar Zone (a deep band of coarse gravel deposits at the base of the Himalayan uplift). The channel clearly shifts on a regular basis. One barrage constructed by the Indians in Nepal now crosses a dry riverbed. The river itself has shifted and flows in a new channel. No long term flow measurements are available at any point in this zone. Observations suggest, however, that flow increases substantially in the lower portions of the basin in India after the river has passed over the coarse grained sands of the Bhabar Zone.

Use patterns along the Tinau below Butwal in India and Nepal are also complex and poorly understood. Some of

the best documented traditional irrigation systems divert water just below Butwal and provide water to as much as 5,000 ha. Below these, “modern” pumped systems and medium irrigation schemes built by the Indian Government divert water from the river. Furthermore, within India numerous diversions for towns and industry occur. Each diversion is accompanied by a return flow and the quality of water in the Tinau probably declines steadily downstream. Flash floods are a major concern at the point where the river leaves the mountains. In lower regions, large-scale flooding during the monsoon replaces the flash flood issue and becomes a dominant shaping factor in people’s lives.

In the areas surrounding the Tinau, groundwater development has grown rapidly over recent decades. Some areas are served by deep wells drilled with assistance from international donors. In other areas, including most of those in the command of large surface irrigation systems, shallow tubewells are common. The number of shallow wells and the extent of their use is virtually unknown. In some areas visited by the study team, wells are capped and covered with soil when not in use to avoid tampering. Farmers move pumps between wells at their convenience. In these areas a survey of operational wells may underestimate the actual number in use substantially. In one area, only one in 4 to 5 wells was actually operational at the time of our visit. The rest were capped and buried for use in other seasons.



Irrigated land in Madi *phaant*: Tinau, Palpa

In many ways, the core issue in the Tinau basin is fragmentation of a complex system leading to counterproductive management interventions that should, with the benefit of hindsight, have been avoidable. Throughout the Tinau basin, water management is treated as a dominantly local issue. In the lower basin, embankments are constructed to protect specific areas from flooding. Little thought is given to how flooding might be reduced by upstream interventions or to the consequences of embankments for other areas not similarly protected. Similarly, in upstream areas diversions are created and waste returned to the stream with little thought to downstream users. As industrial development accelerates in the Nepal Tarai, the consequences of this for water quality may be particularly significant.

Water resource characteristics and use patterns along different sections of the Tinau are interlinked. Extensive water diversions and the development of complex hill irrigation systems have influenced flow dynamics throughout the lower basin. The dynamic, mobile character of the channel where the stream exits the hills constrains possibilities for development of diversions and irrigation systems. Return flows from municipal and other uses influence downstream water quality. Widespread development of groundwater through shallow wells by private farmers influences the need for larger scale surface and groundwater development initiatives by the government. Flooding problems in one area are exacerbated by



Embanked Kuda River: Uttar Pradesh

embankments created in other areas. These sweeping types of interactions are relatively easy to conceptualize. There are, however, no data for quantifying them. This does not, however, imply that the interactions should be ignored or discounted nor does it imply that nothing can be done without detailed information on resource dynamics throughout the basin. The starting point is to outline, at least on a conceptual basis, the interlinked nature of water resource dynamics and use in the basin and then focus on key constraints – in this case flooding and water quality. Limited sets of data can then be collected to address constraints while a more detailed understanding of the basin is gradually developed over the decades required for water resource monitoring to produce reliable results.

D. Gyawali, A. Dixit and M. Moench

25 million at present. The consequences of unregulated development are now beginning to emerge. In Rajasthan, for example, water levels across a wide swath in the central portion of the state have been dropping at rates averaging one metre a year over the last decade.⁴ As the boxes below document, similar problems are clearly evident in many arid and hard rock sections of the country.

Overall, it is now broadly recognized that management of India's aquifers, rather than groundwater development, is among the most major challenges facing the water resource sector in the country. This said, it is equally important to recognize that groundwater overdraft is not an isolated problem. Instead, reflecting the core message of the previous section, overdraft needs to be viewed as a key constraint within a

Groundwater overdraft is a constraint within an interdependent system.

BOX 3:**A Systems Approach to Basin Level Water Management, the Gujarat Case**

Community based local water management initiatives are increasingly recognized by NGOs, researchers and academics as a major strategy to address growing water scarcity problems. Almost all NGO and community based responses to water scarcity and pollution problems in Gujarat (and other parts of India as well) focus on augmenting the available supplies of surface and groundwater in the locality. Efforts to address water demand or non-point sources of pollution are almost absent. Furthermore, most initiatives are highly localized with very little potential impact on regional water dynamics. Water scarcity problems are, however, often regional in nature and emerge from a range of physical (hydrology, geology, climate, etc.), social, economic and institutional factors.

Experience with comprehensive basin level approaches to water management is lacking in India. As a result, there is little basis to evaluate the extent to which local water management interventions — supply and demand side management — could address emerging problems of water scarcity or pollution at a regional or basin scale. Understanding water management needs requires estimation of current and future demand and supply of water in the basin. This is critical for evolving basin or regional water management perspectives. It is also useful

in identifying the right kind of institutional arrangements for implementing management solutions and the role various stakeholders might play. The case of the Sabarmati basin in Gujarat, studied by VIKSAT, illustrates this well.

Most water management initiatives by the government and NGOs in the Sabarmati basin have focused on groundwater recharge. Modelling activities by VIKSAT using the WEAP (Water Evaluation and Planning) system developed by Stockholm Environment Institute, however, clearly indicate the limited role recharge can play from a systemic perspective. By developing an integrated model of water supply and demand in the Sabarmati, VIKSAT was able to contrast the impact of an integrated set of demand side management interventions with a similar array of recharge activities. Based on their model, recharge could only reduce the gap between demand and supply by 8 MCM per year as compared to a reduction of more than 259 MCM/year achievable through efficiency interventions. While the preliminary nature of modelling results and limited data availability are acknowledged, the magnitude of the difference suggests that the potential for demand management interventions clearly outweighs anything achievable through recharge.

D. Kumar, S. Chopde and A. Prakash

Numerous point and non-point sources of pollution go untreated.

set of interdependent systems. Overpumping, the proximate cause of groundwater overdraft, is itself a product of technical and economic change. Solutions may, as a result, lie both in actions that directly affect extraction or recharge levels and in interventions designed to alter the large context from which groundwater use emerges.

Pollution

Water pollution is a well-known but extremely poorly documented problem throughout South Asia. Over the last decade, India's urban population has increased by 36% and, of the total

urban population, official figures indicate that only 64% have access to sewage facilities (Laxmi, 1997). Most towns and villages lack sewage facilities. Furthermore, even where sewage facilities are present, treatment is at best partial. Beyond this there are numerous point and non-point sources of pollution which go virtually untreated. Agriculture, for example, now reportedly uses substantially more fertilizer and pesticide per unit area than is used in the United States (Repetto, 1994). Boxes 1 and 6 provide good examples of the pollution problems now emerging and their likely impacts.

BOX 4: Mining of Aquifers in Mehsana

Mehsana district in North Gujarat is one of the richest aquifers in India. The deep alluvial aquifers extend to depths exceeding 600 metres in central parts of the district and contain substantial supplies of fresh water. As large surface irrigation systems are absent in the district, groundwater is the major source of irrigation accounting for nearly 97% of the net irrigated area in the district. Irrigation grew rapidly in the early 1970s with the introduction of Green Revolution technologies. At that point farmers began investing heavily in tubewells for groundwater pumping. Now the region's agrarian economy is heavily dependent on groundwater, most of which is supplied through private wells.

Uncontrolled extraction of groundwater for irrigation has led to large drops in water levels in the shallow aquifers and the drying up of many thousands of open wells in Mehsana district. Extensive rural electrification, the ready availability of high capacity pump sets and deep drilling technologies initially enabled extensive development of deep aquifers. In addition, governmental subsidies for financing well development and highly subsidized electricity in the farming sector have also played a major role. The rapid development catalysed by these subsidies led to further lowering of water levels in the deep tubewells with a resultant increase in pumping depths. Although groundwater development in the district was initially through shallow dug wells, the current depth of most tubewells in Mehsana ranges from 200 to 300 metres and pump capacities ranging from 50 to 100 HP are common.

According to 1992 official estimates, the average annual extraction of groundwater in Mehsana district is 901 MCM against an average annual recharge of 410 MCM (GOG, 1992). The average annual decline in piezometric levels in some parts of Mehsana has increased from 1 m/year in the year 1971 to 2 m/year in 1991 with some parts recording declines of 5-8 m/year (GOG, 1992). Declining water levels have led to widespread well

failures. In addition, in some areas, pumping from deep confined aquifers has resulted in groundwater quality deterioration. Salinity and fluoride levels in the water pumped through tubewells are now often far above those permissible for safe drinking water. Of the 1,106 villages in Mehsana, a total of 608 villages are affected by excessive levels of fluoride in groundwater. Salinity is also emerging as a major problem for both agricultural and industrial water users.

Regulatory measures to control groundwater development in Mehsana have been attempted. These have included restrictions on institutional financing for new wells and pumps imposed by National Bank for Agriculture and Rural Development (NABARD) and enforcement of well spacing regulations by the Gujarat Electricity Board (GEB) through the denial of electricity connections. Restrictions on institutional financing have not been effective due to the large amount of private investment in well drilling by farmers' groups as well as individuals in Mehsana. Where spacing regulations are concerned, it is often possible to bypass restrictions on electricity connections. Overall, those attempts to regulate groundwater extraction in the district appear to have had little impact.

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Deep aquifer mining: Gujarat

BOX 5: Overdraft and Aquifer Disruption in Tamil Nadu

Groundwater depletion is a well-known problem in Coimbatore district. During the last 30 years, the number of wells has doubled but the net area irrigated by them has increased only marginally from about 141,655 ha to 142,096 ha. As a result, the average net irrigated area per well has shown a 50% decline from 1.56 ha in 1960-61 to about 0.747 ha in 1989-90. Along with this, the number of abandoned wells in the district increased from 4,033 in 1960 to 16,700 in 1990 (Palanasami and Balasubramanian, 1993). This indicates that the groundwater resources of the region are fully developed and new wells are in competition with existing ones for the limited available supplies of groundwater. Similar issues are also found across large areas in parts of Karnataka (Rao, 1995) and are likely to emerge in many other hard rock areas.

As water levels fall, the risks for farmers associated with well construction have also grown. Drilling depths have increased and many wells fail to strike significant amounts of water. Newcomers have to construct wells deeper than their predecessors who constructed wells, say,

10 years ago. Deepening of each well affects other wells and stiff competition among the well owners in exploiting groundwater ensues. Individuals whose wells are affected by a neighbour's effort to deepen his own well cannot seek justice through legal mechanisms because property rights in groundwater are ambiguous and indeterminate. This delicate situation poses heavy negative externalities on future users and adds to the costs for current users.

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Poisoned well lies abandoned: Tamil Nadu

Attempts to address pollution face fundamental challenges.

The social dynamics documented in Box 6 highlight some of the fundamental challenges facing attempts to address pollution. In many cases, particularly those involving industrial pollution, those most affected by problems have far less political or economic power than the polluters. The social response documented in Box 6 is also common. When problems acutely affect larger populations, unified social protest may result. The impact of protests is, however, often short lived. In the absence of ongoing enforcement measures, initial mitigation measures gradually decline. Local governments may take up part of the slack, but the affected populations generally remain in a much worse situation than initially.

These dynamics suggest the importance of an enabling civil environment. At present, the civil environment provides little support when local groups protest. Their protests may be heard, but they can be ignored after a short while. This highlights the importance of establishing permanent organizations at local and higher levels as well as legal frameworks for regulation and enforcement. NGO's capable of sustained and informed public advocacy are also important. Permanent local organizations are needed in order to provide ongoing supervision of polluting activities – rather than relying on the temporary nature of social outrage. Given the social/political power distribution, however, these will have little impact without higher level legal and other

frameworks for enforcement that can balance the social and economic power of large polluters.

Variability

Variability represents a major water management challenge. A typical example of this comes from Gujarat. Throughout northern portions of the state, rainfall is highly erratic. Storms tend to be brief and intense. Drought years are common. As Dr. Pisharote notes for Kutch, half the annual rainfall typically occurs over a period of 2-3 hours during the monsoon season. There are generally only 8-10 rainy days in the year and rain actually falls for an annual average of 12-15 hours (Pisharote, 1992). Under these conditions, run-off is intense and only lasts for brief periods. The area near Mandvi, for example, received 654 mm over a four-day period in July 1992 after receiving only 185 mm total in 1991 (Raju, 1992). Under these conditions, run-off is intense and only lasts for brief periods. Even in high rainfall sections of the state, precipitation is highly seasonal. Out of an annual average of 51 rainy days in south Gujarat, 48.5 (accounting for 94% of the total rainfall) occur between June and September (Phadtare, 1988).

Natural variability limits the array of responses to water scarcity that are technically viable. In the Kutch case, many local residents – and a large number of engineers as well – argued that it would be technically feasible to meet all regional water needs through structures capable of harvesting 25% of the annual average rainfall. Because the rainfall is highly variable both within and between years, however, this estimate is unrealistic. The four days of intense rainfall in July 1992 represent over 80% of the total rainfall

received in some locations over a two year period. Despite the construction of numerous water harvesting structures, it was impossible to capture most of the high flows.

Modelling efforts by VIKSAT undertaken as part of the current study (see the VIKSAT case study in this document), suggest the inherent limitations of local water harvesting in high variability environments. Their study for central Gujarat indicates that local water harvesting could address an insignificant fraction of overdraft problems in the region despite the fact that long term average levels of precipitation would be volumetrically sufficient for a much larger proportion.

A similar issue of variability is present in the Nepal Tarai. There, farmers in traditional irrigation systems often face major water scarcity problems during low flow periods each year. Frequent flash floods, however, often damage the permanent structures. Char Tapaha, one of the systems along the Tinau, for example, experienced flash floods in 1970, 1981 and 1995. These damaged intake structures and in the 1981 case deposited so much debris that the system took two years to repair.

Management challenges imposed by the natural variability of precipitation patterns are compounded by a similar high degree of variability in geologic and other factors affecting water resource systems. It is beyond the scope of this paper to go into these in detail. It is, however, important to recognize that temporal and regional variability represents one of the most important challenges for local water management. Recognizing the constraints this imposes on management approaches and adapting responses

Management options are constrained by natural variability.

BOX 6:**Groundwater Pollution Due to Effluent Discharge in Tamil Nadu**

Groundwater pollution has become a major issue in several parts of Tamil Nadu. Important industries, such as tanneries, textile dyeing units, viscose, paper pulp, sugar, sago, oil refineries, fertilizer units and chemical manufacturers often discharge effluents onto the land surface or into rivers, thereby polluting groundwater as well as surface water bodies. Groundwater contamination has been particularly widely reported in parts of the state where tanneries and dyeing and bleaching units are concentrated in large numbers. As most of these industries are highly water intensive in nature, they are concentrated along the



Tannery effluent: Tamil Nadu

river courses. This gives them good access to water (both surface and groundwater), and also enables use of the rivers for effluent discharge. Important rivers in the state which have become badly polluted include: (i) the Bhavani in Coimbatore district, (ii) the Kalingarayan Canal in Erode district, (iii) the Noyyal in Tiruppur (Coimbatore district), and (iv) the Amaravathi in Karur district (v) the Kodaganar in Dindigul district and (vi) the Palar in Vellore district. Of these, the first five fall within the large Cauvery basin.

Pollution of groundwater in the Palar River basin represents a typical example of the problems now emerging in the above basins. Groundwater quality sample tests conducted at various points in this region by the Tamil Nadu Water Supply and Drainage Board show very high levels of total dissolved solids. Contamination has been observed up to a distance of 8 km from tannery effluent outfalls. A detailed study undertaken by the Soil Survey and Land Use Organization, Government of Tamil Nadu, found that tanneries store their effluent in the earthen lagoons for solar evaporation. The number and the capacity of these lagoons is not, however, proportionate to the quantity of effluent generated by the tanneries. Many of the lagoons overflow and the waste drains into nearby fields. Large-scale breaches in the lagoons are also common. As result, effluents seep and flow into fields where they stagnate. A large number of tanneries directly dispose of effluents into lakes and tanks. This, in turn, contaminates the lakes and surrounding wells. The Soil Survey and Land Use Organization identified about 16,000 hectares of affected land due to the tannery effluent in the Vellore district as early as 1982. The same study was repeated in 1990 only to find further damage to soils, surface and groundwater. A study conducted by the Central Pollution Control Board to assess the groundwater quality collected samples from 12 irrigation wells from 12 regions in 1994. The data show that the groundwater in all the sample wells has excess salinity. The study team has confirmed that, since the natural aquifer was of a good quality, the excess salinity was primarily due to contamination caused by the tannery effluent. In addition, heavy metals such as chromium,

copper, zinc, iron and manganese are now found both in the tannery effluent and in the groundwater.

Another example of the impact of pollution comes from the Noyyal River basin. The social impacts in this region are particularly evident and well documented. Large-scale impacts of pollution were catalysed when the Government of Tamil Nadu constructed the Orathapalayam Dam across the Noyyal in 1992 about 10 km below Tiruppur. This dam was intended to provide irrigation for about 8,000 hectares. It has a catchment area of 2,245 km² which includes most of the area in which the dyeing and bleaching units are located. Water that is stored in the dam is much more than the actual flow in the river. This is because a large quantity of untreated effluent (about 92 mld/day) produced by the Tiruppur dyeing and bleaching units is released into the Noyyal River and contributes to the 'additional storage level' of the dam. Thus, the dam effectively performs the role of a storage reservoir for the contaminated water, contributing quite significantly to pollution of the environment, in particular, groundwater.

In February 1997 water from the Orathapalayam Dam was released. The dam was opened without any prior public notice and the polluted water caused substantial damage to crops, animals, soil and groundwater. According to local villagers, hundreds of cattle died and enormous damage was caused to groundwater along the river. Petitions were filed in the High Court protesting the decision of the government to release the polluted water and claimed compensation for the damages. What follows next is the case study of a village that represents a typical case where high levels of groundwater contamination are reported:

The village of Veerapandi is located 12 km from Tiruppur, on the Tiruppur-Palladam road. This is a big revenue village with a population of 25,000 (Census of India, 1991). One large knitwear factory, along with its own dyeing and bleaching units and two other small units, are located in this village. These industries were started about 20 years ago. They utilize local groundwater resources and

discharge effluent on the open space and roads. This effluent forms a stream that eventually joins the Noyyal River. Wells in this village have adequate water, but they are completely polluted. Agriculture is a dead occupation. The industries have not only made use of the groundwater quite successfully, they have also caused extensive groundwater pollution by the discharge of untreated trade effluent. At present, the water is so polluted that industries have to transport water for their own use from a nearby village.

Pollution of well water has also created an acute drinking water scarcity problem. This became so bad that in August 1997, about 3,000 people organized a procession and picketed the government offices protesting against the dyeing and bleaching units. They held the units to be solely responsible for groundwater pollution and the resultant scarcity of drinking and irrigation water in the area. The sub-collector, one of the higher level government officials in the region, had to intervene to placate the angry mob and helped to arrive at some agreement. Under the agreement, the industries were to supply two tanker-loads daily of potable water (15,000 litres per load) to the village. The agreement was complied with for about a month. Thereafter the supply was ceased on the pretext that the industries were facing great pressure to erect their own treatment plants. Later on, the panchayat union started transporting drinking water in rotation to various segments of the village. Through this each household received water for two and a quarter hours, equivalent to about 100 litres once in 8 days. Soon it was realized that the water supplied by the Panchayat Union was inadequate. In the current scarcity situation, a local water market has developed. A few farmers store lorry loads of water which they sell to those who are in need at the rate of 75 paise per pot: The rate goes up to Rs 2 per pot in times of acute scarcity. Most people in this village use water for bathing only once or at the most twice a week. This is the price that the village population is paying for drinking water after having allowed the polluters entry into the village.

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Technological changes alter the water management context.

to those constraints is central to the development of effective solutions to management needs.

Technical Change

A final major management challenge stems from technological change. The development and spread of high dams, major embankment systems and energized pumping technologies represented a fundamental shift in the ability of people to alter hydrologic systems. Take the case of pumping technologies. Prior to the spread of energized pumping technologies, the ability of society to alter groundwater regimes was, to a large extent, “capped” by the limitations of manual or animal powered pumping techniques. The flows that were possible to generate using these techniques were very small in comparison to natural flows within groundwater systems. Energized pumping technologies changed that limitation fundamentally.

Throughout India, groundwater development has been growing at an exponential rate over recent decades. Figure 1 (compiled from a variety of official sources (CBIP, 1989); (CGWB, 1991); (CGWB, 1995); and (CGWB, 1996)) suggests the rapid rate of growth in groundwater extraction potential caused by the spread of energized pumps.⁵ Technological change on this scale fundamentally alters the context in which water management must occur.

While there may be no immediately evident technical changes on the horizon that would directly affect water system dynamics in the manner that pumping technologies have done, other technological changes may have equal

impacts. Lateral thinking may be essential in order to recognize the potential impacts of technical changes before they occur. Agricultural changes, for example, that are related to the spread of mechanized farm machinery and the field characteristics necessary for it to operate could fundamentally alter run-off and infiltration patterns. This is also the case with urban growth, road networks and other factors that result in the creation of large impervious surfaces. Even less directly connected to water use patterns are the spread of global communications and remote monitoring technologies. These, for example, may soon make it possible to monitor cropping at the level of individual fields and to monitor water flows in systems on a real time basis even under conditions in the Third World. This type of information change could enable institutions – such as water rights – to evolve in ways that



Modern and traditional technology: Rajasthan

were previously impractical. This could eventually have a major impact on water use patterns and system dynamics.

From a management perspective, the rapid pace of technological, social, economic and other changes has important implications. Flexibility is essential. Rigid approaches that presume management needs, issues and techniques which can be projected well into the future and addressed with limited sets of specific interventions are likely to fail as the technological context changes. On the other hand, approaches that are designed to respond adaptively and flexibly as technological conditions change and new opportunities arise may have a much better chance of success. The rapid pace of technological change is a fundamental reason why process types of approaches, rather than more rigid planning approaches, are essential.

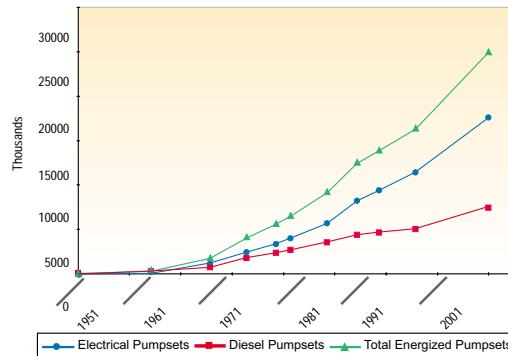
Social

Social issues associated with emerging water management needs take a variety of forms. On one level lie social consequences such as competition, differentiation, inequity and destruction of traditional systems that can be



Vegetable irrigation using sprinkler: Tinau

Figure 1:
Growth of energized pumpsets



directly traced to specific water management problems. On a deeper level, however, lie issues associated with social structures and the implications these structures have for the causes of specific water resource problems and potential responses to them. This arena is characterized by issues such as the role social and economic change play in shaping water use patterns, institutional capacity and scale and issues related to legal frameworks or water rights.

This section discusses a number of the key points that have emerged in the course of the joint research programme related to the above issues. The section is not intended to be comprehensive. Instead, the intention is to highlight details we see as particularly important and relate these back to the larger conceptual framework.

Competition, Differentiation and Equity

Competition, differentiation and equity issues related to water management problems have been a central focus for substantial research in South Asia. Competition over scarce water supplies is growing both between and within urban and rural

Rigid approaches that proceed with limited sets of specific interventions are likely to fail as the technological and social context changes.

BOX 7: Increasing Urban-Rural Competition in Gujarat

Provision of municipal water supply to Ahmedabad was first planned by the municipality in 1890 and the initial water supply system itself was developed in 1891 with a population of 155,405 being served. Since then, municipal water supplies have been augmented numerous times in response to growing demands from large-scale expansion of the city area and the increasing population density within it. Between 1951/52 and 1971/72 groundwater extraction from city wells for domestic and industrial use increased from 6.4 MCM to 69.45 MCM and increased further to 128.7 MCM by 1980 (CSE, 1995).

Unable to meet growing demands, the Ahmedabad Municipal Corporation started drawing water from the Dharoi Reservoir. This water was initially developed to supply irrigation in the downstream command area. Currently, water supplied from Dharoi to Ahmedabad is 189 million litres per day (excluding transmission losses between Dharoi and the Dhudheshar waterworks which supplies water to the city). This accounts for 45% of Ahmedabad's municipal supplies. As a result, the reservoir has seldom been able to provide the amount of water promised to farmers for irrigation. Over the past 21 years, the reservoir was only able to supply the planned allocation of water for irrigation for three years on the right bank and two years on the left bank. The amount of water

released for Ahmedabad and Gandhinagar from the Dharoi Reservoir has, however, steadily increased from 148.145 MCM in 1971/72 to 225.56 MCM in 1996/97 (Puri and Vermani, 1997).

The water table in and around Ahmedabad is declining fast resulting in reduced yields for municipal tubewells. In addition, groundwater quality is deteriorating with increasing incidence of high fluoride levels and TDS in pumped groundwater. These levels are now often beyond permissible limits. In sum, the scope for augmenting municipal supplies through groundwater to maintain current service levels is limited. Ahmedabad's urban population is growing rapidly — historical trends show an annual population growth rate of 2.59%. Assuming demand for domestic water supply grows proportionately, maintaining the minimum level of service in the urban area will be at the cost of rural areas. In some cases, these are likely to completely lose access to surface water supplies for irrigation. Existing competition problems are compounded by declines in the capacity of many of the surface reservoirs. Sedimentation studies done on the Dharoi reservoir indicate a total reduction in the capacity of 13.97 MCM over a 3-year period.

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Source: Projects Division, Dharoi Reservoir, Kheralu, Mehsana district.

Equity is related to the issue of state legitimacy.

areas. This leads to questions over equity in access to water for regions and individuals. The case of Ahmedabad is typical of many cities in arid areas (Box 7). As Box 8 on Tamil Nadu discusses, competition within rural areas is also important and can lead to processes of differentiation in which the poor lose out. Competition and the equity issues associated with it have received significant attention in debates over water resources in South Asia (Shah, 1993; VIKSAT, 1993; Moench, 1994a). There is little point in revisiting the nuances of those debates here. The

implications of competition and equity issues for water management approaches are, however, important and have received somewhat less attention than the issues themselves.

Perhaps the most important implication of emerging competition and equity issues has to do with the question of state legitimacy. In South Asia, state legitimacy is an exercise in the political art of managing the needs of large populations. Much of this art is exercised through the state's role in assuring (and often providing) basic services such

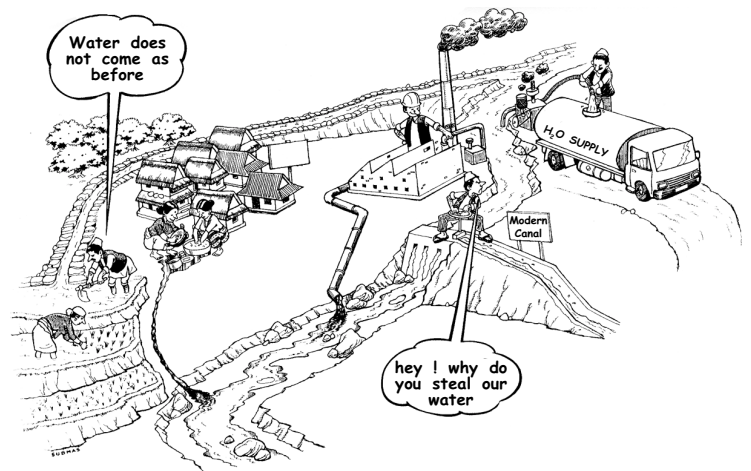
as food, water, power and roads. Historically, water resource development was one of the most direct mechanisms through which states in Asia could directly improve conditions for their citizens and build their political legitimacy (Wittfogel, 1957). The role of water resource development gained further prominence in the 1960s and 70s with introduction of the Green Revolution package of agricultural technologies in which irrigation was the lead input. By providing access to irrigation either directly through surface systems or indirectly through energy and pump subsidies for groundwater development, states enabled rural populations to greatly increase agricultural output and their overall wealth along with it. Furthermore, increases in agricultural output provided a foundation on which urban populations and the urban-industrial economy could grow. This basic pattern remains unchanged in today's rapidly urbanizing world. Competition and equitable access were not an issue so long as the pie was growing. Now, however, competition over access is emerging as a major issue. If the state is unable to meet the fundamental needs of its citizens, its own legitimacy may be subject to challenge. In some areas this has already evolved into a major source of internal political instability.⁷ It could translate into regional instability if extended droughts or floods (such as the recent cyclone in Orissa) occur.

Competition essentially involves issues of access to and allocation of scarce resources. These issues are inherently complicated from a social perspective. Regardless of official policy positions (or for that matter local norms), access and allocation issues tend to have major political and economic ramifications. Furthermore, the mechanisms used for allocation touch deep

cultural, ethical and often religious sensitivities (Moench, 1995). As the boxes on Tamil Nadu and Ahmedabad demonstrate, they also directly affect people's livelihoods. As a result, the political and economic dimensions cannot be ignored or eliminated.

Given the inherent political dimension, the nature of dialogue within civil society is of fundamental importance to the resolution of water management problems. This is a key reason why the conceptual framework presented at the beginning of this document emphasizes the importance of an enabling civil environment and recognizing the process nature of management. Water management challenges now emerging in South Asia represent a fundamental shift from paradigms of water development that have characterized human history since prehistoric times. The change from expansion into an "infinite" resource base to allocation of finite supplies between competing uses draws social fault lines to the surface. How those fault lines are bridged, who benefits and who loses, and what

Competition involves issues of access to and allocation of scarce resources.



Source: *Pani ko Artha Rajniti*.

BOX 8:**Competition and Differentiation Among Farmers in Tamil Nadu**

In Tamil Nadu, competition over scarce groundwater supplies is growing between farmers in many rural areas. This is leading to a process of differentiation in which those farmers with better access to capital and other resources progressively benefit at the expense of those farmers with fewer resources. Competition raises important issues particularly in cases where users have unequal financial endowments. Many dug wells are, for example, jointly owned. Dug wells, which may measure 10x10m square and up to 100 m deep, are often partitioned in the inheritance process. These partitions are then often further divided as land is sold or divided among distantly related family members. As a result, individuals often own different sized shares in wells. Because of land transfer traditions in Tamil Nadu, these shares often relate to a physical portion of a well – not to pumping hours or water volumes. Individual dug wells may have many pumps – each belonging to an individual shareholder.

In the above situation, competition aggravates the precariousness of crop production. Even if farmers have a large share in a well, they have little assurance water will remain in it, since other shareholders can continue to pump. This can inflame competition over declining water

tables. Competitive extraction increases as each shareholder in the joint well seeks to protect “their share” of available water supplies. In some cases competitive deepening occurs even within individual dug wells as shareholders seek to ensure that their section of the well is deepest. The most important implication, however, is the process of differentiation that is occurring. Shareholders in joint wells often have unequal access to it. This results in deprivation and exclusion of the resource-poor farmers from the use of such jointly owned wells. Competition between well owners and the social and economic consequences of progressive lowering of the water table are matters of great concern.

Beyond the differentiation occurring between joint well owners, ever-increasing costs are the most important implication of competitive well deepening. Huge investments are lost as wells are abandoned and the percentage of unsuccessful attempts to dig or drill new ones increases. Eventually, losses represent a heavy burden on communities as well as on individual farmers. Major questions exist concerning the extent to which economic activities in the context of competitive well deepening are sustainable, particularly in hard-rock regions.

Well irrigation has become a gamble and not all those who invest in wells are successful. Many fail and lose in the race of competitive deepening. They either sell their land or become locked in debt. A new dimension of inequality is emerging between those who have successfully maintained access to groundwater through competitive deepening and those who have not. The former are emerging as a class of water sellers while the latter are reduced to the status of water purchasers. There is a sharp polarization between water sellers and water purchasers both economically and socially. Commercial deals between water sellers and purchasers clearly expose the weaker bargaining capacity and the vulnerability of the latter.

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Five pumps on a single well: Tamil Nadu

interests are represented depends on the structures that govern social dialogue. Access to information, legal frameworks and the nature of organizations in civil society are among the key elements that can counterbalance the exercise of raw political or economic power.

Destruction of Functioning Systems

The wealth of history on the decline and destruction of South Asia's traditional water harvesting systems has been extensively documented (Agarwal and Narain, 1997). These systems are widely recognized as a major resource for meeting local water management needs – where they can be maintained or revived. The core questions relate to that last caveat, the maintenance and reviving of traditional systems.

As the boxes 9 and 10 on Tamil Nadu and the Nepal Tarai demonstrate, traditional systems were embedded in specific social and technological contexts. As contexts change, the incentives and logic for users to maintain traditional systems change as well. In the Tamil Nadu case, maintenance of tank systems was heavily dependent on the concentration of land in the hands of a relatively small group of upper caste landholders. When lands were re-distributed, this group lost much of its social power and ability to organize maintenance on a large-scale. In addition, the spread of pumping technologies greatly reduced the dependence of farmers on tank irrigation water. In the Nepal Tarai, traditional systems continue to operate in some areas. In others, however, projects for “modern” irrigation development have been implemented with little knowledge of or consideration for existing systems. In some cases, such as Marchawar in Nepals’

Tarai, canals cut for modern systems have resulted in the direct physical destruction of traditional irrigation works.

Beyond the specific causes illustrated in the Tamil Nadu and Nepal cases, the larger context in which traditional irrigation systems exist is changing rapidly. At the global level, less than 15% of the world's population lived in cities and towns in 1920, by the turn of the century nearly 50% will (Morris, Lawrence et al, 1994, p. 1, citing UNCHS, 1987). Urbanization is also proceeding apace in South Asia although the proportion of rural inhabitants remains higher than global averages (Chatterjee, 1998). Along with urbanization, the globalization of markets, communications and labour represent fundamental context changes for traditional water management systems. Many systems depended on the existence of relatively stable, locally focused

**Markets,
communications
and changing
labour
relationships
represent
context changes
for traditional
water
management
institutions.**



Main canal from Butwal barrage crossing Gurbania canal: Tinau

BOX 9:**Destruction of Traditional Water Harvesting Systems in Tamil Nadu**

Traditional water resources institutions once common throughout India, primarily served irrigation and drinking water needs. Their characteristics depended heavily upon local customs and conventions. In Tamil Nadu, as well as other parts of South India, there were innumerable traditional systems of water harvesting. Tanks (small reservoirs and ponds) were, however, one of the most common forms of traditional water harvesting structures. Most were built for irrigation but others were intended to meet the drinking water requirements of local people and livestock. Temple tanks were also common. In addition to their direct role in water supply, these water bodies performed an important function of groundwater recharge. In addition to tanks, thousands of temporary diversion channels (*kasam* or spring channels) took off from rivers and supplied irrigation water for at least one irrigated crop each year. In many villages these spring channels were the only important source of irrigation.

At present, many of the drinking water tanks, cattle tanks (*kuttai*) and temple tanks are in poor or non-operational condition. Many others have disappeared or been encroached upon by other land uses. The well ordered temporary diversion channel system has also disappeared in most of the villages. According to the original tank memoir (notes from initial engineering surveys), 39,000 irrigation tanks once existed in Tamil Nadu. The number remaining in use is unknown as is the number that have been abandoned or have disappeared. Studies on tanks in Tamil Nadu indicate that large numbers are in decay,

particularly in northern parts of the state. The decline of tanks is directly related to declines in the institutions responsible for their maintenance. A recent study of traditional irrigation institutions found, for example, that institutions responsible for maintenance were defunct in six out of the fifteen tanks of the Palar Anicut System in northern Tamil Nadu. In southern parts of Tamil Nadu, tanks still play an important role in irrigation.

One of the main reasons for the disintegration of traditional irrigation systems in Tamil Nadu has been a large-scale transfer of land from the upper caste landlords to tenants and agricultural labourers. Prior to land reform, landlords not only controlled the land itself but also the water resources. In this context, they performed the role of an effective rule enforcing authority and mobilized free labour from their tenants for tank maintenance. After land reform, cultivation by small individual land owners replaced larger farms run by absentee and large landlords as the primary mode of production. At the same time the introduction of green revolution technologies starting in the mid-1960s increased the demand for reliable sources of irrigation water. This, along with the diffusion of pumping technologies, has catalysed large-scale investment in well irrigation by many farmers. While this has had many advantages for individual users it has also undermined traditional tank irrigation institutions. The decline of tank irrigation institutions is closely associated with growth in the number of irrigation wells constructed in tank command areas.

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Major trends in society shape the context of water management.

communities to provide a basis for ongoing maintenance and operational activities. Where communities have become more mobile (having numerous individuals working outside on a permanent or temporary basis, for example) the social basis for maintenance of traditional system often declines. A similar situation can also occur where governmental assistance for the improvement of traditional systems gradually

undermines their operational and institutional capabilities. This is illustrated in Box 10 on the farmer managed Khadwa-Motipur irrigation system in Nepal.

The above arguments should not be taken to imply that traditional systems are inherently subject to decline or that revitalization is impossible. Instead, the core point is that major

BOX 10:**The Khadwa-Motipur Irrigation System in Nepal**

The Khadwa-Motipur irrigation system in western Nepal is discussed in detail in the Nepal case study chapter later in this volume. The system is farmer-managed, has a command area of 2,000 ha, and has recently received government support. Until the late 1970s a traditional system to divert water from the Khadwa stream served approximately 18 villages. In the late 1970s, the local water users committee was headed by Bhushan Tiwari from a tail end village who was also a member of the Rastriya (national) Panchayat. With his support, the villagers managed to get a “permanent” dam constructed for the system and a partially lined canal constructed up to the village of Bhuwari, the home of Bushan Tiwari. These



Private pump in Tinau command

improvements lasted for one season before major damage occurred. The system was then repaired a few years later only to suffer substantial damage during the following monsoons. The dam was completely reconstructed in 1985 but again collapsed shortly thereafter. Now the system is being rehabilitated again under the irrigation line of credit from the World Bank.

Prior to 1992, water user groups in Khadwa-Motipur and other traditional irrigation systems were informal in nature. They are now being formally registered under the Water Resources Act of 1992. As formal institutions, they are susceptible to becoming a political forum for contesting political power. In some ways, the processes of formalization and system “improvement” are undermining the traditional system that existed prior to the 1970s. Headworks, which were once constructed with inexpensive locally available materials, are now built from expensive materials that are not locally available. When they fail, repair is difficult and local communities have learned to wait for the next governmental rehabilitation project. Furthermore, the scheme no longer brings much benefit. Due, in part, to unreliability of the surface system over recent decades, there are now 67 shallow tubewells and 150 pumpsets in the command. Many farmers no longer depend on the system for water. The net result is a history of “improvements” that have gradually undermined system operation and led farmers to seek alternatives. The traditional system is, in many ways, no longer present.

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trends in society are reshaping the context in which water management occurs. Approaches that ignore or do not evaluate the logic of specific management approaches in the context of these trends are likely to fail. Management approaches must, as a result, reflect and, wherever possible, build off major social trends. Maintaining and revitalizing traditional systems may face particular questions on this count.

The Prominent Role of Economic, Institutional and Cultural Factors

The previous section highlights the role of social change in the decline of traditional water management systems. In many ways, social, cultural, institutional and economic factors outside the physical resource system, and available technology, are the most prominent elements

Societal trends shape water management responses.

influencing water use patterns at local levels. The case of the Shekhawati basin in Rajasthan (Box 11) illustrates the role economic and institutional factors play in rural areas. As discussed further in Box 12, urbanization and larger changes in the structure of society are also major factors. The primary focus here is, however, on factors within rural areas.

Many economic, technical and cultural factors affect crop choice and consequently water management options.

In most agricultural areas, crop choice is one of the largest factors affecting water demand at the field level. The decisions individual farmers make regarding crop selection are based on an array of considerations including prices, risks, input availability, marketing facilities and, at least in some situations, cultural factors. These factors are often interrelated. The crop prices farmers see are often, for example, influenced by global market conditions, governmental support programmes and the presence or absence of marketing facilities. In the Shekhawati Basin case, high prices for oilseeds (a product of both increasing demand and governmental support programmes), the development of organizations for oilseed processing and marketing, and reductions in risk through subsidized credit plus groundwater development resulted in dramatic shifts in cropping patterns. Over a period of approximately 15 years, oilseed production grew from negligible to over 40% of the irrigated area in the basin. This increase was brought about primarily through expansion in irrigated area, although crop shifting from more traditional crops such as wheat may also have occurred. It is important to note, however, that despite the substantially better returns associated with oilseeds, wheat production remains very significant – accounting for approximately 30% of the irrigated area.

Cultural factors may be playing a major role in limiting the shift away from wheat and into oilseeds. In Gujarat and Rajasthan, society places a high social value on food self-sufficiency. During fieldwork in both locations, farmers often emphasized that it is a point of pride never to purchase grain from the market. Growing sufficient wheat for home use is widely viewed as the basic measure of a successful farmer. In some cases visited in Mehsana district of Gujarat, farmers are irrigating wheat using groundwater with pumping lifts of greater than 200 m. In interviews they regularly acknowledge that they could earn much better returns by growing oilseeds and, in some cases, point out that the wheat would actually cost less (despite high subsidies for electricity for pumping) if purchased on the market.⁸ Furthermore, farmers indicated a strong awareness of water scarcity along with the need to conserve or use it as efficiently as possible – but that awareness did not overweigh the social marker value of growing at least some wheat.

The above dynamics within rural areas are further complicated by major patterns of social change occurring throughout South Asia. As previously noted, urban populations in South Asia are growing rapidly, as are the urban populations Worldwide. In 1920, less than 15% of the world's population lived in cities and towns. By the turn of the century nearly 50% will (Morris, Lawrence et al., 1994, p. 1, citing UNCHS, 1987). The same pattern is occurring in India and, to a lesser extent, in Nepal (Chaterjee, 1998). The consequences of this are illustrated in the case of Tamil Nadu (Box 12). Industry is growing and water use patterns are shifting. More importantly, the structure of society is changing

BOX 11:**Social and Economic Change in the Shekhawati Basin, Rajasthan**

In the Shekhawati basin a wide variety of factors (including agricultural pricing policies set by the government, the development and adoption of new seeds along with input subsidies, and state intervention in creating appropriate marketing facilities), have caused significant changes in land use and cropping patterns. Over the past two decades, credit support programmes run by the National Bank for Agriculture and Rural Development (NABARD) were a major factor supporting the digging of new wells and the adoption of sprinkler technology. Changes in the relative price of crops and the development of processing and marketing facilities also made oilseeds more profitable. This led to major reductions in the area under traditional irrigated crops while the area under oilseeds (mustard and rape, which are commercially valuable, low water intensity crops) has grown greatly, and water saving technologies such as sprinklers have been widely adopted. Water demand per unit output may have dropped as a result. This shift has, however, been accompanied by increases in the number of energized wells and irrigated area. As a result, net extraction has probably not declined.

The land use pattern in the Shekhawati basin has undergone significant change since 1980. The basin has recorded an increase from 566 thousand hectares to 585 thousand hectares (that is, an increase of roughly 19 thousand hectares) in area sown more than once. As a result the total cropped area has shown an impressive increase of 16 per cent. This increase has resulted in a reduction in fallow and grazing lands. In addition, the area classified as uncultivable wasteland has declined from over 60 thousand hectares to less than 30 thousand hectares between 1980 and 1997.

The changes in cropped area are reflected in the cropping pattern of the basin. Between 1980 and 1990 the irrigated area increased almost 100%, and it increased a further 30% between 1990 and 1997. In addition, a striking change occurred in the cropping pattern. The area under oilseeds increased dramatically from negligible levels in 1980 to 87.6 thousand hectares in 1997. Oilseed crops now account for more than 40 per cent of the total irrigated area. The next most important crop is wheat, which accounts for about one third of the irrigated area. All these crops are *rabi* season crops. The *kharif* crops are mostly rainfed and irrigation then is mostly protective.

Although the region has shifted from relatively lower value and higher water intensity crops to higher value and lower water intensity crops and many farmers have adopted sprinkler irrigation technologies, increases in irrigated area suggest that groundwater extraction has not declined. In any case, groundwater tables throughout the basin have declined sharply over the last decade, possibly causing irreversible damage to the aquifer.

M.S. Rathore



Sprinklers in Rajasthan

BOX 12:**Urbanization and Rural-Urban Water Trade in Tamil Nadu**

With an urban population of 33%, Tamil Nadu has the second largest percentage of its population in urban areas of all states in India. Composite indices reflecting urbanization characteristics, such as town density in addition to urban population, place it first. Most of this urbanization has occurred over recent decades and the rapid process coupled with speedy industrialization has resulted in a situation where it is increasingly difficult to meet the basic water and other needs of urban populations.

In the last decade, many industrial and commercial establishments in the urban areas have been drawing a huge amount of groundwater through their own deep borewells or by purchasing water. Notable among the cities and towns in the state which depend upon the pumping of water from their rural neighbourhood are Chennai and the Coimbatore-Tiruppur-Erode corridor (in the previously undivided Coimbatore district), Karur (Karur district) and Dindigul (in Dindigul district). The sale of groundwater has been quite extensive in these areas. Perhaps the largest consuming town is Tiruppur in Coimbatore district. This town has earned a place on the industrial map of the subcontinent as one of the large foreign exchange earners due to the heavy concentration of knitwear industries in the town.

The case of Tiruppur illustrates the impact rapid urbanization is having on water demand and use patterns. There are about 752 dyeing and bleaching units functioning in this town whose operations depend heavily on high quality water. In the absence of any other source, these units have been transporting groundwater from the rural areas by truck-tankers. Out of 93 million litres of water used per day (mld) in this town, private water supply alone contributes to about 60 mld, or 64%. The water is transported by the truck-

tankers from several villages within a 30 km radius of Tiruppur. A rough estimate puts their number at 900 to 1000, of which about 90% are reported to be owned by the industrialists. Although much more water is used for irrigation purposes than for the urban industrial and drinking water needs, the Tiruppur industries concentrate their pumping in the selected villages in the area where the quality of water is relatively better. This puts an especially heavy burden on these villages. As a result of this export of good quality water from the villages, there has been a trend in the last 10 to 15 years of agricultural wells going dry and people finding it hard even to meet their drinking water needs. There are now about 30 heavily affected villages around Tiruppur. The people living in these villages, especially farmers, have become increasingly sensitive to the depleting groundwater conditions. Wet crop or garden crop cultivation (in particular coconut, banana and turmeric cultivation) is no longer practiced in these villages. Most deep borewells belong to industrialists.

S. Janakarajan



Water in tankers for sale: Tamil Nadu

rapidly making it difficult to identify a sustainable social basis for management.

The prominent role of social, cultural, economic and institutional factors represents one of the largest challenges for water management. Water management discussions often focus on water management topics *per se* rather than on the larger context shaping water use decisions. Where institutions are concerned, discussions often focus on specific water management organizations rather than on the wide array of institutions, such as agricultural cooperatives or marketing facilities, for example, that shape market structures. Similarly, where economics are concerned, discussions emphasize water and energy prices rather than the economics of crop choice. Water and energy prices can be a minor factor in the larger economics of crop production and may, thus, have little actual impact on the total amount of water used (Moench and Kumar, 1994). In addition, cultural factors such as the social value of food self-sufficiency as a key mark of success can dominate economic factors in water use decisions even where water scarcity is a widely acknowledged concern.

The above points underlie many of the key conceptual elements we see as essential for effective water management. Economic and social factors often change rapidly. Management systems cannot, as a result, remain fixed. Instead, management needs to be structured as a process capable of responding to changing contexts. Systemic perspectives and integrated response sets are equally important, because water management interventions *per se* may have far less impact on actual water use patterns than the wider array of economic, institutional and cultural factors affecting individual water use decisions.

Organization Capacity and Scale

Although larger patterns of social and economic change probably have a greater impact on water use *per se*, water related organizations are extremely important as the focal points through which intervention and management initiatives occur. Among many factors central to debates over water management organizations, discussions among the organizations collaborating in this project highlighted four as particularly important:

1. **The gap between the village and the state:** Throughout South Asia, most organizations dealing with water management fall into one of two large classifications – governmental and village. Most government organizations are centrally controlled either at the national level or the state level. They are part of large governmental bureaucracies and have relatively weak links with the local realities of water management needs. Village level organizations, in contrast, are generally very small and localized. They deal with water management needs at a local level and often operate informally. While these organizations are closely linked with local problems and realities, they function with little

South Asia lacks intermediate level organizations for water management. The village-state gap must be bridged.



Stakeholders' Forum: Gujarat

The process approach emphasizes the evolution of organizational capacities.

technical expertise or other backup. Few organizations function at levels between these two extremes. This polarization represents a significant challenge for effective water management because many needs require regional scale (aquifer or basin) interventions. Traditional irrigation systems in Nepal, which may cover as many as 5,000 ha and involve thousands of farmers, are the only example of intermediate level water management organizations we have encountered.

2. The *orientation* of water management organizations: Most water organizations in South Asia were initially structured to implement water development activities. This orientation remains strong. The tendency for organizations to focus on development is enhanced by the fact that development requires large amounts of funding for construction while management interventions may require substantially less.

3. Organization *capacity* for management is limited: In concert with the focus on development,

most governmental water organizations are dominated by technical specialists. Effective management, however, requires organizations to have an effective capacity to take part in dialogues within civil society. Management processes require institutional evolution and capacity development.

4. Organization *responsibilities* are often disjointed and overlapping: The case of the Tinau River provides the best illustration of this. Numerous traditional and governmental organizations are engaged in activities affecting the water resource system along the Tinau. Because few of these are aware of each other, activities often conflict. Deep irrigation wells funded by international donors, for example, are being installed in locations where shallow wells already meet most irrigation needs. Projects such as the Marchawar Lift Irrigation Scheme are designed and constructed with little knowledge of the traditional systems they bisect. On the Indian side of the border, embankments are constructed to protect areas from flooding. In the process they



The confluence of water, religion and officialdom. State managed canal: Rajasthan

create larger flood problems in other areas and undermine agricultural systems dependent on silt and rapid drainage. There is no mechanism for coordination at a regional or basin level.

From our perspective, the above organizational issues are a major reason behind the necessity of a process approach to management. Organizations often cannot be created, reformed or strengthened rapidly – particularly when the array of activities needed is complex and varies greatly between locations. Process approaches emphasize the gradual evolution of organizational capacities in response to needs and opportunities. While it is clear that core gaps – such as the absence of intermediate level organizations capable of addressing regional problems – must be filled eventually, the specific characteristics of these organizations is difficult to determine in advance. A process approach enables the essential evolution to proceed.

Legal Frameworks and Water Rights

Existing legal frameworks for water management in South Asia are partial at best. In India, there are four sets of legal frameworks affecting water use and management: traditional, common law, legislative and constitutional. While it is beyond the scope of this paper to review these in detail, it is important to recognize that existing frameworks are in a state of flux. This is particularly true in the case of groundwater. As a recent report by the World Bank and Government of India states: “*Systematic approaches to management require a solid legal framework if they are to be implemented. Groundwater legislation will ultimately be essential for management. There is, however, little unanimity*

regarding the form such legislation should take in order to be effective.” (WB, 1998, p. iv).

The case of India is illustrative. In many parts of India, traditional rules of allocation and forms of water rights still govern the day to day use of water at local levels. This is clearly evident in the hill irrigation systems of the Indian Himalayas (and Nepal), many of which operate on the basis of complex local customary rights systems. In addition to traditional practices, Common law (derived from the British, and ultimately Roman, systems) governs most aspects of water in the civil courts. Under common law, groundwater is chattel to land. Extraction of percolating waters with no limit on quantity is the right of every landowner (Sinha and Sharma, 1987; Jacob, 1989). This right is, in theory, limited by the Easement Act and irrigation acts which “proclaim the absolute rights of government in all natural water” (Singh, 1990, p. 50). In addition, a number of other subsequent acts such as the Maharashtra Water

Existing legal frameworks are in a state of flux.



Traditional sancho for water allocation: Palpa

Developing effective water rights systems requires experimentation.

Act, Madras mini-act, Gujarat amendment to the Irrigation Act, and the Model Bill circulated by the Central Ground Water Board all start with the perspective that water rights are all held by the government. These acts relate, albeit indirectly, to constitutional provisions. Under Entry 17 of List II of the Constitution of India, the states have full authority overall water within their borders except in the case of interstate rivers and basins (World Bank, 1998). Other constitutional provisions, specifically those relating to the environment and the right to life, limit the way in which water rights held by either the state or individuals can be used.

The above mix of rights, many of which are contradictory, has been coming under increasing pressure due to a variety of recent events. On one hand, increasing attention is being given worldwide to water markets and their potential use as efficient mechanisms for water allocation. Development of formal water markets (as opposed to water trades between adjacent users) requires a legal rights foundation. On the other hand, recent decisions by India's Supreme Court mandate governmental action in the form of a groundwater authority for regulating extraction to address overdraft. These developments lay the foundation for increased conflict between use patterns established on the basis of traditional or customary rights and new forms of rights. At present, it is far from clear what types of rights systems will be both viable and capable of meeting emerging management needs. The types of privately held transferable rights essential for large-scale water markets to evolve may be socially or politically unacceptable. The physical difficulty in establishing such a rights system should also not be underestimated. There are, for example, over

25 million private pumpsets in India (World Bank, 1998) and, as previously noted, many wells are capped and buried when not in use in the Nepal Tarai. In this situation, the practical difficulties in monitoring groundwater extraction may exceed any benefits that would be achieved through a rights system.

Overall, the fact that clear pathways for reforming water rights do not exist and that substantial experimentation will probably be required before effective rights systems can be developed are key reasons why an evolutionary process approach to water management is needed. Rights systems do represent part of a larger enabling civil environment. They cannot, however, be devised or imposed without substantial experimentation and learning. Furthermore, in many cases traditional or civil rights systems may provide key building blocks for future approaches. While much has been done to document these systems, how the advantages they contain might be integrated into more formalized governmental systems remains relatively unexplored.

Social Responses

The major social responses to emerging water management problems have taken a variety of forms. Throughout much of India, water scarcity has led to the spontaneous emergence of informal markets for drinking, irrigation and, in some cases, industrial supplies. Interviews with field NGOs and farmers also indicate that water scarcity is becoming a major factor driving rural populations to migrate to urban areas. Where organized action is concerned, protests at the grass roots level are common and many rural NGOs have decided

either to focus on water problems or include them in their village level work programmes. A similar evolution has also occurred at the national level with higher-level research organizations and activist NGOs incorporating water problems as major components in their agendas. These national level NGOs and research organizations provide much of the analytical and activist pressure behind recent national level attention to water issues. A recent tangible result of this is the Supreme Court decision mandating action by the Central Ground Water Board to address overdraft problems (World Bank, 1998). Beyond this type of formalized action, water issues are becoming major focal points for political attention.

The cases of Kathmandu and Gujarat (Boxes 13 and 14) are a good illustration of the gradual evolution of social responses to water scarcity. Historically, water supply depended on the initiative of individuals and local communities to dig wells or divert streams to meet their water needs. With population growth, agricultural intensification and urbanization, needs grew beyond the scale at which individuals or communities could easily respond. At this point governments began the development of supply systems. Often these started as what we now term “traditional” systems and then evolved in a piecemeal manner into irrigation or drinking water supply systems containing a mix of modern and “traditional” technologies. In the Kathmandu case, growing demand and operational issues have outstripped the capacity of the government to manage the system, and scarcity for users emerges as a result. Rather than addressing these internal management issues, the governmental response focuses on the development of new supplies. At the same time, scarcity (either

in an absolute or quality sense) creates the conditions in which markets emerge. This form of social response is generally paralleled by the emergence of social protest. Although initially disorganized, social protest over water scarcity problems often leads to the emergence of institutions or forums outside the government that advocate for change. Where educational, financial and organizational resources are available, as in Kathmandu and Gujarat, these institutions can provide an increasingly informed and sophisticated basis for social debate over potential responses. Where these resources are less available locally, as the case of pollution in Tamil Nadu suggests (Box 6), external organizations may enter. Often, however, a long term process of protest, minor governmental responses and local adaptation to scarcity emerges as the dominant response.

Beyond the broad patterns noted above, summarizing the full array of social responses is beyond the scope of this paper. A few common elements are, however, important to note. We view these elements as a central component of the context in which management must occur.

First, social agitation is frequently emerging in moments of crisis and water issues are becoming centrepoints for political attention. As the box on groundwater pollution in Tamil Nadu documents (Box 6), agitation is often intensive but short-lived. Groups organize to protest a specific issue – water scarcity, pollution problems, electricity prices or shortages, etc. – and the crisis is temporarily averted only to emerge again as attention wanes. Despite its temporary nature, the extent of social agitation around water issues is increasing. The degree to which water issues have become a focal

**Social responses
to water
management
problems take a
variety of forms.**

BOX 13:**Social Responses to Deficient Drinking Water Supply, Kathmandu**

Kathmandu, the capital of Nepal, sits on a plateau in a broad valley surrounded by the Mahabharat Mountains. The Bagmati River and its tributaries are the valley's principal river system and its springs are the main source of drinking water for the residents, particularly for greater Kathmandu — the urban core of the valley. Whereas the snow-fed rivers of the country bypass the valley in the east and west, the Bagmati, is rainfed. Residents of the capital served by the city drinking water system face recurrent water scarcity even during high rainfall portions of the year. Responses to scarcity have been ongoing for twenty five years and provide an interesting case study of how different social groups within the capital have perceived and responded to the problem.

For the sake of analysis, responses to scarcity can be categorized as occurring within four social and institutional groupings: (1) individual and community initiative; (2) the government; (3) the market; and (4) civil society institutions.

The first grouping consists of individuals and local communities (or user groups) who took the initiative to develop local water supplies to meet their own needs. This

“traditional” form of water development prevailed throughout most of the valley until recent decades.

The second institutional grouping, and the currently dominant one, is that of the government and the governmental water utility that now has the formal responsibility of supplying water to greater Kathmandu. Historically, drinking water supply to the town of Kathmandu was met through stone waterspouts. These flowing spouts are located within rectilinear pits built in the ground. The spouts were supplied through *Raj Kulos* (state canals), which served irrigation water needs. These stone spouts used local water sources and, though they received state sanctions, were highly decentralized.

Modern intervention for improving drinking water in Kathmandu started more than 100 years ago during the reign of Rana Prime Minister Bir Sumsher. It was during his rule that Kathmandu's first drinking water system, the Bir Dhara, was built. The supply system also had the ostensible function of supplying water to the fountain in front of his palace, which was called “Fountain Palace” (in Nepali *Fohora Durbar*). Subsequently there have been



Private water tanker: Kathmandu



Rower pump: Kathmandu

several interventions to tap water in the surrounding hills as the population increased and the character of the capital changed from agricultural to a commercialized metropolis. In the early 1970s Nepal secured the first loan from the World Bank to upgrade the drinking water supply system for Kathmandu. A few years later, the Bank funded the initiative to tap into the valley's groundwater. Subsequently, more water has been tapped to fulfill water needs of the city's population.

The network that currently supplies water in the Kathmandu Metropolitan Municipality and Lalitpur Municipality covers an area of 50 km² and serves 935,000 consumers via 96,058 connections.⁹ Daily drinking water production is 107,000 m³/day with an estimated system loss rate of 40%. Water supply is intermittent and several localities on the network are not supplied. The system receives water from seven different production arrangements involving surface and groundwater sources which supply water to seven sectors of the city.

By the 1980s, the water supplied via sources within the valley was considered to be inadequate and sources outside the valley were investigated. The source identified as most feasible was the Melamchi River, which could be tapped via a 27 km tunnel through the mountains north of the valley. The Melamchi Project is currently being pursued, with the Asian Development Bank taking the lead role. When completed, the Melamchi project is expected to augment the drinking water supply of Kathmandu substantially. The efforts of the state agencies has been guided by the incentives for continued augmentation of supply as their dominant response to water scarcity.

The third institutional response has been the emergence of water markets and related commercial organizations. Scarcity of drinking water supplies from the government system has forced individuals to develop or return to other options. Many residents in the city have directly connected

centrifugal pumps to the mains, while land owning households have installed hand pumps, rower pumps, or open wells. Others have resorted to collecting rainwater at least during the monsoon months. More affluent groups, such as Kathmandu's hotels, industries and commercial establishments have installed deep tubewells. Since many



Traditional drinking water source: Kathmandu

of the sources are of uncertain quality, commercial establishments have sprung up that offer water treatment and water quality testing services. Many entrepreneurs supply drinking water. Water sellers using private tankers are also active, and bottled water use is now common. In doing so they provide a key service and also makes significant profits. One 8,000 litre tanker of water costs Rs 1,000, one litre of bottled water costs Rs 20. The situation of scarcity has been used by some to make a profit by providing the services.

The final institutional response to the water supply situation in Kathmandu has been by activists, consumers' forums, journalists and academics. These critique the systemic flaws in the management of the valley water supply utility and question the need to develop new supplies by demonstrating that existing supplies could meet needs if management were improved. Questions are raised in newspapers, TV and public programmes. These critiques are, however, infrequent, disorganized, and too feeble to

receive major attention by government agencies and donors who continue business as usual. Critiques have, however, had limited impact. The inefficiency of the parastatal utility has been noted by the World Bank and it has proposed that management of Kathmandu's water supply system should be leased out to the private sector. The question of why the supply points in the distribution network do not receive the quantity of water that must theoretically be available remains unanswered.

The Kathmandu case indicates the varied nature of responses to drinking water supply scarcity. Every socially organized group prefers solutions that reflect their own strategy, fear of risks and perception of nature. Most individuals, whatever group they fall within, strategize to secure access to drinking water either by manipulating the governmental supply system, or by creating access to the market, by protest or by the development of private sources.

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Pumping water from a supply main: Kathmandu



Bottled water is becoming popular in Kathmandu

BOX 14:**Responses to Groundwater Depletion in Gujarat**

Mehsana district in northern Gujarat has been a focus of attention for hydrologists, agricultural economists and government policy makers working on water resources for several decades. This is due to the extensive alluvial aquifers underlying the district, exponential growth in the number of wells, the intensity of groundwater irrigation and its contribution to the agrarian economy of the region. Groundwater over-exploitation problems first emerged in the early '70s in the intensively cultivated areas of northern Gujarat when expansion of tubewell irrigation caused water level declines in the shallow alluvial aquifers and the drying up of open wells.

In order to understand the nature of the causes of water level declines a study sponsored by the UNDP was done of the Mehsana aquifers in the early 1970s. This was followed by several publications, which focused on emerging physical problems and potential technical solutions such as artificial recharge and water harvesting. In 1976, artificial recharge experiments were successfully carried out in Mehsana with assistance from the UNDP. This confirmed the technical viability of recharge options. However, recharge activities did not take off on a large-scale due to lack of funds. The availability of sufficient water for recharge to have much impact on groundwater overdraft problems is also uncertain.

By the late 1980s water problems in Mehsana and other areas were becoming more widespread and groundwater management became one of the core issues in the overall debate on water among academicians, government policy makers and NGOs. The response from NGOs such as the Shri Vivekananda Research and Training Institute (SVRTI) in Mandvi, Kutch and the Aga Khan Rural Support Programme (I) (AKRSP (I)) came in the form of local water management initiatives in their project areas. These and other academic and research institutions took up several research studies looking at the social and economic impacts of resource depletion.

In the early '90s, farmers from villages near Upletta in

Rajkot district of Gujarat started diverting rainwater into their farm wells in an effort to replenish their drying wells. Later, this was picked up on by many religious and spiritual institutions, NGOs and grass root organizations in other areas of Saurashtra as a worthwhile method of addressing the scarcity issues.

A conference organized by VIKSAT in 1993 first looked at the technical, social, economic, legal and institutional issues in groundwater management in India. It was followed by several publications discussing the range of issues and the physical, social and economic options for managing groundwater (Moench, et al, 1994). The mid-1990s saw many NGOs and grass root organizations in the state replicating the experiments by Swadhyaaya, Sri Vivekanand Research and Training Institute (SVRTI) and Aga Khan Rural Support Programme, India (AKRSP) in local water management, while many others also advocated a supply based approach as a solution to groundwater depletion problems and water scarcity.

In the late 1990s, a prestigious rural institution, the Mehsana Dudh Sagar Dairy, began to be actively involved in local water management activities in Mehsana. This is occurring with funds mobilized from the village dairy cooperatives that are affiliated with the larger dairy cooperative. The larger cooperative has set up a foundation, the Motibhai Foundation, to work on addressing water management issues in the district. The involvement of the dairy represents a significant change in the degree of local attention being devoted to groundwater management. Most NGO efforts have been externally financed and involve, at most, only nominal contributions from local populations. Activities by the dairy represent the first large-scale, locally financed initiative by a large local organization in Gujarat. Along with activities by the dairy, greater recognition of the widespread problems is coming from the national government, and major projects on groundwater management are proposed.

D. Kumar, S. Chopde and A. Prakash

In order to address water management needs, enabling environments that reduce polarization and encourage local initiatives are essential.

point for social attention is illustrated by the comments of Indrajit Gupta, the former Interior Minister of India, following the recent nuclear tests. He stated then that: “The nuclear tests are a great achievement for India, no doubt, but we can’t even supply ordinary drinking water and electrical power to the people of this country”.¹⁰ On a more local level, in some areas political parties are beginning to focus on water management as a core part of activities to build their support base.¹¹ From large-scale issues – such as the Narmada or Pancheswar dams¹² – to more diffuse problems associated with groundwater overdraft, water issues are now central points for political attention.

Second, in addition to short-term agitation and the increasing political debate over water issues, longer term movements are beginning to emerge in some areas. Many small-scale initiatives that were catalysed by NGOs exist in rural regions. Most of these are confined to a few villages and their focus and sustainability vary greatly. Box 14 on the Gujarat case illustrates the gradual evolution of NGO activities into nascent, potentially large-scale, rural movements. The case study of the Swadhyaya movement, also in Gujarat, represents a different type of initiative. There, religious leaders encouraged farmers to recharge groundwater by diverting storm flows into existing dug wells have catalysed a relatively large-scale movement. Supplementing water supplies – rather than managing available ones – has been a key feature of most NGO and other rural movements to address water resource problems. These supply side interventions are beginning to be supplemented by demand side management activities. For example, sprinkler systems, which are widely viewed as saving water, are being

adopted on a large-scale in many areas. Most of this is occurring on the basis of actions by individual farmers rather than through initiatives by rural water management organizations. It has, however, been supported through subsidized credit programmes run by the government through the National Bank for Agriculture and Rural Development. Rural NGOs are also beginning to promote demand side management activities, though little progress has been made in most cases. Overall, there appears to be a very gradual evolution away from initial supply focused activities and toward a recognition that demand side management will be essential to address scarcity in many situations. This evolution is clearly evident in the Gujarat case documented in Box 14. The above said, most activities through local NGOs remain supply focused.

The core point in the above discussion is that water issues are becoming a central part of debates within civil society at both local and national levels. The emergence of these debates coincides with nascent and often limited initiatives for actual water management at local levels. One of the largest challenges facing water management in the future will involve the evolution of both the larger civil society debates and the more specific water management initiatives. In the past, many water management debates became polarized between, for example, dam proponents and anti-dam activists or between those in favor of centralized versus decentralized approaches. Polarization often results in deadlock with little social space for effective action. If water management needs are to be addressed, enabling environments that avoid polarization and encourage local initiatives to evolve are essential.

Ways Forward – What does all this mean for local management?

What does this all mean for local water management? This report represents the first phase of a study, that will systematically examine water problems in a series of case study regions and then identify the types of local water management options that could be implemented in order to address them. As planned, the first phase has involved a broad scoping process intended to collect background information, develop concepts and create the basis for more quantitative and targeted investigations in subsequent phases. The above caveats aside, the research has major implications for water management initiatives.

First, local water management is a misnomer. Even if strategies and implementation projects are carried out by local communities and are essentially “local,” they are most likely to evolve if the higher level structure of civil society is supportive. “Enabling environments” are regional or national and require support at that level. Similarly, on a physical level, management approaches should not be polarized between “local” and centralized strategies. Instead, issues and appropriate responses should vary in scale according to context and needs. Some of this will involve national level action and some local.

Second, the key questions surrounding water management have to do with governance processes within civil society and not technical or site specific details. Physical problems and potential technical responses to them are, in most cases, relatively clear. How society can implement them effectively

is far less so. Details vary greatly between sites and regions. Few models are easily generalized at this level. The larger questions of civil society processes may, however, be more easily generalized.

To project collaborators, the way forwards, toward sustainable water management, requires action in three areas:

1. *Implementation and documentation of management initiatives*, particularly ones involving participation by local populations and organizations as well as the government, to address specific water resource constraints;
2. Strengthening the basis for *informed debate* within civil society regarding water management needs and options; and
3. Beginning the process of *reforming water related institutions and organizations* away from development and into the types of structures needed to support the larger social process of management.

As emphasized at the beginning of this report, *water management issues are governance issues that ripple throughout society and must be addressed at a societal level. That is, perhaps, the single most important theme running throughout research by the collaborative group and, as a result, this report.* Each of the arenas listed above are central to addressing the governance nature of water management issues.

Local water management is a misnomer. Management needs vary in scale and responses should as well.

Informed dialogue is crucial for reaching a social consensus regarding emerging problems and appropriate responses.

Implementation and Documentation

On a practical level, water management problems cannot be addressed unless implementation activities occur. At present, implementation initiatives are widely scattered and poorly documented. While many focus on specific water resource constraints, few are based on any larger perspective regarding the larger systems into which they fit. Furthermore, most emphasize narrow technical solutions rather than recognizing that the most important points of leverage may lie within in the surrounding socioeconomic context. Strengthening and expanding implementation activities based on the conceptual elements outlined at the beginning of this report is essential in order to develop a broad base of experience. Without documentation, however, this experience cannot be used to inform future experiments and the long term process of evolving effective management systems. Documentation is, as a result, essential.

Building the Basis for Informed Dialogue

The importance of documentation relates to the necessity for informed dialogue within civil society based governance processes. From our perspective, a relatively high degree of social consensus regarding the nature of emerging problems and management options is essential for progress. Water problems touch too many people's lives in too many ways for them to be addressed purely through technically focused governmental action. Furthermore, too many groups within society have the capacity to block management initiatives

unless a larger social consensus can be built. Informed dialogue is, as result, essential. The key word is informed. This requires:

1. Information: In the absence of a broad base of accurate information (on the nature of emerging problems, related social issues, management options, etc.) debates over water problems will be based on the entrenched position of narrow perspectives. Actions that improve both the information quality and information access are, as a result, important points of leverage. Given the extremely broad array of water management problems and needs, information needs to be targeted on key issues in order to be useful. Furthermore, information is only likely to be used if it relates to water management needs that are current focal points for public and policy attention. As a result, tightly focused research activities that address key issues and are capable of adding detailed insights will prove more effective than broad regional studies.

2. Conceptual Understanding: Information is of little use unless it can be interpreted. Conceptual frameworks are essential for this. Furthermore, conceptual frameworks are central for the identification of gaps in the understanding of complex interlinked social and hydrological systems. Most importantly, however, conceptual frameworks are the underlying structure guiding debates over options and needs. *Shaping conceptual frameworks shapes the nature and direction of debates within civil society.* This is perhaps the most important point of leverage for organizations seeking to support the evolution of effective water management approaches. Research to test, strengthen and develop conceptual frameworks is, as a result, a key point of

leverage. As with information, conceptual strengthening is likely to prove most effective if it focuses on key issues that are central to current public and policy debates.

3. Communication: Information and concepts are fine but will have little impact unless they are accessible to the broad array of groups central to any broad based dialogue within civil society. Broad-based communication strategies that reach key audiences, particularly water users, and the strengthening of organizational structures for information dissemination are essential.

4. Forums for debate: Debates within civil society generally occur through the media and in political

forums. These forums are often not suitable for focused debates or conceptual evolution. As a result, development of more focused forums, such as a *South Asian Water Resource Network*, in which those with particular interests in water issues can engage is key to the evolution of knowledge and dialogue.

5. Processes: Identifying systematic processes which, while retaining an adaptive and flexible nature, also lead relatively rapidly toward management action. We know of no process examples of this type in South Asia. Integrated Resource Planning processes being developed in the U.S. may, however, provide some guidance. This processes is outlined in Box 15.

Broad-based communication through multiple forums is central to informed dialogue.

BOX 15:

Integrated Resource Planning in the United States – A process example

Integrated resource planning (IRP) is standard practice in the electricity industry in the United States and is beginning to be applied to water resources by organizations such as the Metropolitan Water District of Southern California. A key difference between IRP and earlier, supply-focused, approaches to planning is that demand side management is given equal weight to the generation of new supplies. An additional key difference between IRP and earlier planning approaches is that IRP is intended as an open participatory process leading to a review of final plans by the public or a public agency.

Process differences between IRP and earlier approaches have been outlined well in a recent paper by Jan Beecher of the National Regulatory Research Institute. According to her, traditional processes are characterized by unilateral decision-making, procedural formality and rigidity, adversarial processes, an emphasis on due process, a fact-finding orientation, narrowly defined

issues, limited participation, short and closed-ended time frames, high resource requirements, and a high degree of institutionalization. By contrast, alternative processes are characterized by collective decision-making, less formal and rigid procedures, consensual processes, variable treatment of due process considerations, a problem-solving orientation, broadly defined issues, wide participation, longer time frames, variable resource requirements, and a low degree of institutionalization (Beecher and Stanford, 1993).

These alternative processes encourage the formation of plans that can be implemented more easily than many of those produced through traditional methods. They generate a much broader consensus regarding the issues, the types of actions appropriate to address them, and the real costs (social as well as economic) associated with different options. Finally, it is important to note that IRP is designed as an ongoing, iterative process.

M. Moench

Synthesis and evaluation of information and harvesting lessons from other regions would help develop concrete reform proposals.

Institutional Reform

Supporting institutional reform processes, wherever possible, is the final key element we view as essential. Institutional reforms are likely to be a product of the informed debates within civil society discussed above. That said, however, focused attention on this aspect is particularly important. The formal institutional structures recognized in both India and Nepal often limit information availability and the types of management approaches considered in debates. Government organizations, for example, often have a high degree of control over water resource data and limit access to other groups. Similarly, existing water laws limit the array of management approaches that can be tested in implementation initiatives.

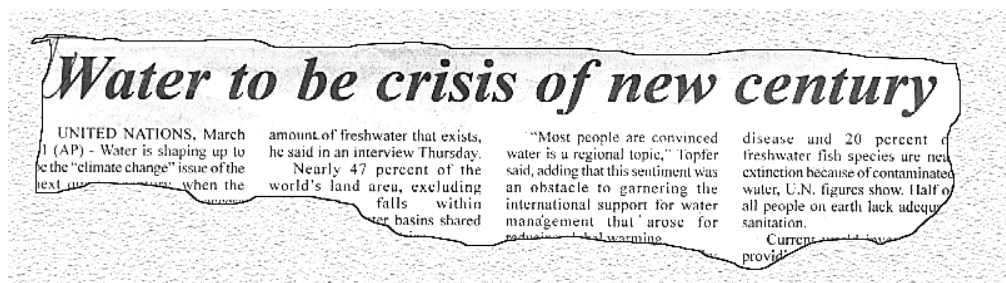
Overall, particular attention needs to be given to identifying and promoting potential institutional reforms that could reduce constraints to both innovative implementation initiatives and the evolution of informed dialogue within civil society. Three sets of activities could contribute to institutional reform processes. These are:

1. Synthesis and evaluation of information on traditional and other institutions for water management in South Asia. Extensive research

has been undertaken on traditional rights structures, water related organizations, formal legal structures, etc. in South Asia. Little of this has, however, been synthesized in a way that enables evaluation of the basis it may provide for either actual management initiatives or larger governance processes. Synthesis and evaluation is essential if this base of knowledge is to be a central feature of institutional reform debates.

2. Harvesting lessons from other regions. Many parts of the world are going through a similar transition from water resources development to management as that occurring in South Asia. As part of this process a wide variety of insights and experiences have been generated. Harvesting the lessons from this could provide valuable insights for organizations in South Asia.

3. Development of concrete reform proposals. In most cases, institutional and water rights reforms advocated by researchers are very general. The devil is, however, in the details. Activities such as the development of model water rights laws or management legislation, along with specific proposals regarding how they might be implemented, could have a much more major impact than general discussions by presenting policy makers and the public with specific proposals to react to.



Notes

- ¹ This is not to say that certain approaches do not have broad applicability within broad categories of problems. Demand side management, for example, is widely needed in response to water scarcity problems in most arid areas. The characteristics of most demand side management packages will, however, vary greatly depending on local conditions.
- ² The wider the array of actors having the capacity and standing to engage in this dialogue, the more representative and broader it will be.
- ³ A prime example of this comes from the Ta'iz area of Yemen. There, a limited number of operators owning deep drilling rigs are beginning to open deeper aquifers critical for drinking water supply and irrigation uses. Protection of drinking water supplies can be relatively easily achieved through centralized regulation of these drillers. In contrast, increasing the efficiency of irrigation uses in the same area depends heavily on the actions of many thousands of small farmers and well owners. In this later case, participatory approaches are essential.
- ⁴ Maps prepared by the Rajasthan Groundwater Department.
- ⁵ Statistics after 1993 are estimates and those after 1997 represent proposals for development prepared by the CGWB (CGWB, 1996).
- ⁶ The next generation of Indian satellites will have a resolution of 1x1 metres and an ability to collect multispectral data at 5x5 metres. Discussions are already ongoing regarding monitoring of crops and water use at the level of individual fields using this technology.
- ⁷ Water and agricultural power pricing policies and availability are, for example, one of the most politically sensitive issues in India. In many states they are the core issue on which governments stand or fall. (Moench, discussions held with government officials as team leader for part of the World Bank-GOI Water Sector Review)
- ⁸ Interviews with farmers, Fall 1997.
- ⁹ ADB (1997).
- ¹⁰ Quoted in the New York Times, page A3, May 28, 1998.
- ¹¹ Discussions with local BJP leaders in Rajasthan, February 1998.
- ¹² The Pancheswar Dam is a 315 metre high multi-purpose project proposed to be built in the Mahakali - a border river between Nepal and India. The Mahakali Treaty signed between the two countries on December 1996 sets the stage for implementation of the project. For discussions on the political nature of the controversy surrounding the treaty, see Gyawali and Dixit (1999).

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CHAPTER 2

Fractured Institutions and Physical Interdependence

***Challenges to Local Water Management
in the Tinau River Basin, Nepal***

Introducing the Tinau River System

The Tinau River originates in the Himalaya of central Nepal and debouches onto the Tarai plains before flowing into India, where it joins the West Rapti River near Gorakhpur. This river is one among the many interactive highland-lowland regional complexities of the South Asian river system called the Himalaya-Ganga.

The major tributaries of the Ganga, Brahmaputra and Indus of the Himalaya-Ganga are both a boon and a bane to the people living in the region who depend on them. The Himalaya-Ganga is an integrated system facing the stress of change. Within it, the developmental needs of the people have to be defined and managed in ways that reflect the complex, interlinked and interacting nature of the physical, social and ecological sub-systems that together characterize the region.¹

Nepal rests in this interacting highland-lowland regional complexity. The country is a smaller representation of the larger regional context, which consists of the highest mountain chain on this planet and diverse ecological zones, together with the flora and fauna they support. The region encompasses a rich plurality of social systems, incorporating within them hundreds of ethnic groups, scores of languages and almost all the religions of the world. Social and agriculture systems are also intrinsic parts of this varied hydro-ecological regime.

This wide variability lies at the core of the challenges in water management facing Nepal. As the population grows and its demand for food,

health and other services increases, development needs will confront environmental values and equity concerns related to poverty alleviation.

Even though the region falls under the general influence of the monsoon, the river systems flowing through the country show distinct characteristics depending upon their place of origin. The Himalayan rivers have sustained dry season flow from snowmelt, whereas the flow in rivers originating in the Mahabharat ranges are supplemented by springs and base flow but contain low dry season flow. The Tinau River studied in this paper falls in the latter category (Figure 1). Rivers that originate in the Churia ranges of the south are ephemeral.

Through relatively small, the Tinau basin encompasses distinct geographical regions and the diverse social and cultural systems that they support. Both the surface and the groundwater resources of the basin have been extensively exploited, and the contiguous region is beginning to show early signs of stress exacerbated by the in-migration, rapid urbanization and industrialization, which followed the completion of the Mahendra and Siddhartha highways.

Successful water management strategies are those that can cope with surprises, whether sprung by nature or by society. They have to be matched appropriately with the behaviour of the physical resource as well as with the stress of change bearing on the social milieu and its incentive structures. The style of management will have to change when the scale of intervention varies.² The

Successful water management strategies are those that can cope with surprises whether related to nature or society.

Figure 1 (a):
River systems of Nepal and Location of Tinau Basin in the Himalaya-Ganga

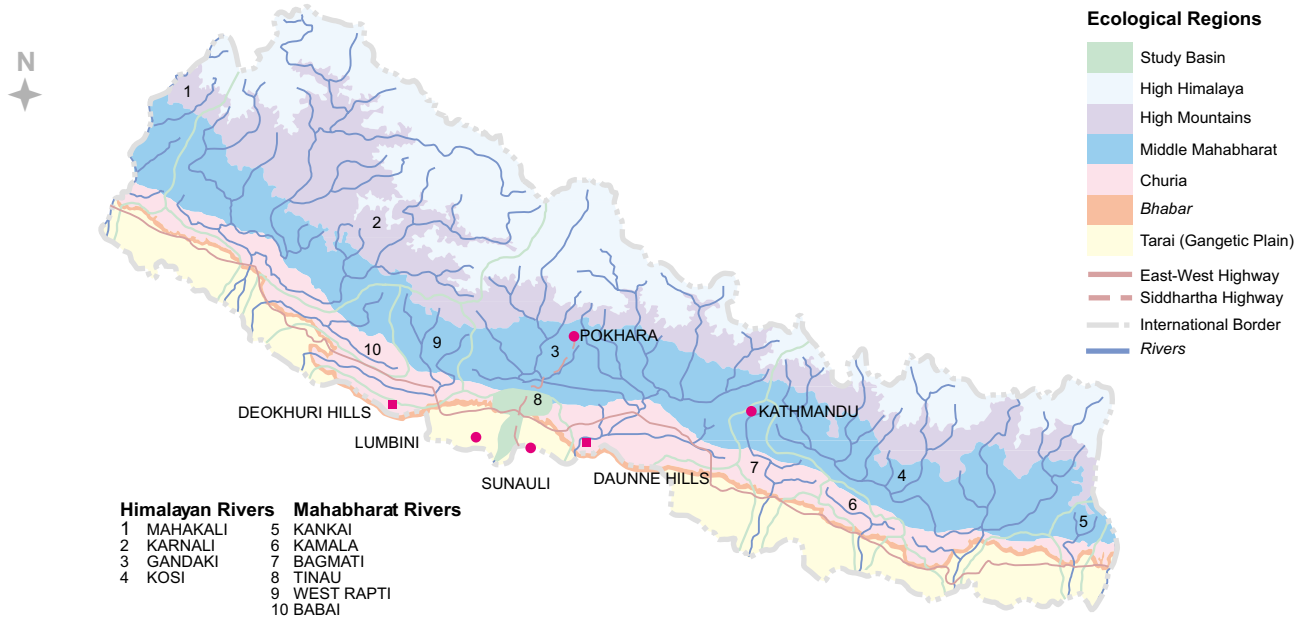
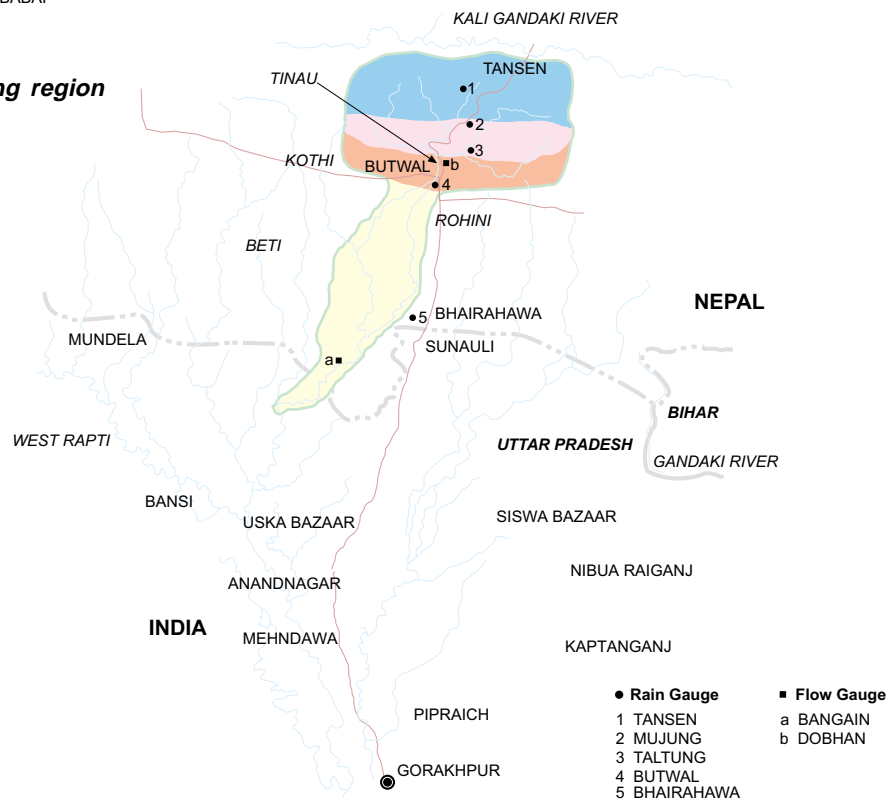


Figure 1 (b):
Tinau basin and adjoining region



Defining the Tinau “basin” (once it exits the hills) is difficult because the hydrologic boundaries between it and adjacent rivers are poorly defined.

Tinau has seen several responses to water management along its course. They include particular projects and development initiatives in specific hydro-ecological niches that range from community-led irrigation efforts to municipal or state ventures supported by foreign aid agencies. As the scale of intervention increases, the varied management styles that have evolved independently of each other will perforce have to interact. When they do, a viable management strategy will have to be ready in place so that the system is not overwhelmed by surprises.

This paper examines the Tinau River basin as a physical system and analyses the functional water uses within the basin through case studies. Each case study discusses the physical system itself as well as the institutions at work within it; it also summarizes the situation in the basin in the form of key issues. The paper’s objectives include the following:

- To explain the physical complexity and variability of the Tinau River basin.
- To map the extent and nature of functional water uses in that basin.
- To analyse along horizontal and vertical transects the roles and adaptive responses of water management institutions.
- To identify issues requiring detailed analysis and further research.

The study uses an ethno-ecological method of analysis. In a nested case study approach, attempts were made to capture the nature of variability and management responses. Fieldwork in the case study region included visits and interactions with key informants. The aim was to

understand the systemic interrelationship between water use and related institutions, and the points that are facing stress.

In Nepal, the Tinau flows through two districts, Palpa and Rupandehi. The headwaters of the river lie on the southern slopes of the Mahabharat range surrounding the Madi *phaant* (parcels of irrigated land on the valley floor) of Palpa district. Tributaries contribute to the Tinau from much of western Palpa and include streams such as the Kusum, Dobhan, Sisne and Jhumsa *kholas*. The Tinau then flows through a gorge section of the Churia hills before debouching onto the plains at the town of Butwal, Rupandehi district. Immediately downstream of Butwal, the river splits into two branches, the eastern is called the Tinau and the western is called the Dano. The two branches rejoin at Bangain in Marchawar, from which point the river is called the Danab. After flowing a further five kilometres in Nepali territory, the Danab then flows into India, where its name changes to Kuda, acquires a meandering character and joins the West Rapti River near Gorakhpur in Uttar Pradesh. The Tinau and the Dano also form the eastern and western limits of the river’s inland delta in the Nepal Tarai.

An analysis of the available maps shows that the total drainage area of the Tinau/Kuda up to the point where it meets the West Rapti is about 3,200 km², of which about 850 km² is in India. This area includes the neighbouring streams of the Tinau such as the Kothi *nadi* and the Beti *nadi*, which originate in the Churia hills in Nepal east of the Banganga River but meet the Tinau River in India. The Tinau proper in Nepal has a total drainage area of about

1,194 km². In the hills, the river drains an area of 554 km², and its drainage in the Tarai of Nepal is about 640 km².

The drainage area of the river in the Tarai plains of both Nepal and India cannot be precisely defined mainly because it overlaps with areas of the Rohini River in the east and the Banganga River in the west. All three rivers continuously change their courses and split into distributaries that capture one or another channel of neighbouring streams as they move from the north to the south. As a result, the available maps do not represent the actual alignment of the rivers in the Tarai accurately. Additional difficulties in defining basin boundaries are introduced by the fact that the Tarai part of the basin is underlain by a continuous east-west alluvial formation that also receives flow from ephemeral rivers originating in the Churia hills.

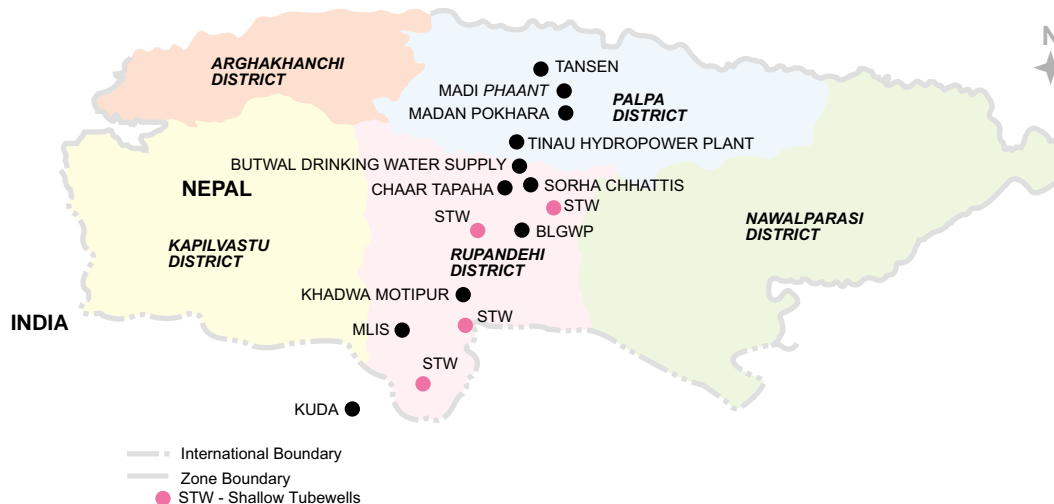
Unlike larger snow-fed rivers like the Karnali, Gandaki and Kosi emerging from the High Himalaya of Nepal or the smaller flash flood-prone streams that originate in the Churia (Siwalik) hills, rivers such

as the Tinau drain a catchment that includes both the Mahabharat (the middle hills) and the Churia ranges. Because their discharge depends not only on rainfall but also on sustained groundwater and subsurface inflow, these rivers have a more stable flow during the dry season than do the rivers that originate in the southern Churia ranges. The Tinau resembles West Rapti, Babai, Bagmati, Kamala and Kankai rivers that drain the middle Mahabharat ranges. The Tinau and its tributaries are extensively used for irrigation, hydropower generation and drinking purposes in the two districts. Location of the water management systems studied in this chapter are shown in Figure 2.

Floods are common during the monsoon months, when rivers like the Tinau have sharply peaked hydrographs. Dry season flow, wherever present, derives from groundwater and base flow contribution. Groundwater from the riparian landmass, especially the Churia hills, enters the river

In the Tarai, surface river channels shift continuously and are underlain by the interconnected aquifers of the larger Ganga system.

Figure 2: Major water management institutions on the Tinau River in Palpa and Rupandehi districts.

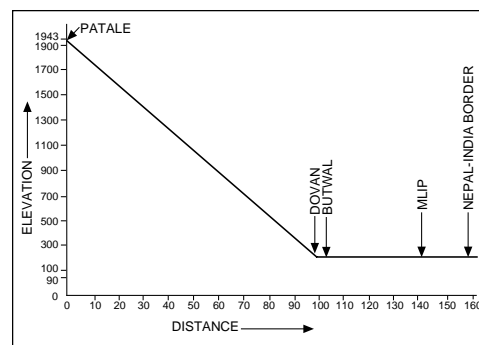


The Tinau basin experiences high rainfall variability, intense cloudbursts, both low and high flow extremes and (during high flows) large amounts of sediment transport.

channel at sections where the piezometric surface intersects the ground profile. After Dobhan, the Tinau flows over a geological formation known as the *bhabar*. The *bhabar* zone is a stretch of deposits composed of poorly sorted outwash, boulders, cobbles, gravel and sand. It is about 5 to 10 kilometres wide and soil conditions along its entire east-west stretch of the Himalayan piedmont are poor. This zone forms the transition between the northern end of the Indo-Gangetic plain and the Churia hills. Originally a malarial jungle, the *bhabar* has emerged as a region of rapid population and urban-industrial growth since the 1960s, when Nepal's East-West Highway was constructed along the Churia foothills .

Because of the weak geology and the unstable nature of the Churia hills, landslides in the upper catchment of Tinau are frequent. During the heavy rains, the river transports high sediment load, which is deposited in its inland delta once the river's incline, and thus its carrying capacity, decreases upon reaching the plains. The channels here are in dynamic flux and the rivers change their courses periodically. The channels of the river between its main branches shift regularly, depending on the nature and intensity of the monsoon as well as the state of riverbed aggradation. The slope of the Tinau from the hills up to the Nepal-India border is shown in Figure 3.

Figure 3:
Elevation transect of the Tinau River.



The climate of the Tinau basin ranges from hot tropical in the southern Tarai to warm temperate in the hills of Tansen. In the Tarai, summer temperatures reach 40° C while in the upper hills it remains cool. The main source of precipitation in the basin is the summer monsoon. Bulk of the annual rainfall occurs in the four months between June and September. The remaining rainfall is received from the westerlies during the winter months of December/January and pre-monsoon months. The monsoon, although generally regular, occasionally fails or delivers only scattered cloudbursts. Annual rainfall in the five stations at Tansen, Mujung, Taltung, Butwal and Bhairahawa, from the northern hills to the southern plains respectively, is shown in Table 1. The average annual rainfall in the hilly section of the basin is about 1,500 mm and in

TABLE 1:
Average Annual Rainfall at Tansen, Mujung, Taltung, Butwal and Bhairahawa (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Tansen	17	32	13	29	74	228	487	256	262	41	3	26	1,470
Mujung	30	14	20	28	84	311	431	277	301	46	7	34	1,583
Taltung	24	23	33	36	99	332	649	426	410	55	11	33	2,132
Butwal	13	15	15	20	93	375	722	489	455	142	5	18	2,326
Bhairahawa	16	9	15	17	56	282	554	334	281	69	9	12	1,651

Sources: Department of Hydrology and Meteorology, Department of Soil Conservation and Watershed Management.

the southern parts, it is about 1600 mm. In the Churia range the annual average rainfall is about 2,000 mm and occurs in high intensity bursts, often with three to four hundred mm in 24 hours. In the Tinau basin, the maximum recorded 24 hour rainfall was 320 mm in 1981 at Taltung in the hills.

Surface Water

The Tinau is gauged at Dobhan before the river flows into Butwal. Although records are discontinuous, available data indicate a mean annual flow of 24 m³/s. Minimum flow in April is close to 1 m³/s. Judging from the records between 1964-1969, the average monsoon flow of the Tinau in August can be as high as 108 m³/s and the instantaneous flood peak is close to 2,200 m³/s. Run-off from the Tinau is influenced by rainfall patterns in the upper catchment and unassessed diversion for irrigation by upstream users. Such use is widespread and intense, but the volume is difficult to determine because almost all the upstream irrigation practices are informal and unregistered.

Downstream along the river between Dobhan and Bangain, where the Tinau and the Dano join near Marchawar, groundwater appears to contribute to stream flows. Rivers originating in the Churia range that flow into the Dano also add to the discharge. This is indicated by the difference in flows measured at these two locations (Table

2).³ The highly seasonal nature of precipitation and absence of snowmelt sources mean that river hydrology in the dry season is mainly a function of its base flow contributions.

In contrast to the dry season calm, the high intensity monsoon rainfall in the upper reaches, particularly in the Churia range, often triggers landslides, and the resulting floods lead to bank cutting.³ Landslides frequently dam river and, when these temporary dams are overtopped, they breach and cause devastating floods. This phenomenon, which is preceded by fish kill in the dried out downstream reaches, is known in Nepali as *bishyari*, and is regular enough for it to find a place in the language. In the past, the Tinau has experienced several such *bishyaris* which, along with other flash floods, have caused large-scale loss of human and animal lives as well as massive destruction of property. The Dauretole neighbourhood of Butwal, for example, was completely and suddenly washed away by a *bishyari* in the 1970s. During *bishyaris*, the amount of boulders and mud gouged out and swept from the river banks in the hills to the lowlands is phenomenal.

Aside from *bishyaris*, normal sediment transport in the Tinau is limited to the monsoon when brief intense rainfall results in rapid rise of the water level at gorge. These events also lead to high sediment transport, which has serious implications for irrigation technology, since flash

Cloudbursts are common in the Churia range and often cause bishyari, massive floods from landslides that temporarily dam rivers and then break.

TABLE 2:
Mean Monthly Flow of Tinau at Dobhan and Bangain (m³/s)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Dobhan	4.39	3.03	2.45	2.16	2.35	15.1	58.3	107.86	46.7	24.7	7.61	4.94	23.5
Bangain	7	6	4	3	7	45	192	108	188	101	13	9	56.9

Source: (Delft, 1988)

High sediment levels lower performance of:

- *irrigation intakes,*
- *pump blades,*
- *flushing tanks, and*
- *canals.*

floods wash away supposedly “permanent” (that is, cement concrete) diversion weirs and bed loads choke intakes and canals. As the river enters the Tarai, the bed load and large sediment particles are deposited on the debris fan of the inland delta, while the suspended load flows downstream. Data on sediment load out of Dobhan in the Tinau is not available. However, at Bangain, different estimates of sediment load carried by the river exist. Hedeselskabet (1987) estimates sediment load consisting of sand to be only 30,000 tons/year, though the same report mentions annual load of 400,000 to 500,000 tons.⁴ Finer sediment load is estimated to be 20 to 40 times higher than sand load. Analyses of samples show that the suspended sediment consists mainly of silt and clay, 80 per cent of which have a particle size less than 0.06 mm. Delft (1988) has estimated the bed material load to be 3,550,000 tons/year. It is not clear how these quantities were computed.

In any case, the sediment quantity and content in the river has affected the performance of the intake, sediment flushing system and the pumps of the Marchawar Lift Irrigation System. The traditional farmer-managed irrigation systems, on the other hand, seem to have adapted to this natural regimen and are less affected by it because they rely on temporary brushwood weirs.

Groundwater

Unconsolidated sediments forming highly permeable aquifers, some of which are artesian, underlie the Tarai in Rupandehi district. Recharge results from a combination of rainfall and inflow from rivers as they leave the Churia hills. Other rivers that flow from the mountains similarly

contribute to the recharge of the aquifers of the Tarai that can be simple or artesian. The previously noted *bhabar* formation lies south of the Churia foothills and north of the alluvium of the Indo-Gangetic plain. Rupandehi district has an area of 1,140 km², of which the *bhabar* zone underlies at least 100 km² (Tillson, 1985), although hydro-geologists from the Bhairahawa-Lumbini Groundwater Development Project (BLGWP) estimate the area of *bhabar* to be twice as much.⁵ Groundwater aquifers generally begin at the end of the *bhabar* region. For the purpose of studying groundwater systems, Uprety (1989) used the 150 metre contour line as the physical end of the Tarai’s quaternary sediments. If one considers only the Tinau basin, the *bhabar* portion is not very large. In the *bhabar* region, the depth of the water table is low, and permeabilities are reported as 50 to 200 metres per day. In the remaining areas of the Tarai, there are wide variations in soil characteristics as well as in the extent of irrigation, both of which affect recharge. The groundwater aquifers of the district as well as the northern Ganga plains are probably recharged from the *bhabar* though the actual amount of recharge remains unassessed.

What is the groundwater potential of the Tarai in the Tinau basin? It is not possible to define this separately because the basin is underlain by multiple aquifers covering the three Tarai districts of the Lumbini zone: Nawalparasi in the east, Rupandehi in the middle and Kapilvastu in the west. The entire Tarai region between the Daunne hills near the Gandaki River to the Deokhuri hills east of the West Rapti is made up of interlinked groundwater aquifers. Though many studies have been undertaken on groundwater, the estimates are

preliminary and vary depending upon the underlying assumptions, which also vary.

Tillson (1985) estimates percolation rates within a range from 156 to 504 mm/year depending on the type of soil. The average percolation rate is 330 mm/year, which is equivalent to about 17% of the rainfall. Applying this rate to the whole of Rupandehi district – area 1,140 km² – yields a recharge to the shallow aquifer of about 375 MCM (million cubic metres). If, conservatively, only 10% of the annual rainfall of 1,900 mm (the average of the northern and southern parts) is assumed to recharge the shallow aquifer, the volume over the same area would be about 216 MCM/year. Another preliminary estimate of the potential recharge was made by assuming the effective porosity of sand and gravel aquifers as 15% and considering that the average rise of the water table during the monsoon period is 2.3 metres over the area of 1,140 km². If one third of this formation were composed of permeable deposits, the net recharge would be about 130 MCM,⁶ not including the amount rejected due to the saturation of the soil in the rainy season and the evaporation loss due to the high water table during the summer period. If pumping lowers the water table, there will be more recharge than this estimate suggests.

The estimated figure of 130 MCM is, therefore, a conservative estimate – a minimum under natural conditions – and should include all recharge from the *bhabar* zone. A final estimate can be made based on the percentage of direct rainfall recharge in the *bhabar* region. With an annual rainfall of about 2,200 mm along the

foothills, and about 100 km² of *bhabar* formation, this estimate suggests a recharge volume of close to 96 MCM. In sum, different estimates suggest recharge amounts between 96 MCM and 375 MCM as the lower and upper limits.

In the Tarai region of Rupandehi district, groundwater dynamics are affected not just by rainfall but also by percolation to deep aquifers from shallow groundwater and by southward flow into aquifers in Uttar Pradesh in India. In the upper, mountainous regions of the Tinau, groundwater availability is generally low, although it has been contemplated as an option for supplying drinking water to Tansen Municipality.⁷ Groundwater contributions to the base flow of the Tinau River in the hills are unknown. By the time the Tinau and the Dano reach the Indian border, however, groundwater contributions to base flow are clearly substantial. If this were not the case, large diversions for irrigation in the Tarai between Butwal and Marchawar and then within India should deplete all surface flow. The relatively high flow – much higher at Uska Bazaar near Gorakhpur in India than at Marchawar in Nepal, even with the influx of other tributaries – can result only from subsurface inflow from the *bhabar* and the Tarai zones.

More details on ground and surface water interaction are available in the BLGWP area. Tubewells constructed for this project draw water from aquifers 50 to 300 m below ground surface. In about two-thirds of the BLGWP area, wells constructed in Stage 1 are artesian. These conditions are not expected to persist; a long-term decline of up to 15 metres is foreseen. This implies that water will percolate from the unconfined to

Estimates of groundwater availability and recharge vary greatly and are highly dependent on the assumptions made.

Ground and surface water interaction is significant, but scientific documentation about the relationship is lacking.

the confined aquifer, thereby affecting the rivers' discharges. Hedeselskabet (1982) estimates that discharge in the rivers will be reduced by 20-30% as BLGWP's first phase pumping reaches full capacity. The study estimates demand at 56 MCM/year, suggesting a reduction of 0.3 to 0.5 m³/s in stream flows. UNCDF (1987), mentions the total annual water demand to be 90 MCM/year suggesting reductions of 0.55 to 0.85 m³/s with the rule proposed by Hedeselskabet.⁸ This analysis, however, only refers to Stage 1 of the project. As stage 3 of the BLGWP is coming to an end, using similar assumption reduction in stream flow should be higher. The possibility of reduction in stream flow is also supported by Delft (1988), who mention the interlinkages between surface flow, shallow and deep aquifers.

Downward leakage from a shallow aquifer into a deep aquifer is both possible and probable since maps indicate that shallow aquifer heads are above those of deep aquifers in most of the district, particularly the northern part above the BLGWP area (Upreti, 1989). The interlinkages imply that ground and surface water interaction is significant within the Tarai region. Scientific documentation, however, is lacking. A proper foundation for the Hedeselskabet reduction rule, for example, is not mentioned in the available reports. Similarly, observations of groundwater contribution to streams are based on general flow observations rather than on detailed monitoring or measurement. Also the actual amount of water used for irrigation is a function of crop type, efficiency, operating hours of pump, area under irrigation and cost of pumping. These are variable and unassessed. As a result, the relative balance between groundwater contribution to surface flow and vice versa are far from clear.

In addition to interaction with surface streams, flow within and between aquifers is significant. In general, the geologic structure of aquifers and high levels of recharge along the base of the Churia result in groundwater flow towards the south. For general purposes, the international boundary can be used to estimate the outflow of shallow groundwater across the border into the northern Uttar Pradesh Tarai.⁹ The length of outflow section in the district is about 40 km. The transmissivity in Vishnupura, which is located in the upper section, is 160 m²/day. This figure decreases to 100 m²/day in the middle of the district and again increases to 200 m²/day towards the west. The gradient in the eastern half of the outflow section is about 0.0016 and in the western half about 0.0008. Thus, the volume of water outflowing into the aquifer in Uttar Pradesh may be estimated to be about 7.8 MCM/year. The outflow volume is a small portion of the annual recharge potential estimated earlier. The difference between recharge and the subsurface outflow into Uttar Pradesh is dissipated primarily through evaporation and partially through inflow into the Tinau, the Dano and other rivers along with withdrawals from dug and shallow wells (a minor component at present). Theoretically this may be salvaged by carefully planned exploitation, provided that the lithology of shallow aquifers (thickness and transmissivity) permits large-scale groundwater development.

Institutions and Development

The Tinau basin includes the municipal areas of Tansen in the hills, Bhairahawa in the Tarai plains and Butwal at the Churia piedmont. Bhairahawa is the international gateway to Lumbini, the birthplace of Buddha, which is about 23 km to the west. There are also villages along

the north-south highway such as Manigram between Bhairahawa and Butwal in the Tarai, as well as villages in the upstream reaches that are evolving into small townships with dynamic commercial or small-scale industrial activities. These townships and villages have actively taken advantage of possibilities offered by development of new infrastructure (roads, telecommunications, and education) to further their economic activities. In addition, access to new infrastructure has strengthened some of the traditional institutions, particularly those related to irrigation and agriculture marketing, in the region (INFRAS and IDA, 1993). There is, for example, a major bi-weekly *haat* bazaar at Butwal, where farmers from the hills and the plains meet to buy and sell their farm produce and other wares. This bazaar is the largest and most dynamic in Nepal, and since the completion of the east-west (Mechi-Mahakali) and north-south (Sunauli/India-Pokhara) highways, it has linked with other *haat* bazaars in Bhairahawa and elsewhere.

The Tinau region has a long history of settlement based on the use of water resources for agriculture. In the Tarai reaches of the basin, settlements date back to the time of Gautam Buddha and the reign of the Sakyas who inhabited this region. Indeed, in the life of Buddha, a story is told of how Lord Buddha mediated a water dispute between two warring clans over the uses of the Rohini, which flows east of its birthplace at Lumbini. During the last century, the region was covered by dense, sparsely populated, jungle. The landscape started to change with the construction of Chhattis and Sorha Mauja farmer-managed irrigation systems, which were, for example, built about 150 years ago. They function as some of the largest farmer-managed surface irrigation

systems in Nepal. Similarly, on the west bank of the Tinau, opposite the Chhattis and Sorha mauja, lies the Chaar Tapaha irrigation system, which is also managed by the beneficiary farmers.

Although major irrigation systems were constructed over a century ago, rapid changes began in the post-1950 period after the overthrow of the century-long feudal Rana dynasty in 1951. At this time the government began a programme of tapping new surface and groundwater sources for irrigation to meet the national objective of increasing food production. Before this, except for a few initiatives towards the end of Rana rule between the two World Wars, the Nepali State had not considered providing irrigation as one of its prime functions. Instead, the state had focused on classifying agricultural land into four categories depending upon its productivity and levying tax accordingly.¹⁰ With democracy came the ideology of the welfare state and Nepal's new rulers needed a source of popular legitimacy. As a result, a succession of governments has pushed for irrigation development initiatives in this region.

One of the first state-led irrigation initiatives occurred in the early 1960s. An irrigation barrage with a network of canals was built on the Tinau, close to Butwal, and downstream of the intake of the existing Chhattis and Sorha Mauja irrigation systems. Built under the minor irrigation development programme assisted by the Government of India in the aftermath of the Kosi Agreement of 1954, the objective of the project was to irrigate a command area in Marchawar located about 30 kilometres to the southwest.¹¹ The barrage and earthen main canal of the project were sited in the unstable inland deltaic portion of the Tinau River (Figure 4a). As a result, a large section of

The ideology of the welfare state has given politicians a source of popular legitimacy in the form of irrigation development.

the canal was washed away by floods in the year after commissioning of the barrage and the river shifted course, bypassing the structure. The new irrigation scheme never functioned and the canal system in the lower region remains all but abandoned except for its use for drainage collection and as ponds. In addition, a section of this canal system was repaired and used for the UNCDF-funded Marchawar Lift Irrigation Scheme, described in Case Study VIII.

Temporary dams for irrigation have traditionally been erected through massive community mobilization.

Aside from design oversights, the new irrigation system completely ignored a pre-existing, functioning farmer-managed irrigation system in the Marchawar region. This traditional system was similar to the Sorha-Chhattis Mauja irrigation systems, but was possibly older. Local lore describes the *tharu chauthary* (headman) who initiated this system. It consisted of fairly large temporary weirs at Gurbania and Harewa on the Tinau a few kilometres south of Bhairahawa-Lumbini Highway and an extensive network of distribution canals extending almost all the way to the Indian border (Figure 4b). This dam was washed away

every monsoon (as it was meant to be when water was not required) and was rebuilt at the start of the dry season with massive community mobilization. Every year after the monsoon floods, the entire labour force of the villages of the region would be mobilized to construct a bamboo/brushwood and mud weir that raised the water level in the river to the intake of the main canal. The weir fed the distribution system, which was cleaned and maintained every year by this system of community labour.¹² The alignment of the canals matched long-established property rights to the riparian lands and natural drainage patterns.

The Butwal barrage superimposed an externally conceived and geometrically designed network of canals on a functioning system. The new alignment of the canal from Butwal physically disrupted the traditional Gurbania canal network. It also disrupted the functioning water management institution and its interrelationship with landholding and drainage patterns. Farming plots and their ownership patterns in Nepal, both in the hills and in the Tarai, form a crazy-quilt,

Figure 4a:
Indian Scheme layout from 1960s that carved up the Gurbania network.

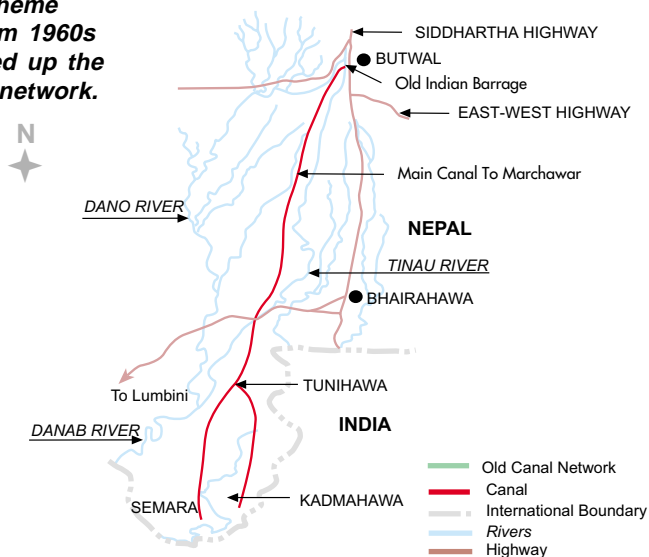


Figure 4b:
Layout of traditional Gurbania canal network.



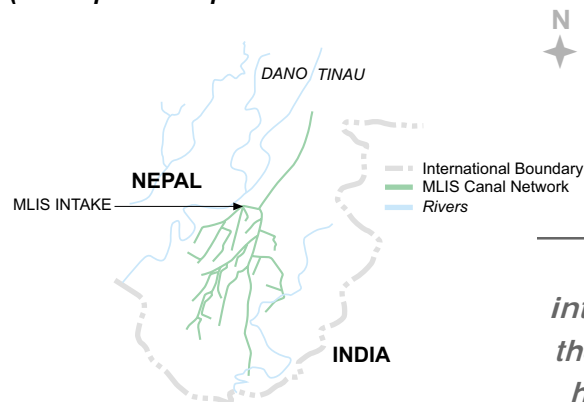
and are not geometrically neat. They are determined not only by the land contour but also by history and the prevalent social dynamics as well as by the ensuing water rights and requirements. Imposing a geometric framework on such a living system is tantamount to carving up the existing social order. In any case, the new system became non-functional when the river changed course and bypassed the barrage. The Indian and Nepali governments made no effort to restore the system for the next two decades. The change that would have been wrought by the imposed geometric framework could not be sustained, and the farmers went back to healing a wounded system with their traditional water management means and the temporary weirs.¹³

In the late 1970s the Tinau River system saw four major government-led water initiatives that were characterized by both institutional amnesia regarding previous formal efforts at water management and continued obliviousness to regarding informal farmer-managed systems. One was the Bhairahawa Lumbini Ground Water Project (BLGWP) with credit assistance from the World Bank. A second was the Marchawar Lift Irrigation Project (MLIP), which was implemented with help from the UNCDF to irrigate the lower part of the area that would have been served by the abortive Butwal barrage scheme. Like this earlier intervention, the conceptualization of the

Variegated Dynamics

As described above, even though the Tinau covers a relatively small area, the basin contains great physical and social variability. The region encompasses diverse ecological regions of the Mahabharat, the Churia and the Tarai (Figure 5) as well as a range of ethnicities and

Figure 4c:
Network of Marchawar Lift Irrigation System
(developed on top of Indian scheme and traditional network)



Development interventions in the Tinau basin have occurred in a conceptually and practically fragmented manner.

MLIP also ignored the existing irrigation arrangement and imposed a geometric design over a traditional arrangement (Figure 4c). A third initiative, though not related to irrigation development *per se*, was the 15-year Tinau Watershed Management Project implemented with Swiss and German assistance in the aftermath of a devastating *bishyari* on the Tinau. This was another isolated initiative that, although intended as integrated rural development in Palpa (the hilly portion of the Tinau River basin), did not take a broad perspective of the basin. Another initiative was the World Bank funded development of Butwal's drinking water supply. These project centric and engineering-led interventions occurred in a fragmented manner both conceptually and practically.

languages.¹⁴ Water in the basin is available as spring sources, river and stream flow as well as groundwater in artesian and non-artesian conditions, and is managed by different institutions that reflect the variegated social systems. The spatial distribution of rainfall is also not uniform;



① Rain water jar at Madan Pokhara



② Weir of Tinay HEP

Figure 5:
Schematic view of the Tinau River and water uses dependent on it.



3
Abandoned Butwal barrage



4
MLIS canal



the southern part of the Tinau basin close to the Indian border as well as its northern part on the Mahabharat range receives less rainfall than areas such as Butwal in the Churia foothills in the middle. Residents of the Marchawar region, for example, mention that rainfall there is less than normal every four to five years, resulting in drought-like conditions.

The small region of the Tinau basin encompasses diverse social, ecological, physical and cultural systems which result in a complex mosaic of water management systems.

Given the limited nature of water-related data that has been collected, this diversity of institutions and management styles places a severe limitation on making precise estimates of resource availability. The first problem is the variability of physical conditions that have not been analysed in adequate detail or in a broad enough perspective to permit confident generalization. Another limitation is the assessment of the surface flow itself. Because water applications by different users are not monitored simultaneously, it is difficult to make a composite assessment of how much water is withdrawn from surface and

groundwater sources and how much is available. The third difficulty lies in the varied social systems and, consequently, water management styles within the basin. Ignoring them has led to the promotion and implementation of narrowly focused projects that have not looked at interlinkages between various upstream and downstream systems.

The present preliminary analysis attempts to understand the dynamism of water resource management within the Tinau, the social dimensions affecting its use, and the interlinkages at work. The following sections describe various cases of water use starting from the headwaters of the river in Palpa and moving downstream along the plains into India. Many of the water use systems discussed below are located along roads or planned roads that have been built as part of past projects. In this sense, the study has a restricted scope which excludes from field-level analysis many roadless portions of the Tarai generally and the Tinau particularly.

CASE STUDIES:

Case Study I: Tansen Municipality

Background

Tansen Municipality is located on the uppermost hills of the Tinau catchment on the southern slopes of the Sri Nagar hills between 1,200 m and 1,500 m above sea level. It is the district capital of Palpa and is 30 km north of Butwal. Its growth, like that of other settlements, along the north-south Gandaki growth axis, was spurred by the completion of the Siddhartha Highway.¹⁵ Palpa Valley, where Tansen is situated,

was a principality before the unification of Nepal. Although the Gorkhals captured Kathmandu in 1769, Palpa was captured later, in 1806. During the years of Rana rule that started in 1846, and ended in 1951, Palpa maintained a somewhat independent status by virtue of the fact that it was governed by “rebel” Ranas who were exiled to its governorship. The result of this status was that Palpa undertook many independent development initiatives such as Tansen’s piped drinking water system, built in the late 1930, which survives to this day.¹⁶ In addition, Tansen has traditional *dhungey dharas* (stone water spouts), located generally in the lower sections of the town, which

tap into hillside springs. Due to poor maintenance, they too have fallen into disrepair and some have ceased to function. Some households have used high density polyethylene (HDP) pipes to connect some of the functioning ones to taps.

Following the completion of the Siddhartha Highway, which linked Sunauli at the Indo-Nepal border with Pokhara in the middle hills, the population of Tansen began to increase. In the early 1970s, Tansen had a population of about 6,000; it had doubled by 1979.¹⁷ By 1998, the population had reached close to 15,000. The expansion of administrative services around Tansen also contributed to the growth. Drinking water systems were expanded as the town's population grew. The oldest is a gravity system from Banja, a spring water source, which was completed in the 1930s. In 1972, the Holangdi source within Palpa Valley was tapped and pumped to the reservoir at Basantapur. With assistance from the Japanese government, the construction of the Bhulke system was started in 1976 and completed a year later. After this, the Japanese government prepared an elaborate Water Supply and Sewerage System Master Plan for the town, which envisioned pumping water from the Kali Gandaki River at Ranighat. The proposal, however, was not taken up owing, among other factors, to the excessive pumping head of more than 1,000 metres.¹⁸

System Description

At present, Tansen gets its water supply from three sources. The first is the old gravity system, which stores water in a 170 m³ capacity reservoir at Muldhara, and then supplies it to a section of the town via private connections and public stand-posts. This system was rehabilitated in 1995. In

addition to this there are two pump systems. One is the Holangdi system within the Palpa valley, which pumps from a sump well of 75 m³ located at Holangdi spring and which supplies a 130 m³ reservoir. The other system pumps water from the Bhulke spring on the Kali Gandaki watershed to the northwest of Tansen. It also taps the Krunga *khola*, where water is first brought by gravity to the second pumping stage and lifted further. Water is pumped in four stages to a reservoir at Batase *danda* (hill) and then distributed by gravity. In the dry season, a total of 1,500 m³ per day are pumped from the two sources; 1,000 m³ from Bhulke and another 500 m³ from Krunga *khola*.

The transmission line is about 8 km long and the water is lifted 550 metres. The four pumps with a capacity of 21 m³/hour need a total power capacity of 300 kW. A 33 kV transmission line has been extended to Bhulke. There are presently 1,200 private connections, few of which are metered, and about 100 public stand posts that supply drinking water to the town's population. Because the systems operate at lower than the design capacity – Bhulke (65%) and Holangdi (80%) – only 800 to 1000 m³ water is supplied in a day giving a daily per capita supply that ranges from about 53 to 67 litres (lpcd). With 42% leakage in the system, the per capita availability is reduced. Since the water supply system also caters to floating population, this figure could be even lower.

Institutions at Work

In Tansen Municipality, the Department of Water Supply and Sewerage (DWSS) of HMG's Ministry of Housing and Physical Planning (MHPP) employes pump operators and administrative staff to operate and maintain the

*As early as 1930
Tansen had a
piped drinking
water system.*

In Tansen, the drinking water supply system is inefficiently operated and economically unsustainable.

system. Although water is pumped continuously, it is supplied to different sectors of the town on a rotational basis. Each sector receives a supply for only about two and a half hours. While the annual operating cost of the system is 7-8 million rupees, only 6-7 hundred thousands rupees is raised as revenue.¹⁹ Due to the high cost of operation and low revenue, the supply system is deteriorating. Pump efficiency has gone down considerably and sections of the supply line have been damaged and leak profusely. In addition, the electricity supply is erratic and often subject to load-shedding. As a result, only half of the total daily water production capacity is available for use in the dry season. This is causing hardship to the people of Tansen, who cite water supply shortage as the main constraint to the growth and development of their town. Clearly, the operation of Tansen's drinking water supply system is not sustainable economically without government subsidy.

Key Issues

- In 1991 almost a third of the total electricity consumed in Tansen Municipality was utilized in pumping water. Dependent as it is on a supply of cheap and reliable electricity, Tansen needs to revise its tariff and redesign its power and water distribution systems.
- A higher tariff can serve as a disincentive for increased consumption. In Tansen appropriate mechanisms have to be evolved to recoup from the users the cost of supplying water.
- The supply level is low due to the inefficiency of the pumps. Arrangements need to be made to maintain and repair them on a regular basis.

- Increased water needs in Tansen could lead to increased disputes among current users as new claims on the existing sources will stress the arrangement of water allocation beyond capacity.

- The generation of solid and liquid waste is likely to increase. Because a completed sewer system does not exist and waste treatment receives very little focus, water quality may decline in the head region of the Tinau. Although pollution has not yet reached a critical threshold to affect water quality, the possibility is high because the Tinau with a low flow in the dry season does not have sufficient flushing capacity to assimilate the waste. This is likely to lower quality of river water for existing downstream users and impinge upon their water rights.

- Water conservation, proper pricing, and use of rainwater harvesting are important options to explore. The rainwater harvesting option, for example, could reduce the volume of water to be pumped and thereby minimize the cost incurred.

Case Study II: Madi Phaant

Background

Madi *phaant* is the main valley of Palpa district and forms the upper catchment of the Tinau River. The watershed area of the Tinau in Palpa covers much of the western half of the district south of Tansen, and the Madi *phaant* valley occupies about a sixth of this catchment. It lies at an approximate elevation of 1,000 m and is surrounded by the Mahabharat hills to the north and the Churia (Siwalik) hills to the south.

The Madi *phaant* has a warm temperate climate with an annual average temperature of 16°C (maximum 31.6°C and minimum 3.4°C). The surrounding hills, depending on the altitude, can have a cool temperate climate. The valley receives an average of about 1,800 mm of rainfall annually, which is the primary water source. Water availability in Palpa, as elsewhere in the hills of Nepal, is a function of the terrain. Valley bottoms have irrigated agricultural land and often groundwater fed stream flows. Hill settlements rely on springs for drinking water and agriculture in the upper slopes is rain-fed.

The Madi Valley has an approximate area of 97 km² and falls within the administrative jurisdiction of 71 wards of twelve Village Development Committees (VDCs, which used to be called Village *Panchayats* prior to 1990) and one municipality.²⁰ The valley bottom consists of irrigated agricultural land called *khet*, and the surrounding hillslopes host forests (now mostly community managed), non-irrigated land called *baris*, as well as hamlet settlements and Tansen Municipality. There are 31 community-managed forests with a total area of 1,011 ha in the hills around the valley catering to the partial needs of 3,145 households for fuelwood and fodder.

Land ownership in the Madi *phaant* is mixed. While slightly over half the land is reported to be *raikar* (private), significant portions are owned by *guthis* (religious trusts) of important temples and monasteries as well as by absentee shopowners to whom the land has accrued as defaulted collateral. The paddy fields of Madi *phaant* have traditionally been bequeathed to the *guthis* that manage the temples of Palpa. These systems existed even before the Shah dynasty began 1769.²¹

Old people indicate that this system has existed as long as they can remember and was spoken about by their grandfathers as well. The more well-known of these trusts are Ridi *guthi*, Majhadevi *guthi*, Kalankidevi *guthi*, Mandabya *guthi*, Ranighat *guthi*, Narayan *guthi* and Ranaujjeshwari Bhagwati *guthi*. *Guthi* land constitutes most of the land in the Khauruwa *phaant* of the Tinau, while in Saranja *phaant* there is a preponderance of *raikar* (private) land. Both these *phaants* are situated within the larger Madi plain. The example of Ranaujjeshwari Bhagwati *guthi* is instructive. The temple in its present form was established in 1834 by General Ujir Singh Thapa, nephew of Nepal's first prime minister Bhim Sen Thapa, who became the governor of Palpa in 1815. Ujir Singh established a *guthi* for the temple with the royal seal of King Rajendra Bikram Shah.

Because the management of *guthi* lands is centrally controlled in Nepal by HMG's *Guthi Sansthan* and since there are limitations on buying, selling or changing land use as well as rent payments, the tenants of *guthi* land are effectively its owners, but with a built-in degree of uncertainty. The terms of payment to religious *guthis* are traditional and can be as low as providing one he-goat a year for sacrifice or small quantities of flour during festivals. Despite the low rent, tenants have not found it easy to change from cultivating the traditional rice to more lucrative vegetables. Even within the Madi *phaant*, some villages, such as Madan Pokhara (Case Study III), have managed to take advantage of the market better than others.

A major development intervention in the upper Tinau area was the Swiss-German project initially

Guthis (religious trusts) legally own much of the land in the Madi phaant but it is farmed by long term tenants who are, in some ways, the defacto owners.

Watershed management has to do with afforestation and check dams as much as with livelihood issues concerned with irrigated agriculture.

called the Tinau Watershed Project (TWP) and later renamed the Palpa Development Program (PDP). The TWP was initiated after the massive flood in the Tinau in 1978 that washed away Dauretole, a section of Butwal. At that time, it was assumed that deforestation in the upper catchment was the culprit, and watershed management (afforestation through tree planting, gully stabilization etc.) was perceived as the solution. In fact, the cause of the 1978 flood was not deforestation, but a massive cloudburst that deposited 125 mm of rain in a few hours, triggering a landslide in the black shale section of the gorge, which blocked the Tinau. When the overtopping of this natural “dam” took place, the surge washed away Dauretole and caused unprecedented damage.²²

By 1988, it was clear that the issue of watershed management was not merely about planting trees and building check dams on gullies. The earlier understanding that deforestation and flooding were part of a vicious circle gradually proved untrue as new evidence showed the more complex nature of linkages and associated uncertainties. (Thompson

et al., 1986). It became clearer that proper management was tied to fundamental issues of development, such as building local infrastructure, enhancing social capital, as well as promoting local governance through decentralization and empowerment. Thus TWP became PDP and placed special emphasis on building “green roads”,²³ community forestry and rural poverty alleviation through community mobilization. Other aspects of PDP’s programme that ran through government agencies, such as livestock development and watershed management, were deemed unsatisfactory and dropped. The PDP was phased out in 1995 because the issue of decentralization and local governance could not be adequately resolved. Donor support is now confined to promoting local initiatives in grassroots development efforts and income-generating activities.

System Description

The main stem of the Tinau River originates from Kaphaldanda in ward numbers 2 and 8 of Devinagar VDC at the eastern end of the valley. It is joined by several smaller streams such as Pasti, Loreng, Dangsing, Gophadi, Pugdi, Muntung, Chidipani, Sapangdi, Boksadi, Rakse, Majhor, Chuhar and Khawa. While tributaries originating from the Mahabharat range to the north are more stable, those from the southern Churia ranges are ephemeral and bring a lot of sediment flow with the monsoon. These streams carry water only during the rainy season and in the months immediately after it. All these streams, including the ephemeral ones, have take-off points for irrigation in the form of temporary brushwood weirs. These are washed away every monsoon and have to be rebuilt. They are managed individually



Irrigation parcels in Madi *phaant* use brushwood dam diversion

or collectively with varying sets of rules and regulations. The various irrigation systems in the Madi *phaant* valley can be grouped into several sub-systems. Representative irrigation systems are described below:

a. Upper Tinau: From the spring at Kaphaldanda to Chhedua *kulo* (channel), individual farmers on both sides of the stream tap water. Because of the temporary nature of the diversions and their inherent heavy seepage downstream, disputes between users are not severe. If more efficient extractive technologies or more water intensive crops are introduced, the potential for conflicts in the future exists.

b. Middle Tinau: This sub-system consists of several irrigation take-off points such as Chheduwa, Tal, Bokhap, Bagnase and Khauruwa (also called Pachase) *kulo*. A representative example is Chhedua *kulo*, which is located in Rupse VDC, ward number 3. This ancient traditional system has a canal length of 4 km, which irrigates about 42 ha of *khet* cultivated mainly for rice and secondarily for wheat, corn and some vegetables. The Chhedua *kulo upabhokta samitee* (Users' Committee) manages it. This *samitee* has representation from 135 households. A nine-member elected executive committee governs it on a daily basis. The general body meets twice a year and its decisions are minuted. Failure to live up to the decisions made can result in a fine of Rs 50 and failure to pay this results in not having access to water for irrigating rice seedlings. The current difficulties relate to shortage of water during the dry season and the ill feelings that arise among different users as a result. There is a feeling that more frequent meetings need to be held to

handle this problem and also to develop a separate fund for the *samitee*.

c. Boksadi-Khahare system of Rupse: This system consists of takeoff points for smaller irrigation systems such as Bandhuwa, Gaurawari, Chimli, Rajiya, Khasaha and Bhangtar *kulo*. A representative example is Bandhuwa *kulo*.

Bandhuwa (Mohane) *kulo* is also located in Rupse VDC, ward number 3. This takeoff irrigates approximately 22 ha. It does not have even an informal users' group although it serves 54 households. Problems in this system relate to sharing watering turns, but have been resolved by village interaction (*sarsallaha*) with the mediation of a VDC representative. Users agree on the need for a formal user' group and a separate maintenance fund. However, the difficulty is in finding non-controversial people to elect to the executive.

d. Majhare system: The Sinchase *khola* and the Damahar *khola* join to form this tributary of the Tinau. It contains many small irrigation systems of which the Majhare *kulo* is an example.

The source of the Majhare *kulo* is Teen Kanya *mul* (source) located below Aryabhanjyang in Pokharathok VDC. Even though the *kulo* commands an area of 75 ha with 35 to 45 households benefiting from it, there is no organized committee with rules of use. At the time of irrigation for rice or wheat, whoever comes first uses the stream flow. If someone else has come at the same time, then there is an agreement on the spot about how to share the water. When rainfall is low much of the land remains fallow, which occurred in 1959 and later in 1998.

Between the late 1980s and the mid 1990s, watershed management concepts in the Tinau evolved from a simple focus on reforestation to larger questions of community development and governance.

Many effective water management institutions in the Tinau are mainly informal in nature.

e. **Middle Tinau Saranja *phaant***: This is a large stretch of land in the middle of the valley, which uses water from spring sources and seepage flow that arises from water use in upstream reaches. Examples are the Sodhan Katuwa *mul* (source) and Garniya *kulo*.

Sodhan Katuwa *mul* is a spring source at the southwest end of the Madi valley which provides a continuous flow of about two inches. There are additional sources of smaller magnitude, which are used to irrigate about 16 ha of Saranja *phaant* in the middle of the Madi valley. (This could possibly be seepage from the Old Tinau channel.) The main use of this water is for growing rice seedlings in the dry season immediately preceding the monsoon. People informally contribute labour, wooden and bamboo stakes as well as brushwood for canal construction. Those who do not contribute do not get water to cultivate the seedlings for transplantation. While there is enough water for growing seedlings, there is not enough for the main rice crop or wheat. In case the monsoon fails, there are informal discussions about how to share this water on an hourly basis. Old established practices play a major part in this. Most of the land belongs to the Shree Narayan temple *guthi* in Tansen Municipality, and the farmers are all tenants who belong to VDCs such as Madan Pokhara, Kaseni, Pokharathok and Chirtungdhara. They have filed a petition in the court to have the land declared *raikar* (private) in their names, but the court has not decided the issue yet. They do not feel that a formal users' committee can be set up without these issues being resolved.

Garniya *kulo* is an old irrigation system, which includes 160 households and irrigates about 20

ha of land in Chidipani VDC. The Palpa District Development Committee (DDC) has given a grant of Rs 25,000, which is used for weir construction. There is no users' group formed yet, but there is a thirteen member construction committee. The management system is traditional consultations (*sarsallah*), which occur at the end of *Jestha*, and those who do not contribute labour are excluded from access to water for irrigation.

f. **Tansen *Khola* sub-system**: This system uses the waters of the Tansen and Gawang *kholas*, which are tributaries of the Tinau, to provide irrigation to the Chalise, Nayare, Simbutari, Churkek, Belari as well as the Hadaha canals.

Hadaha Khauruwa *kulo* is a traditional system irrigating 9 ha of land. It was modernized in 1977 by adding a cement weir and canals to expand irrigation to 25 ha. This system is located in Madan Pokhara VDC and has a formal structure with a user group executive committee of nine, which meets every month. The general users' group meets at least once, often twice a year in January and May. The decisions of meetings, which relate to such issues as fines and the distribution of hours of water use, are minuted. Labour contributions for canal maintenance are obligatory and enforced through fines of Rs 50 per day, which are deposited in the users' group account. Those who do not pay their fines are barred from using the water.

At present, the users' group has a fund of Rs 28,000, which has come from the Rs 50 per user collected and from a Rs 21,000 grant from the Palpa DDC. Floods damaged the cement intake built recently and the expansion of the system to irrigate 25 ha requires 3.2 million rupees. These

funds are not yet available from any source. As a result, some of those who participated in the committee to obtain access to water are restless.

Miyaltar *kulo*, an old system that irrigates 132 *ropanis* of *khet* land, created a formal water users' association in 1997. This association has 32 participating households with an eleven member executive committee. The primary crops are monsoon and spring rice with wheat as a secondary crop. The users' committee has a fund of Rs 6,600 from users and Rs 15,000 from the Palpa District Development Committee. A major achievement mentioned by users is the improvement of the intake weir. The meetings of the group are held as necessary and the minutes are maintained in written form. The fine system is Rs 50 per day for labour not provided, and a user who does not pay his fine is precluded from use of water from the *kulo*. For the winter crop, the meeting sets the rotation regime. A problem that has cropped up is encroachment on canals, which has led to conflicts.

Institutions at Work

Irrigation in Madi *phaant* is managed primarily by informal traditional systems with varying degrees of organization. At one extreme, there is individual "right of prior capture" such as for the small spring sources of the Tinau near its headwaters at Kaphaldanda in the east. At the other extreme are organized systems like Chhedua *kulo* and Hadaha Khauruwa *kulo*. These organized systems have elected executive committees, regular minuted meetings, required labour contributions and enforcement of fines as part of their regular operation. In between these extremes are other systems that have informal

arrangements, are not registered or are only beginning to consider formal registration.

Two factors are playing major but contradictory roles in regional water use: traditional land tenure wherein much of the land is owned by absentee landlords, and modern transportation, especially the Siddhartha Highway connecting Pokhara in the hills with Bhairahawa near the Indian border in the plains. The former has dampened agricultural innovation while the latter has promoted it. Farmers are responding to these pressures by changing crops from grain to vegetables and litigating or agitating to have better tenancy rights.

Key Issues

- The new land tenancy act, passed by Parliament but contested in the Supreme Court, allows 50% of the land of a landowner to revert to the tenant. In the context of *guthi* land and the litigation that is underway, the new act is likely to expand land tenure conflicts in the Madi *phaant*.
- Vegetable production is more lucrative than conventional rice farming. However, such a shift may require a more intensive use of water. This may lead to change in existing arrangements of allocating water and to increased disputes, especially among the less organized groups.
- Some farmer groups are more skillful in using the state machinery to get access to funds for weir and canal construction, which means the establishment of permanent intakes and lined canals as opposed to brushwood weirs and unlined canals. Such technical innovations lead to better water efficiency for upstream users at the expense of downstream ones.

Decisions on water shares are often made on the basis of informal discussions.

- Because there is little coordination between different users' groups and because the administrative structure of Madi *phaant* is fractured, the conventional approach of setting up valley-wide authority for regulation and mediation may not be feasible. An egalitarian forum or structure that allows different groups to interact with each other may function more effectively.

Education gives a sense of self confidence and egalitarianism that foster creativity, which allows farmers to take advantage of the market.

Case Study III: Madan Pokhara Sprinklers and Water Harvesters

Background

Madan Pokhara is one of the six VDCs surrounding Madi *phaant*. It has a population of 6,858 in 1,082 households. This village has made a name for itself as a major supplier of vegetables to the *haat* bazaar of Butwal. Land in Madan Pokhara is mostly *raikar* or privately owned, and the farmers here have the distinction of being the first in Nepal to experiment with sprinklers for irrigation. They began to experiment with vegetables in the late 1970s with the introduction of PVC pipes allowing them to tap the various springs and streams (which flow into the Tinau) for vegetable production. Completion of the Sunauli-Pokhara Highway, which passes by the village in 1969, was an important infrastructural asset, as it allowed the villagers to take advantage of the market in Butwal.

While infrastructure is important, it can remain a passive resource. Unusually for a village in Nepal, Madan Pokhara has two high schools, the earlier one having been established in the 1950s. The level of education is very high, giving the people an enhanced sense of self-confidence and

egalitarianism. The village has an average literacy rate of 72%. During the People's Movement of 1990, which restored multiparty democracy to Nepal, of the 36 people arrested in Palpa at the start of the agitation, 21 were from Madan Pokhara. This confidence, as well as the broad outlook that education and consciousness-raising provide, has encouraged experimentation with new technologies (such as sprinklers and improved varieties of vegetables) and enabled them to take advantage of the market. In addition to vegetables, another important export of Madan Pokhara is schoolmasters to the various schools of the western region of Nepal.

System Description

Starting in 1979, progressive farmers began to use PVC pipes to tap streams like Juke *dhara*, Gamdi, Rip *mul*, and Andheri. Because of their ability to take advantage of state support structures, the farmers were able to mobilize resources from the Agriculture Development Bank and other sources to tap water throughout the VDC for vegetable and fruit cultivation. They also began to use sprinklers of which there are currently 95 in Madan Pokhara. Because of the good returns from vegetable farming, many who had government jobs in the past have left the service to take up full-time farming. The shift in cropping pattern from grain to fruits and vegetables is now almost complete.

Between 1962 and 1972 there was widespread deforestation in the VDC area. Many small spring sources dried up. Since 1974 village people have made special efforts to conserve forests, and the condition of springs has improved. Restoration has allowed 78% of the village to have

drinking water piped to their homes. For people living in altitudes above 3,800 feet, there are no spring sources from which water can be brought by gravity flow. In searching for ways to meet this challenge, they learned that rainwater harvesting was practiced in the Philippines and that a similar system had been installed in the village of Baungha in Gulmi district north of Palpa. Pressure was put on the Palpa DDC, which in turn mobilized Finnish aid for developing drinking water supply. A rainwater harvesting pilot project for 20 households was completed by the VDC in 1994. Its success has prompted the current construction of 311 rainwater harvesting systems for households as well as 3 larger systems for primary schools. An experiment is also underway to collect and store rainwater in plastic-lined ponds for vegetable irrigation. Electric pumps were also tried for irrigation, but given the high tariff of electricity in Nepal, they were found to be uneconomical: currently only one farmer uses electricity to lift water from one of the Tinau's tributaries for vegetable production.

Institutions at Work

While individual farmers have tapped the spring sources for sprinkler irrigation to make profit in the market, high levels of education and awareness have also enabled farmers of the village to participate fully in the activities of the VDC and its decisions. Local government is therefore used a social capital resource to obtain access to state-supported credit, foreign aid and other resources. The dominant institution that guides prosperity in Madan Pokhara is, however, the market and awareness building education has played a key role in the farmers' ability to take advantage of it.

Key Issues

As production processes become integrated with (or dependent on) the market, one may see egalitarianism erode in the face of individual interests. During times of low rainfall, individual interests may override common concerns, requiring more formal arrangements through the VDC for water diversion and use.

Case Study IV: Drinking Water in Butwal Municipality

Background

Butwal used to serve as a trading outpost between the Palpa hills and the plains. It is situated on the outwash fan at the foothills of the Churia range. After the eradication of malaria and the completion of the Siddhartha Highway that connects Bhairahawa at the Indo-Nepal border with Pokhara, the town began to see migration from different parts of the kingdom. This trend has continued with the completion of the East-West Highway through Butwal making it an important national junction. The town is also emerging as an important industrial development centre. A 1993 study outlines the dramatic growth of Butwal caused by the following factors (INFRAS and IDA, 1993):

- With the construction of the road to Pokhara and the extension of the East-West Highway to the west, Butwal became a centrally located town, which was traditionally an interface between the Tarai and the hills. Road completion provided new opportunities for the wholesale trade of manufactured

Eradication of malaria and opening of highways has led to rapid growth of Butwal.

Indian goods, ghee, ginger, herbs and other hill products.

- Early metal workshops established by United Mission to Nepal (UMN)²⁴ initiated the growth of a metal manufacturing sector catering to transportation demands. Butwal's growth is also based on industrial development; some industrial parks have been established recently.

- Many migrants from Palpa were businessmen. Entrepreneurial and innovative families with links in Tansen manage a considerable part of the business in Butwal.

- Proximity to India has also stimulated Butwal's development as well. Nearby Bhairahawa is an important customs entry point.

The census of 1991 estimated the municipality's population to be about 44,000 living in nine wards. In that year the municipality's jurisdiction was expanded to six neighbouring village *panchayats* with whose inclusion the population reached about 50,000 in 1991. According to a 1996 study, the population of the municipality was 60,000 (Hyundai and Cemat, 1996)²⁵ and is projected to reach 91,111 in 2000. Because it is a highway junction, there is a large floating population.

System Description

The town Batuali, the old part of Butwal was supplied with drinking water from a system that was built when Pratap Sumsher was governor of Palpa. Subsequently, supplies were augmented by pumping water from the Tinau River. This system was built with the assistance from the Indian Cooperation Mission (ICM)

in 1965 when the highway to Pokhara was being constructed.

The 1973 drinking water sector study by Binnie and Partners briefly discussed existing water supply system, sewerage and drainage facilities of Butwal. Under the World Bank funded Second Water Supply Project, the feasibility study for water supply, sewerage, and drainage was completed for the town. The report identified both surface and groundwater sources including expansion of the system built by the ICM to meet rising needs of the town. Subsequently Proctor and Redfern (1984) reviewed the feasibility report. Hyundai and Cemat (1996) recommended rehabilitation of the drinking water system of Butwal to provide 24 uninterrupted service to about 68,333 people in 2000, which is 75% of the population projected to reach by that year.

The municipality of Butwal has both formal and informal water supply facilities. The supply system uses three sources: groundwater, the Tinau River and the Chidia *khola*. This is a small surface source located in the Churia hills about 1.5 km north of Butwal. Water is supplied by gravity to a 900 m³ capacity reservoir situated at Ramphedi in the norther part of the town. From the Tinau River water is pumped into the same reservoir. Water of the Tinau is tapped using a sump well 8 m deep with three radial collectors. The intake is located downstream of the tailrace of the Tinau Hydropower Plant. From the sump well water is pumped by four 17.5 HP capacity pumps. A fifth pump is provided as a standby unit.

To tap groundwater sources, two deep tubewells have been installed at Milan Chowk on the left bank of the Tinau. Water is pumped from the wells

Butwal municipality uses both surface and groundwater sources for drinking water supply.

into a 500 m³ capacity reservoir. The deep tubewells were developed during the Third Water Supply Project funded by the World Bank in 1981.

The two deep wells each of 75 and 85 HP designed capacity yield water at the rate of 47 litres/second. The radial collectors were damaged in the 1993 floods, but have not been repaired. Water of the river is allowed to flow directly into the sump well. Due to poor operation and maintenance the capacity of both the deep tubewells has been lowered. Breakdown of the pumps on the bank of the Tinau River is frequent.

From the two reservoirs, water is distributed by gravity. The larger reservoir serves the northern section of the town while the smaller one serves the southern section. Those without access to municipality services use independent and informal sources like springs and the Tinau. The supply system covers an area of about 3 km² and delivers water through a 45 kilometre of distribution network consisting of galvanized iron (GI) and high density polyethylene (HDP) pipes. Water is supplied on an intermittent basis to 41,000 consumers via 3,546 private connections. One hundred and thirty are public stand posts. The system currently supplies water to thirteen wards of the municipality, local industries, hotels and lodges, schools and other public offices.

The average per capita use in private connection is about 110 lpcd, while in the public stand post, the figure goes down to 72 lpcd. In many localities of the municipality, supply of water is poor and inadequate. Hyundai and Cemart (1996) estimates the leakage to be 45%, while officials of the Butwal Branch of the NWSC mention much lower percentage. Though the

quality of groundwater is within acceptable limits, quality of the Tinau water deteriorates during the monsoon months when the turbidity in the river increases due to sedimentation. A pressure filter of 3 MLD capacity was expected to improve quality, but does not function due to lack of fitting. The quality of supplied water is poor as only bleaching power is added as disinfectant.

In the wet season the three supply system produce 8 to 8.5 MLD water, while dry season production is substantially reduced. The flow of both the Tinau and the Chidia *khola* drastically diminish in the months of April-May, which are the dry seasons. Also its installed capacity has been substantially reduced due to ageing of the transmission pipes. Theoretically, by continuously operating deep tubewell possible gap between supply and demand can be narrowed. Declining specific yield of wells as well as high cost of pumping, however, emerge as major constraints.

The expansion and growth of Butwal from a rural staging centre into an industrial township has brought to fore new forms of environmental challenges. There is no sewer system in the municipality. Use of septic tank and pit latrine is common. Instances of waterlogging and ponding, however, is low because the landscape slopes southward and the geological formation has high permeability.

A number of outfalls that collect drainage water from roadside and core section of the town flow into the Tinau close to water supply and irrigation intakes. Solid wastes are dumped on the banks of the Tinau. The other sources of pollution in Butwal are wastes from industries. Though responsibilities

Safe disposal of municipal wastes is an emerging challenge in Butwal.

of treatment and safe disposal of wastes remain with the industrial estates, in many cases untreated wastes are discharged into surface drains. The layout of the drinking water systems and localities critical from environment perspectives are shown in Figure 6.

Institutions at work

The operation and management of the water supply system for Butwal is under the Nepal Water Supply Corporation (NWSC) a parastatal organization under the Ministry of Housing and Physical Planning (MHPP), which is responsible for water supply in eleven urban centres of Nepal, including Greater Kathmandu. According to ADB (1997) the annual operation and maintenance cost of NWSC is Rs 232 million, and its annual billing is Rs 269 million. Hyundai and Cemmat (1996) estimate the average monthly billing at Butwal to be Rs 418 thousand, giving an annual billing of Rs 5.1 million. The MHPP exercises control over operation and development of NWSC. Sixty one per cent of its investment come from external sources. IDA's credit to the NWSC amounts to 17%. Butwal Municipality cross subsidizes operation and management of Kathmandu's water supply system. The Ministry of Finance, which underwrites the IDA loans to the Nepal Water Supply Corporation, meets the charge of public stand-posts. NWSC employs 2,078 staff.

Executives of the municipality seem to be aware of many of the challenges that the town faces. The municipality declared 1998 to be the "Drinking Water Year", and as part of this commemoration it provided a loan of Rs 5 million payable in 5 years to the Butwal office of NWSC to be used for improving the water supply in the municipality.

Key Issues

- Water quality is a significant concern. Because pumping is done directly from the Tinau, and there are no sedimentation tanks, the turbidity of the supplied water is high. The present water treatment facility is insufficient.
- Dependence on electricity for the operation of the systems is another issue. Immediately after the pump system came into operation, the supply of electricity was inadequate. In March of 1998, there was a major disruption in the supply because of damage to one of the plants of the system – Trisuli Hydropower Plant – and led to power cuts in the national power grid. This seriously affected Butwal's water supply
- The rising population and growing industries in Butwal have increased the demand for water. There are plans to augment the supply by rehabilitating, installing more wells and by developing additional surface water sources. This expansion may increase the demand on the Tinau, and could result in competition with existing irrigation users and give rise to new disputes.
- Waste disposal is a major issue, but has received little attention. Butwal has no sewerage system or waste treatment facility. Its surface drainage system is inadequate and discharges waste and storm flows into lower regions of the town. A proposal to discharge storm water into the Tinau led to a dispute with farmers of the Sorha/Chhattis Majua irrigation systems. Subsequently an agreement was reached to release the wastes downstream of the intake point of the irrigation canal. The fundamental nature of the emerging dispute has not been resolved by this agreement.

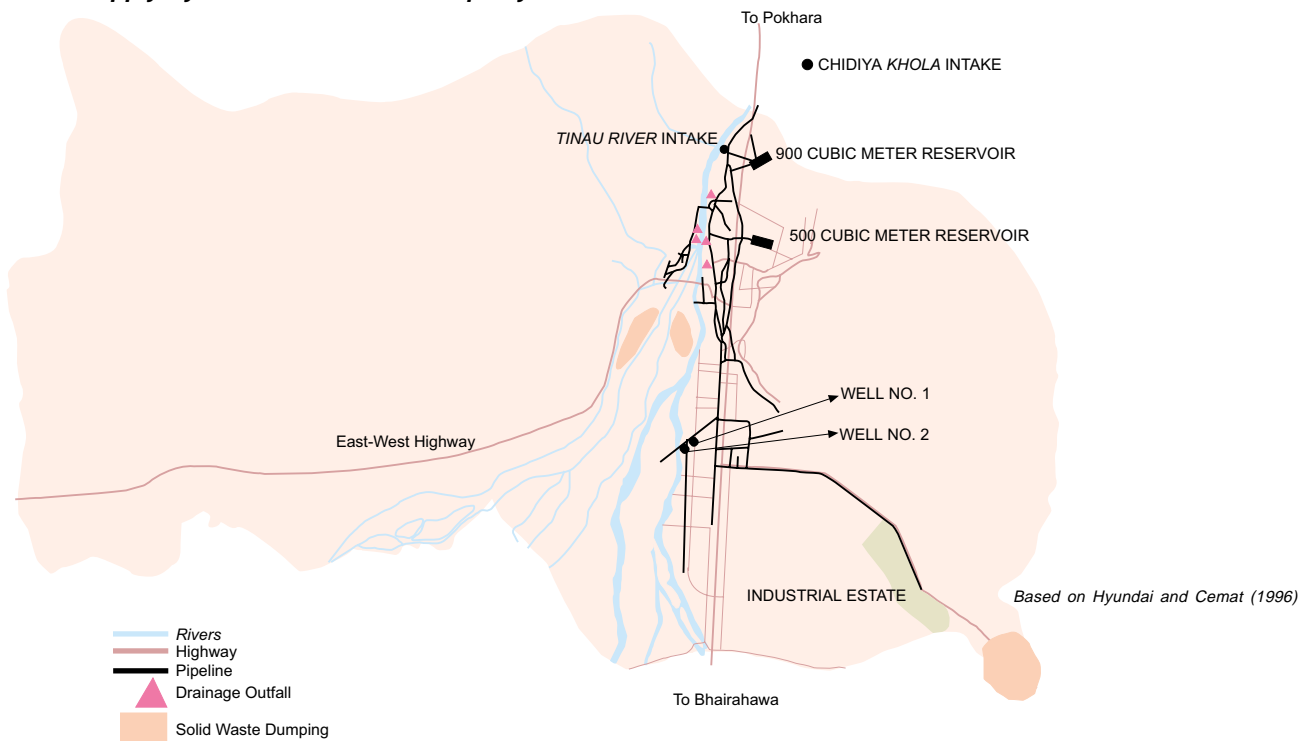
Key issues in Butwal Municipality include:

- *water quality,*
- *population and industrial growth,*
- *waste disposal and*
- *potential for groundwater contamination.*

Waste from private toilets is disposed off in septic tanks and soak pits. While these are conventional techniques, groundwater pollution may be increasing with urban and industrial growth. In some cases septic tank waste is carried in containers and disposed off on land

or the Tinau, which greatly increases contamination hazard. The high permeability of the *bhabar* region suggests the possibility of contamination of the regional groundwater aquifer, which requires careful and detailed scientific assessment.

Figure 6:
Water supply system of Butwal municipality



Butwal: 1978
Source: WBCS, 1987

The sparsely populated Butwal in 1978 is presently an active expanding urban centre.



Butwal: 1998

Case Study V: Hydropower

Background

Water from the Tinau is diverted through a weir and a tunnel to a run-of-the-river, underground hydroelectric plant at the gorge section of the river just upstream of Butwal. Because the plant makes use of the gradient of the riverbed to generate power and does not store or consume water, it has little impact on users downstream in the *bhabar* (Butwal, Sorha Mauja, Chaar Tapaha) or Tarai zones (Marchawar, Manigram). Although this plant that was established in the mid-1960's does not store or consume water, it is important for several reasons.

Electricity from the Tinau Hydroelectric Plant has played a significant role in the industrialization of Butwal. While private power companies have been formed in Nepal in the past and some of them did manage to generate and sell some electricity, their institutional presence remained ephemeral: indeed, none of them exist any longer. However, the institutional set-up of Butwal Power Company (BPC), which designed and built the Tinau Plant, did endure and presented itself as an alternative model of hydropower development in Nepal even though it fell under government control later.

After Tinau, the company went on to build the 5 MW Andhikhola Hydroelectric Plant in Syangja district just north of Palpa, and the 12 MW Jhimruk Hydropower Project in Pyuthan district to the west. Currently BPC is engaged in a partnership with Norwegian investors in building the 60 MW Khimti Hydroelectric Project in Ramechhap district

east of Kathmandu, which is the largest private investment in Nepal. The company is negotiating with the government to build the Melamchi water supply system for Kathmandu, which will entail the construction of a 27 km tunnel with a 15 MW power plant in the city's outskirts. Factories and engineering works established by the BPC group of companies are engaged in rehabilitating the electromechanical parts of the Marchawar Lift Irrigation Scheme in the downstream reaches of the Tinau (Case study VIII).

System Description

The Tinau Hydroelectric Project diverts the river through a tunnel and is capable of generating 1,000 kW for supply to Butwal at 3 kV. A 65 metre long dam across the river raises the water level by 8 metres, allowing flow to be diverted through a trash rack to the desilting chamber, where manually operated radial valves have been installed for intake control and sediment flushing. From there, water is taken to the powerhouse through a 1,266 metre long brick and cement mortar lined horizontal tunnel of 2.1 m diameter. The tunnel has a centreline that is at least 25 metres inside the outer surface of the hill. The underground powerhouse consists of three generating sets imported from Norway, which have their own governors, penstock valves, oil circuit breakers and instrument panels. The three units consist of two turbines of 250 kW and one of 500 kW.

Since the powerhouse floor is below the river level, seepage water is an expected problem. To cope with heavy seepage during floods, several pumping systems have been installed. The seepage water is collected in a tank and drained out with

Butwal Power Company (BPC) presented an alternative model of hydropower development for Nepal.

the discharge from the turbines back to the river through a 752 metre long and 3.85 m diameter tailrace tunnel. The power generated is transmitted to Butwal and connected to the 33 kV/3 kV substation there, thus linking it to the national grid.

Institutions at Work

In December 1965, Butwal Power Company Limited (BPC), was registered by the UMN²⁶ with the objective of producing, transmitting, distributing and selling electricity mainly within the Lumbini Zone in central Nepal. The Electricity Department (ED)²⁷ of His Majesty's Government of Nepal first provided the company a temporary licence to produce and distribute diesel power. In June 1966, a proper licence valid for ten years was issued and, in March 1968, a licence was given to produce and sell diesel power to the Butwal public. The first consumer to receive BPC's diesel-generated electricity was an industry in Butwal in December 1968. A year later, in October 1969, supply was given to three private consumers, and by April 1971, 323 electricity consumers were on the company's roster.

Construction of the Tinau Hydropower Plant was begun in 1966 by BPC, a few months after it was registered as a company. In December 1970, 50 kW of the first stage of the project started generation. The second stage of production, 250 kW, was begun in July 1974. In April 1978, the third and final stage of the power plant was completed, increasing its total capacity to 1,000 kW. His Majesty the King formally inaugurated this project in February 1979, and it was nationalized (or handed over to HMG by BPC without receipt of any compensation) on July 16, 1980. HMG then

handed over the ownership of the project to Nepal Electricity Corporation (NEC), which took up its operation and maintenance.

Approximately a year after the hand-over, in September 1981, a severe flood on the Tinau damaged the powerhouse and encased the generators in mud. After four months of cleanup work, the plant started to generate electricity and was restored to full capacity. Several years later, the plant's capacity was reduced to approximately 900 kW because one of the generators was damaged and the required rewinding had not been done. Subsequently, poor maintenance has caused the output to be reduced even further as the data of Tinau's contribution to meeting the peak load of the month shows (Table 3).

Operation of the plant has been problematic under the parastatal ownership of NEC/NEA. Such old machinery requires systematic and meticulous preventive maintenance, an issue that is a chronic problem in all technical areas of Nepal, whether power, irrigation or water supply. In the Nepal government's technical culture, as expressed in its budget philosophy, operation and maintenance activities are not accorded the kind of seriousness that high level and expensive technical artifacts demand for their proper functioning. A standard grouse of the engineering staff in all government-owned or government-led utilities and departments is that the operation and maintenance budget, never more than symbolic in most cases, is the first item to be slashed when any austerity measure comes in vogue.

The system also suffered from the fact that the generation and distribution voltage of 3 kV was not the standard in Nepal and hence the power

The initial nationalization and current reprivatization of the BPC is indicative of the ongoing policy swings that have constrained private sector hydropower development in Nepal.

plant had to supply an isolated segment of Butwal town. A 3/33 kV link transformer was installed to the Tinau plant with the national grid, but for many years the NEC/NEA did not permit synchronization into its larger system. The power plant, therefore, had to supply only an isolated part of the system, which was inefficient use of its potential. The interconnection of the powerhouse with the national grid was completed only in 1995.

Operation and maintenance are low priority items, both in terms budgets and the government's work culture.

Key Issues

- The history of BPC and the Tinau power plant highlights the problems of private sector involvement in power generation in Nepal. A few years before BPC's Tinau plant was nationalized, smaller electric works such as Bageshwari Electric of Nepalganj and the Eastern Electricity Corporation were taken over and merged into the government parastatal Nepal Electricity Corporation.²⁸ At that time Nepal, and the major donors that were supporting it, believed in state-led and state-consolidated development. Private sector contributions were not supported.²⁹
- For UMN to bring money for construction into Nepal, conditions were imposed: assets so created were to be handed over to HMG six months after the completion of the project.³⁰ This was apparently seen as a routine legal formality on International Non Governmental Organization

(INGO) operations and not as a foregone conclusion, since no specific prior understanding had been made or discussed between UMN, the donor agency NORAD and HMG. HMG was a minority shareholder in the BPC and held the chairmanship position on its board, and thus had sufficient insight into and influence on company affairs. Thus the UMN expected that the BPC would continue to own and operate the system in the future. It is within this framework that the Tinau Hydropower Plant was taken over by HMG and given over to the NEC.

- In subsequent projects built by the BPC, HMG took over the shares, but they were retained by the Ministry of Finance and not handed over to the NEA. As a result, after the takeover of Andhi *khola* and Jhimruk power plants, the Ministry now owns close to 97% of the shares of the BPC. The remaining shares are divided between the UMN, NEA and the Nepal Industrial Development Corporation.³¹ Today, privatization and liberalization are in vogue. As a result, there is a move, both from within HMG and from external donors, including the Norwegians, towards the privatization of the BPC by selling HMG's shares to the private parties. The necessary documents have been prepared, a public notice issued, and the process of privatization is on, although controversy has emerged between HMG and private parties involved.

TABLE 3:
Tinau HEP's Contribution in MW to the Monthly Peak Load for FY 1996-97

Saun	Bhadra	Asoj	Kartik	Mangsir	Poush	Magh	Fagun	Chait	Baisak	Jeth	Asar
16/7-16/8	17/8-16/9	17/9-16/10	17/10-15/11	16/11-15/12	16/12-13/1	14/1-10/2	11/2-13/3	14/3-12/4	13/4-13/5	14/5-14/6	15/6- 15/7
0.44	0.44	0.50	0.54	0.50	0	0.55	0.22	0.20	0.48	0.45	0.50

The month of Saun corresponds to July-August
Source: (NEA, 1997).

Case Study VI: Farmer-Managed Irrigation Systems

Background

Local farmers have been diverting the water of the Tinau to irrigate areas that lie on its east and west banks since historical times. There are three such irrigation systems using temporary intakes on the Tinau: the Chhattis and Sorha mauja on the east and the Char Tapaha Irrigation system on the western side. Locally, Chhattis and Sorha mauja mean thirty-six and sixteen *birta* (revenue villages) respectively, while “chaar tapaha” means “four canals.”

The Chhattis and Sorha mauja systems were built by the local *tharu* community about 150 years ago. They are some of the largest farmer built and managed irrigation systems in Nepal. The main 10 kilometre long canal was originally built to irrigate Sagarhawa, which today is at the system’s tail end. While *tharu* settlements are very old, more recent ones were promoted by the State and provided with support for expanding the pre-existing system. The translation of the name Chhattis Mauja itself, “the thirty-six *birta* revenue villages” suggests that they were formed due to the state’s push, and not a spontaneous effort.

Such settlements were organized through the grant of a land title: the landlord collected revenue and forwarded a fixed annual sum to the State. Landlords (*zamindars*) were not so much private owners paying taxes, but functioned as representatives of State entrusted with maintaining law and order, including assuring tax collection.

After the initial establishment of the systems, people from different parts of Nepal started to migrate to the region resulting in a gradual decline in the forest cover of the “*chaar kose jhari*”, the thick tropical forest of *bhabar* zone. These forests were cut and converted into agricultural land, a trend which increased after 1950. Migration increased for several reasons, including the eradication of malaria in the 1960s and the completion of the Bhairahawa-Pokhara and East-West highways of Nepal. In addition, many people from the hills came to the Tarai after their settlements were affected by floods and landslides.

The command areas of these irrigation systems lie in the *bhabar* zone. As previously noted, this zone is characterized by high infiltration rates due to unconsolidated flood plain deposits brought by rivers from the Churia. The landscape gently slopes southward and has a soil-base a couple of feet in depth. Unlike in the lower Tarai plain, use of groundwater is limited to the lower end of the region, where deposits allow wells to be constructed easily. In the upper reaches of the canal systems, coarse soil deposits and high infiltration rates cause high levels of seepage and necessitate more irrigation application than at the lower sections of the command area. Seepage losses are particularly high in the months of April and May, and result in water scarcity in the surface irrigation systems. In those months, water availability in the Tinau drastically reduces and becomes less than 1 m³/s. As a result, irrigation water cannot be supplied to tail-reaches and cannot supplement the third crop in the spring. The outcome is increasing evidence of water scarcity during these months.

There is a history of farmer-managed irrigation systems even in areas where settlement was promoted by the state.

Two major components of irrigation management are water allocation and canal maintenance.

System Description

Chhattis and Sorha Mauja

The Chhattis and Sorha mauja have a combined command area of 5,000 ha. The Chhattis Mauja irrigation canal has the capacity to irrigate about 3,500 ha of land in Makrahar, Ananda Ban, Jogikuti and Sagarhawa villages.³² The Sorha Mauja irrigates a smaller area, 1,500 ha between Chhattis Mauja and the Tinau River. The two irrigation systems are, therefore, contiguous. The Sorha Mauja System is about 95 years old and irrigates land in Madhuban, Anandavan, and Khopia. The average households in the area have 8 members and the irrigated landholding averages 1.0 ha in the head reach of system and about 1.5 ha at the tail end.

The Sorha and Chhattis mauja irrigation systems divert water from the Tinau River at its left bank at Butwal at a place is called Kanyadhunga. Two kilometres downstream of the main diversion, at a point called Tara Prasad Bhod, the water in the jointly operated canal is split into two separate channels. The Sorha Mauja canal is allocated 40 per cent of the combined canal flow, while the rest of the flow is assigned to the Chhattis Mauja system whose main canal is eleven kilometres long. This allocation was decided in a 1969 negotiation mediated by the government. The main canal is operated jointly.

The irrigation systems incorporate a 33 branch canal sub-system that draws on water from the main canal and is used by a total of 54 village units. This is accomplished by 44 temporary canal outlet structures. The canals of both the irrigation

systems are unlined and the layout of this system is shown in Figure 7.

Chaar Tapaha

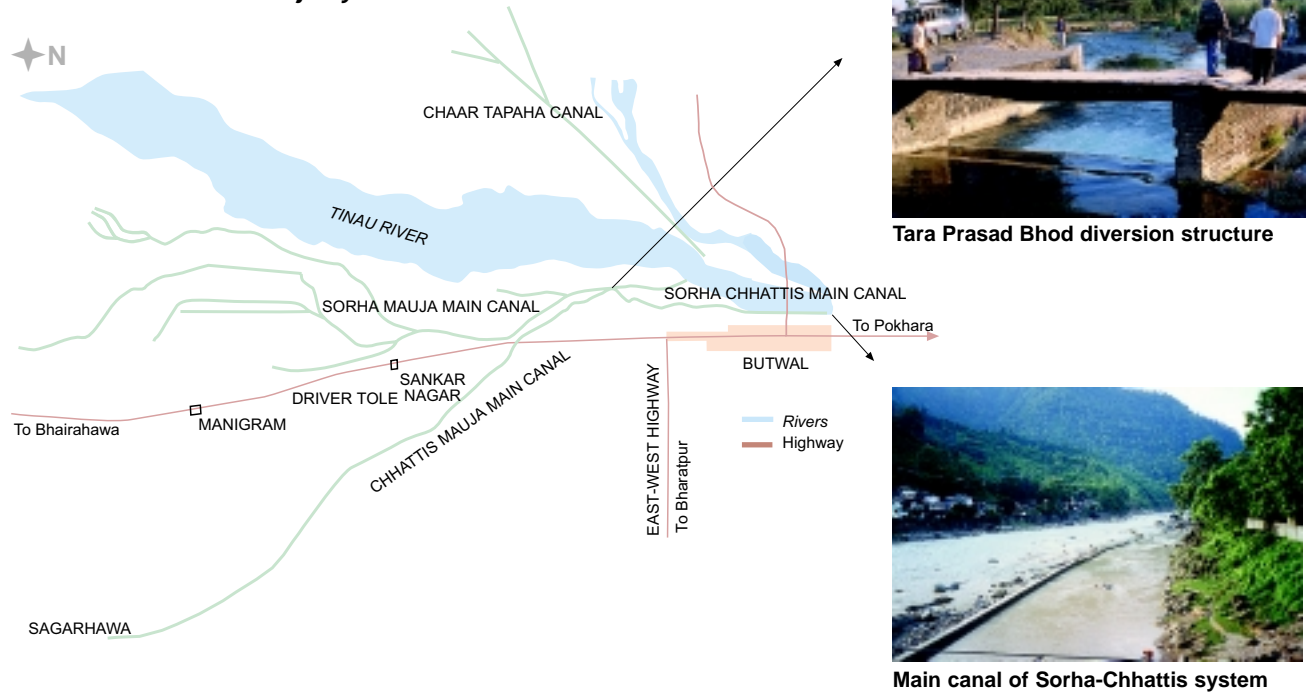
Before the Chaar Tapaha irrigation system was built, farmers tapped small local stream-channels. There were no major canals. Following migration from the hills, the population started to increase, which resulted in more land being brought under cultivation and increased the need for water. Smaller canals, which received water from local sources, were mostly built through individual efforts. Some farmers built larger canals and some were managed on a community basis. Later representatives of these different canal groups decided to form an umbrella organization, the Chaar Tapaha Committee, which functions today as the water users committee.

The Chaar Tapaha irrigation system uses water from both the Tinau and the Dano rivers. There are four unlined canal systems altogether that take water from the rivers: Panch, Eghara, Khadawa and Chaar Tapaha. This network irrigates the villages of Motipur, Amuwa, Pharsa Tikar, Semlar, Bangai, as well as ward numbers fourteen and fifteen of Butwal Municipality. The total land area that can be irrigated by the system is about 4,800 ha, benefiting 43,000 people in 4,175 households. The canals divert water using temporary diversions, which are made of stone, mud, brushwood, and bamboo. Some of the recently rehabilitated structures on the canals are made of cement concrete.

Institutions at Work

The management of these irrigation systems by farmers' associations is stressed by challenges

Figure 7:
Sorha and Chhattis Mauja systems.



related to the growing domestic and irrigation demand for water. The irrigation organizations have evolved over decades from informal system to formal ones. Farmers now feel the threat of losing control over the water resources in these systems.

The users' committee of Chaar Tapaha, which was registered by the District Administration Office of Rupandehi in 1983, manages its overall system. The constitution of the committee is the guiding document legitimizing decisions and activities. It is based on traditional rules and norms that have been in practice for decades, with every farmer within the irrigation command area being an equal stakeholder responsible for the management of the system. There are two major components of the management system - water allocation and

canal maintenance. Water allocation is proportional to land ownership. A farmer who has a larger area of land gets more water, but must pay more water tax. Tax rates vary from Rs 5,000, to Rs 11,000 depending upon the size of the *mauja*. The tax is adjusted every year. Unlike the Sorha-Chhattis system, the management of Chaar Tapaha is less orderly.

Water allocation within these systems is related to the availability of water in the Tinau River. Since the intake of the left bank Sorha-Chhattai Mauja is one hundred metres upstream of the right bank Chaar Tapaha intake site, disputes exist between the systems regarding water allocation. The two management committees of the systems have an understanding to share water by turns.

The water shares of the Sorha and Chhattis Mauja irrigation systems were negotiated by an external adjudicator.

Traditional FMIS face many issues including:

- *water scarcity during dry months,*
- *increasing difficulty in maintaining temporary diversions,*
- *pollution,*
- *changing labour availability for maintenance,*
- *debates over system performance,*
- *destruction from flash floods, and*
- *high sedimentation.*

The management committee of the Sorha-Chhattis system is elected. Each member of the management committee has equal responsibility regardless of the area of land he/she owns. For participation in maintenance works, the command area of each canal is divided into different blocks, (known as *mauja*). Each *mauja* has sub-committees for the maintenance of canals within the area and for monitoring water allocation. It is compulsory for specified members to attend to canal and headwork maintenance. There is also a mandatory provision for 60 persons from each *mauja* to participate in the reconstruction and rehabilitation of the headwork and canal systems. Anyone who fails to contribute to this collective community enterprise has to pay a fine. The constitution of the Water Users' Committee has specified the conditions under which the user should pay regular charges and extra charges or fines.

Key Issues

- The inadequacy of water in the dry months and flooding impeded drainage in the tail reaches in the monsoon are major problems in all three systems. These conditions often cause loss of agriculture production. The extent of water scarcity is highly seasonal and fluctuates from year to year. In the dry months, when irrigation demand is high, water in the canals is at its ebb. Irrigation and drinking water needs grow continuously from December to June until the monsoon gains its full strength by the end of June.
- Scarcity often causes farmers to leave land fallow. Where possible, people cope with water scarcity for domestic use by using open wells, boring deep tubewells or using hand pumps. Deep

boring is successful only at a few places toward the southern section of the irrigation commands, south of the *bhabar* zone.

- Irrigation system performance is emerging as a significant issue. Canals are unlined in all three systems and high seepage rates reduce water availability in the lower sections of the command. The high seepage does, however, contribute to the recharge of the regional aquifers, but the precise linkage remains poorly understood.
- Farmers are advocating permanent intakes for each of the canal systems due to the complexity of maintaining collective action for intake rehabilitation and canal cleaning. According to them, temporary intakes are increasingly difficult to maintain because the bed level of the river is declining due to the extraction of sand and gravel for construction. These changes in river morphology have not been studied scientifically.
- Chaar Tapaha experienced flash floods in 1970, 1979, 1981, 1995 and 1998; the 1979 flood being particularly devastating. The cause of this flood was a landslide a few kilometres upstream of Butwal, which blocked the flow of the Tinau for several hours before it burst through. It took place in the early monsoon when farmers were planting rice. The flood swept away all intakes and most of the canals of Chaar Tapaha as well as parts of Butwal. Traditional informal farmer-managed irrigation systems are structured with resilience to deal with such natural phenomenon while formalized users' groups exhibit tendencies towards dependence on government.
- The Tinau has a high rate of sedimentation and tends to change its course. Sedimentation is

a significant problem affecting the efficiency of canals and the productivity of farmlands, especially when large amounts of sand are deposited. The 1979 flood deposited boulders, sand and unproductive sediment over the canals and farm land. The damage was so serious that it took two years to restore the canals to normal.

- New forms of stress are emerging due to urbanization and rising pollution. Waste from Butwal Municipality is dumped on the banks of the Tinau and the Dano rivers close to irrigation intakes. During lean season scarcity, pollution levels are high due to low dilution capacity of the river. Despite this, people are compelled to use river water for domestic and livestock purposes, which has affected the health of local people.
- The changing nature of labour relationships, triggered by urbanization and increased mobility due to improved transportation, are exerting stress on the irrigation institutions. Defaulting on long-held norms farmers show an inclination to work elsewhere instead of contributing to activities like cleaning canals or erecting the diversion. Irrigation institutions face the challenge of successfully reconciling new emerging social practices with old tradition.

Case Study VII: Khadwa-Motipur Irrigation System

Background

Khadwa-Motipur, another farmer-managed irrigation system (FMIS) in the Tinau basin, lies in the lower, southern portion of Rupandehi district. The headwork site is located beside the

Bhairahawa-Lumbini road, about 10 km west of Bhairahawa, upstream of the confluence of the Dano and the Siyari rivers. This government-assisted scheme with a gross command area of 2,000 ha and net command of 1,200 ha is expected to benefit three Village Development Committees (VDCs) — Bashauli, Pakadi and Bhumari. A total of around 10,000 families have their lands within the command area of the system.

Khadwa-Motipur is being rehabilitated through the Irrigation Line of Credit (ILC) pilot project, a World Bank loan to HMG/N, implemented by the Department of Irrigation. ILC was initially launched to establish a framework for the future (National) Irrigation Sector Program (ISP)³³ and was later extended as a pilot project to test procedures for a sectoral approach to participatory irrigation. The ILC pilot project takes up the following types of schemes:

- (a) construction of new small and medium irrigation systems to be managed by farmers;
- (b) rehabilitation of farmer-managed small and medium irrigation systems;
- (c) rehabilitation of small and medium government managed irrigation systems and their turnover to farmers; and
- (d) construction of new groundwater schemes to be managed by farmers.

Khadwa-Motipur is the second type of scheme in this classification, a medium-scale, farmer-managed irrigation system needing rehabilitation. The ILC pilot project seeks to be demand driven, and the project cycle begins from information

*The NISP
promotes
construction,
rehabilitation
and the
turnover of
irrigation
schemes to
farmers.*

collection, goes on to its dissemination and ends with farmers taking responsibility for the operation and maintenance of the scheme.

Under the ILC, requests for governmental assistance should originate from the concerned farmers once information about the project has been widely disseminated. The requests are then screened at the District Irrigation Office (DIO) with screening including a walk through the scheme to identify needs. This is followed by a feasibility study assessing not only technical and economic parameters, but also social and institutional ones. Once the scheme has been appraised and construction approved, the users need to establish a formal Water Users' Association (WUA).

An agreement is then signed between the DIO and the WUA. The WUA is expected to raise a cash contribution to deposit in the bank for later use for operation and maintenance. During construction, the WUA has the responsibility of mobilizing labour and jointly supervising (with the DIO) construction works. When the scheme is commissioned, farmers are formally responsible for the operation and maintenance of the system. In Khadwa-Motipur this procedure has generally been followed but, as discussed below, there have been many loopholes.³⁴

System Description

Although now separated from the main stream, the river supplying Khadwa-Motipur is part of the Tinau River system and could be one of its abandoned channels which ultimately join the Dano River about 5 to 6 km downstream from the headwork site of the project. It is fed mainly

from seepage, spring and drain water. Its dry season flow in April is around 50 to 60 litres/second and it carries a moderately low sediment load. At the headwork location, the river passes through a narrow gully with a firm high bank. The command area lies on the southern side of the Bhairahawa-Lumbini Highway between the Tinau and the Dano rivers (in contrast to the headwork, which lies just north of the highway).

The headwork consists of a barrage with six gates. Other structures included in the scheme are one head regulator, one road culvert at the Bhairahawa-Lumbini Highway, one cross drainage work, two village road bridges, one foot bridge and a 1,500 metres long bund along the river banks as well as river training works. The idle length of the canal is 2.5 km, while the main canal and branch canals are 10 km and 1.7 km long respectively. The earthen canal capacity is 1.8 cumec. The scheme also includes four branch canals and several tertiaries.

The villages of Parsawa and Motipur lie in the idle length portion of the canal. Towards the head-reach of the canal, in the eastern part lie the different wards of Barsauli village while Budawa lies in the western portion. Different wards of Pakadi VDC lie towards the middle reach of the canal, while Bhuwari lies towards the tail-end of the canal.

Institutions at Work

Before the construction of the Bhairahawa-Lumbini Highway, farmers tapped water from the Siyari River, about one km upstream from the present confluence, using an earth and wood

Under the NISP, implementation is supposed to be demand driven but there are many loopholes.

diversion bund. Because the Bhairahawa-Lumbini Highway would cut across the existing canal, the Department of Roads constructed a culvert at the point of intersection.

Local villagers articulated their request for assistance from the government under the ILC in terms of the *kachha/pakka* distinction. There is a preference for a *pakki bandh* (a permanent concrete dam) over a *kachhi bandh* (a temporary earthen dam) because the *kachhi bandh* has to be constructed anew every year (sometimes even more than once a year) while a *pakki bandh* ostensibly does not have to be rehabilitated repeatedly.

Historically, until the late 1970s, eighteen villages served by the system would jointly build a temporary weir to divert water from the Khadwa stream. In 1979, a water users' committee was formed with Chandra Bhushan Tiwari from Bhuwari village (towards the tail-reach of the canal) as chairman. Tiwari was a member of the Rastriya Panchayat (national legislature of the party-less Panchayat system) and thus an influential local person. During this period, the villagers collected funds for building a permanent dam. When the dam was built in 1980, it was formally inaugurated by the HM King, who had come to visit the region.

Baked bricks were used in constructing the dam in 1980, which were also used to rehabilitate portions of the canal that had been breached. The canal was constructed up to Bhuwari, the home village of Tiwari, but after one season, the bank of the canal near the headwork was breached and the dam collapsed. It was rehabilitated after roughly two years only to be washed away and

again, with the sediments from the flood clogging the canals.

In 1985, Deepak Bohora, who was then a member of the Rastriya Panchayat (and also a key figure in the decision behind the Marchawar Lift Irrigation System), made state funds available for the reconstruction of the dam. Because the dam was not properly designed (for instance, it had no reinforced concrete pillar), it collapsed once again. The farmers then began to request assistance from the government through the ILC pilot project.

The local users formally followed the procedures for requesting funding for the scheme under the ILC, including filling out the sub-project request form and assisting in identifying and establishing the feasibility of the scheme. The final push for taking up the scheme for rehabilitation came from Sarvendra Nath Shukla, a local Member of Parliament who was then the State Minister for Water Resources and a scion of the influential Shukla *zamindars* of Marchawar. He initiated the scheme in 1996 and construction commenced in 1997. The scheme was first designed as an overflow weir diversion, but an unprecedented flood in July 1996 caused the DIO to revise the design with support from a Technical Assistance Team. Finally, through local pressure, the overflow weir was replaced with a full barrage.

The present users' committee was formed in 1996. The main persons in the WUA are all from Pakadi village located in the middle-reach portion of the canal. In contrast to the earlier committee, whose chairman was from the tail-end portion of the scheme, this time those from the middle portion of the canal dominate the committee.

Issues facing the Khadwa-Motipur scheme include:

- *poor cost recovery,*
- *formalization of WUA,*
- *frequent damage,*
- *the growth of tubewells in the command area, and*
- *lower than anticipated increases in yield.*

When the design and cost estimates of Khadwa-Motipur were first prepared, the estimated cost was Rs 11,166,173. This was subsequently revised to Rs 18,481,775 in 1997. According to this figure, the cost per hectare comes to be around Rs 15,400 while the internal rate of return figured at around 47 per cent. By the end of the 1997/98 fiscal year, the construction costs had reached Rs 26,000,000. Consequently, the cost per hectare has escalated while the IRR has come down considerably.

Powerful local actors could use state irrigation support as a political tool.

The farmers were expected to contribute Rs 80,000 at the rate of Rs 100/*bigha* by the end of the 1999/2000 fiscal year. According to the DIO, only after the farmers have deposited this amount, will the gates be installed. To date, however, farmers have been able to contribute only around Rs 27,000. The department officials complain that they spend days waiting for the WUA representatives to show for meetings, but without success, that the farmers are “not active in participation”.

Key Issues

- When the scheme was first proposed cost estimates were much lower but the time it reached completion, costs had almost doubled. The escalation could be due to improper feasibility and design analysis at the very beginning. Initial estimates are deliberately deflated by construction-biased agencies and consultants to make the scheme feasible. This is usually done by increasing the command area estimates, underestimating existing yield, over-estimating the expected yield in the future and reducing design structures to the bare essentials.
- Prior to 1996 the irrigation water users' groups that existed were informal in nature. These now have to be registered with the District Water Resource Committee and the formal nature of these bodies may result in them becoming forums for contesting local political power.
- In the past, the scheme was often damaged, but headwork was built at a low cost and with locally available materials. It meant that the farmers could rehabilitate it. Because the headwork is built from imported materials, local resilience has been undermined. Given the nature of cloudbursts and hydro-ecology in the region, it is likely that the scheme will be damaged in the future, while provisions for repair does not exist.
- Within the command area, there are several shallow tubewells pumpsets with the help of which local farmers irrigate their fields. Where groundwater pumping is available it is unclear whether farmers will have an incentive to participate in WUA's operation and maintenance activities.
- Increases in agricultural output from this scheme are likely to be small. Existing yields are higher than cited in the feasibility report because of the tubewells and diesel operated pumps which are used for irrigation in the area, but which are not acknowledged by irrigation agencies.
- The participatory irrigation development approach endorsed by the government and donors faces implementation difficulties. The ILC programme, which preceded the NISP, was originally designed as a comprehensive package of assistance comprising of social, physical, environmental, legal and organizational aspects rather than a narrow set of design and construction activities. NISP shows little sign of

institutionalizing the new approach of investment in irrigation because of entrenched reluctance within the department to move away from its construction focus.

Case Study VIII: Marchawar Lift Irrigation System

Background

The region that includes Marchawar was historically known as Shivaraj. It lies about 40 kilometres southwest of Butwal and about 20 kilometres east of Lumbini. Today's Marchawar was settled by people from the south about four to five generations ago. Although the area was cultivated and the land was irrigated even during the time of the Buddha, the region resembles much of the northern Ganga plains with a feudal socio-political system governed by local elite. Most farmers are descendants of tenants brought by landlords who were invited by the government of Nepal to resettle lands handed back to Nepal after 1816 by the British Raj.³⁵ The tenants were mainly Muslim and Hindu farming or "peasant" castes. Lateral linkages of association for trade and marriage are common with similar groups in Uttar Pradesh. Local populations marry, work, travel, and trade across without any border formalities.

Marchawar was relatively lightly populated between 1930 and 1980. Even in the late 1960s, population density in Marchawar was lower than that in Uttar Pradesh, where administrative attention to farming, communication, and trade and revenue collection was better than in Marchawar. The area does not have migration and resettlement from the hills such as that

characterizing the areas to the immediate north in BLGWP and Butwal. This has a major influence on the social make-up in the irrigation command area and thus on the success or failure of the irrigation scheme.³⁶

System Description

The Marchawar Lift Irrigation System, which was funded by the United Nations' Capital Development Fund (UNCDF), was started in the late 1970s. It was designed to irrigate the area originally planned to be served through the surface water canal, constructed in 1960 with Indian assistance from the barrage near Butwal. As previously noted, a flood washed away the main canal near the headwork of this system the year after it was constructed. After the headwork failed, it was not rebuilt. Later the surface lift pump irrigation system was conceived to supply water to the southern sections. The northeastern sections of Marchawar continue to be without adequate surface water irrigation since the failure of the canal from the Butwal barrage. Farmers there feel that their right to Tinau's water pre-dates the conceptualization of the lift irrigation system.³⁷

Any understanding of the Marchawar Lift Irrigation System (MLIS) is incomplete without some discussion of its history. The region was served by a traditional farmer-managed irrigation system (FMIS) at least as old, if not older, than the Chhattis Mauja System. The traditional irrigation system at Marchawar consisted of a temporary dam at a place called Gurbania on the Tinau River west of Makari village. The dam site is located to the south of the Bhairahawa-Lumbini Highway bridge on the Tinau and the system

Like many other schemes, the Marchawar scheme has evolved through many incarnations.

The earlier feudal order present in Marchawar was able to mobilize thousands of farmers for building temporary weirs and maintaining canals.

consisted of an intricate canal network. One canal from Gurbania followed a southeast alignment to Parsiya, where it bifurcated, with one branch going to Kadmahawa and Mardhawa and the other to Maryadpur, Majhgawa, Hardi and Rohinihawa. A second temporary dam at Harewa was also erected, and a canal from it passed by Hardi to Asuraina village. A drainage called Kathphor *nala* (or Matiyar *nala*) emerged from the Jignihawa *tal*. Tail-water from the two canal systems mentioned above also drained into the *nala*. The drainage channel was dammed near the villages of Nawabi and Thumhawa and used to irrigate lands in the villages of Mahadehi, Semara and Thumhawa.

The local feudal order of Marchawar was able to mobilize thousands of villagers for the tasks of building the temporary dams every irrigation season and of maintaining the old canal system.³⁸ Even though the system was kept operational, the prevailing social formation entailed substantial inequity and violation of human rights, perpetuated by the feudal formation. When the Rana rule in Nepal ended after the British departed from India, the entrenched feudal system in Marchawar began to be challenged.

The aftermath of political changes in 1951 in Nepal also saw a mini revolution against the local feudal order in Marchawar. The late Dr. K. I. Singh, who during the post-Rana interregnum became Nepal's Prime Minister, instigated the local rebellion. Challenging the feudal order led to a deep rupture in the local social formations. Following the "K. I. Singh revolt" it became difficult for the feudal lords of Marchawar to coerce large numbers of people to contribute labour for maintenance without equitable apportioning of

costs and benefits. The interregnum in Marchawar lasted until 1957, when the first general elections in Nepal brought forth a multiparty parliament with an absolute majority of the Nepali Congress. In December 1960, the multiparty system was done away with by a royal decree and the Panchayat System was instituted in 1962.

It is at this juncture of post-democracy and pre-panchayat rule that the Indian Aid Mission, with the concurrence of the Nepal government, conceptualized a surface irrigation system to benefit the command area of Marchawar.³⁹ The barrage of this system is located just south of Butwal on the debris fan of the Tinau River. The water was to be delivered to Marchawar by a canal aligned with the western bank of the river. At Tunihawa near Maryadpur, the canal bifurcates into two branches. One branch was meant to serve the villages of Kadmahawa and Bogadi, the eastern villages, while the other branch was extended to Semara, a village close to the Indian border. Semara is also the tail end of one of the primary canals of the MLIS. The Butwal barrage and its canals were superimposed on the pre-existing canal network built and managed by farmers. As previously noted, the new irrigation system was very short-lived. It had, however, a major destructive impact, because the alignment of the canal and its placement literally carved up the existing irrigation canals at Marchawar. In several places the new canal either blocked the existing system or disturbed the drainage pattern.

As the new system was constructed in the aftermath of the mini-revolution, the changing social dynamics in Marchawar could not challenge the trampling of the existing irrigation arrangement by the Nepali and Indian states.

Because of the destruction of the old social order, the system could not be sustained. At the farmers' level, there did seem to be some effort at restoring the old Gurbania system. A functionary of the MLIS's WUA remembers participating in erecting the Gurbania weir for the last time a few years after the Indian system collapsed.⁴⁰ This led to an overall social and economic decline in the region, which in turn gained notoriety as a dacoit-infested area due to frequent instances of robbery and looting.

The MLIP was intended to support the social and economic development of Marchawar.⁴¹ The project was implemented in two phases: Phase I from 1981 to 1989 and Phase II from 1992 to June 1996.⁴² Both phases were construction dominated. The first phase followed the victory of the then Panchayat system in the national referendum of 1980 over the supporters of multiparty democracy. The second phase started after the Peoples' Movement of 1990, which saw the restoration of multiparty democracy in the country.

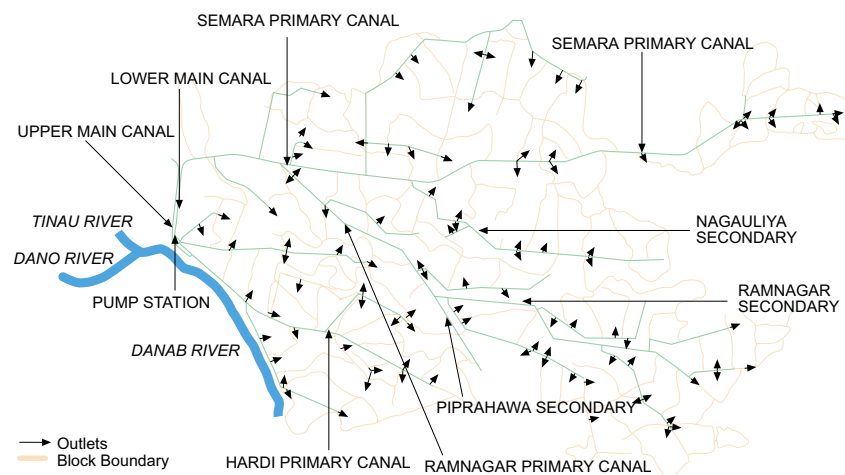
The initial assumption was that the Tinau River had sufficient water to irrigate a command area of 7,200 ha gross, or 5,766 net. The command area of the system has since been revised several times. Irrigation application at MLIP varies greatly between the wet and dry seasons due to the low availability of water from the Tinau. Summer paddy irrigation is restricted to a maximum of 3,600 and winter wheat to 2,200 ha. The system presently provides supplemental irrigation to about 2,815 ha of land,⁴³ which serves a population of some 22,400 people. The layout of the irrigation system is shown in Figure 8.

The pumping system consists of ten pumps manufactured by GANZ-MAVAG of Hungary with motors from Yugoslavia. Six pumps have a low pumping head, referred to as low lift (LL) pumps, while four pumps have a higher head, referred to as high lift (HL) pumps. The pump station lifts water from the river into a sedimentation tank, from where water is supplied into the upper main, lower main and Hardi primary canals.

The upper lift pumps feed the upper main canal, which uses part of the canal from the defunct Butwal barrage. In this section water flows "uphill". The low lift pumps serve the lower canal and Hardi primary systems. The upper and lower canal systems can be operated independently, and water can be diverted from the high level pumps to supplement the low-level system if required. The actual installed capacity is nine pumps with one pump serving as a permanent standby. Of the ten pumps, six have a discharge capacity of 575

Pumped systems for irrigation require a sophisticated capacity for operation and maintenance among farmers and this is often lacking in places such as Marchawar.

Figure 8:
Marchawar irrigation system layout.



litres/second and the remaining four have a capacity of 765 litres/second. The electricity supply is from the Integrated Nepal Power System (INPS) in Lumbini.

The length of the main canal of the Marchawar is 3.0 km, that of the primary canal 8.7 km and that of the secondary canals 17.6 km. The irrigation system has approximately 29.1 km of tertiary canals that serve the command area. There are nine sub-canal systems within the network that includes 148 hydraulic structures of various types and sizes to regulate water distribution and to measure discharge. The distribution system is designed on the basis of proportional division using broad-crested weirs to equitably spread water supplies. Approximately 25.7 kilometres of all weather roads have been built.

The irrigation system is divided into 9 sub-systems according to the branch canals (7 lower main, one independent and 1 upper main, but the latter is not yet registered with the main committee). Of the 8 lower main sub-systems, 127 blocks have been developed in order to facilitate water allocation and management at block level as the foundation of the WUA. Each block committee is formed of five representatives of block farmers. Each system is then constituted of five elected members representing block committees, and the main committee is comprised of twelve representatives — eight system committees' chairpersons as ex-office members and four representatives elected by block committee chairpersons. Thus there is a three-tier system structure with 127 assembly members in the WUA. Two general assemblies – Marchawar *shabha* – are designed to take place before starting the winter and summer crop cultivation each year.

Institutions at Work

The first phase of the project started as a major activity of the Department of Irrigation, which implemented it by employing a contractor to build the pump house, the sedimentation tank and part of the canal system. In the second phase, after the political changes of 1990, the Department of Irrigation employed expatriate and Nepali consultants to construct the distributary and tertiary canal networks and their support facilities.⁴⁴ The joint implementation and management arrangement with the private sector was an interesting feature incorporated into the organization of the project. It was during this period that HMG introduced its new irrigation policy, under which the management of MLIS was formally handed over to the Water Users' Association in early 1998.

The pump house and the sedimentation tank remain under the full ownership and management of the Department of Irrigation. The rest of the system is managed and used, but not owned, by the water users' group. Operation and maintenance of the pump house is contracted out to a private workshop, Nepal Hydro and Electric (NHE) of Butwal, whose responsibilities are limited to the pump house, machines and equipment. Cleaning the intake of silt deposits is the responsibility of the Water Users' Association, while 90% of electricity costs are borne by the department.⁴⁵

Key Issues

- The management and operation of the pump irrigation scheme is a highly skilled exercise, more sophisticated than is within the current capability

Management of the MLIS by a combination of actors (WUA, the DOI and the NHE) is still contested and their role need to be harmonized within a new framework.

of Nepal's farmers or the rules and management styles of its official agencies. As a result there are substantial technical and institutional problems in routine maintenance and operation of the irrigation system.

- The farmers cannot maintain the machinery themselves and have to depend on skilled personnel to do the job. In Marchawar the responsibility for technical aspects has been contracted out to an outside party, the NHE of Butwal, which has successfully experimented with casting spare parts of pumps and replacing them. This arrangement seems to work successfully but its sustainability needs to be explored because farmers, currently need subsidies to meet operational costs and the Department of Irrigation does not have strong capability in mechanical engineering.

- The issue of cost opens up the question of irrigation water tariff. The monthly electricity charge for pumping can be as high as Rs 300,000/month, but the annual water charge of Rs 6/*kattha*/year only brings in Rs 119,000, equivalent to a monthly income of about Rs 9,000 if all of the water cess is raised. Given the difference, substantial increases will be required before farmers will be paying anything approaching the cost of pumping water.

- The irrigation system is dependent on the availability of water in the Tinau at the pump station. Since this is insufficient, substantial portions of the command area cannot be supplied. Additional water from a different source would increase the overall viability of the operation. One possibility is to establish deep wells near tail ends of canals, as well as in the upper section of

Marchawar not served by MLIS that could use the still existing Gurbania canal network.

- Like all surface irrigation schemes, Marchawar also reveals differences in the availability of water and services to the head-reaches compared to what is available to tail-enders. Disputes regarding prior rights both within the Marchawar system and between MLIS and upstream users, such as Sorha-Chhattis and Khadwa-Motipur systems, may become major issues in the years ahead.

- Water Users' Association needs institutional strengthening. At present, the WUA lacks many of the capacities necessary to manage a technically and economically complicated system such as Marchawar. The handover by the government and donors was sudden and was not preceded by adequate preparation of the WUA.

Case Study IX: Groundwater

Background

The region's groundwater aquifers generally begin in the tail region of the Sorha, Chhattis and Chaar Tapaha irrigation systems. There are four categories of groundwater users in the region: deep tubewells such as those constructed under the BLGWP and ILC at Marchawar, shallow tubewells installed by farmers with support from the government and development banks, private diesel pumps, and handpumps, rower pumps as well as treadle pumps. Following the widespread use of shallow tubewells in the 1980s, the third and the fourth categories of uses have recently spread in shallow groundwater areas with the deepening of market penetration.

Increasing the water tariff is essential in order to cover costs but this represents a major challenge for the WUA at Marchawar.

Bhairahawa Lumbini Ground Water Project

The Bhairahawa Lumbini Ground Water Project (BLGWP) operates under the Ground Water Development Board of HMG/N. The project was executed in three phases; the first phase from 1976-1983, the second from 1984-1991 and the third from 1991 ending in 1999.

BLGWP was implemented using a "government provides all" approach.

In the mid-1970s, the Department of Irrigation started to install pumps to tap deep aquifers and improve the reliability of the water supply for irrigation. The World Bank funded the project. By 1999, when the third phase is expected to end, the project will have installed a total of 181 electrically powered deep tubewells with vertical turbine pumps. The command of a deep tubewell averages around 120 ha and meets the needs of 80 families. Units are independent and are expected to discharge 300 m³/hour. In total, the pump systems installed under the project are expected to provide irrigation to about 20,880 ha of land⁴⁶ and to benefit 17,690 farm families. In addition to installing the wells and pumps, the project also provides basic infrastructure, including canal networks, gravel roads and 11 kV transmission lines, as well as extension services, to farmers.

In the initial stages aid agencies covered almost all the construction and operating costs. Given the technology involved and the density of field coverage, costs are high. There have been implementation problems with both the technology and the institutional design. Beneficiaries are now required to increase their contribution. They have to provide land for the PVC pipes and free labour as well as to meet pumping costs. Wells are at

different stages of development and some are being turned over to farmers' group for operation. Overall the project is considered to be successful, even though the area actually irrigated – 14,809 ha – is less than that expected to be irrigated. Availability of irrigation services has increased cropping intensity from 118% in the first phase to 196%. There has been crop diversification and production has increased three fold.⁴⁷

Institutions at Work

The project is in transition from a supply to a demand driven mode. Also there is an increasing tendency for private rather than public investment and expenditure. The objectives are to reduce operation and maintenance costs and to transfer the tubewell systems to beneficiaries for operation and maintenance. Though some published studies indicate annual operations and maintenance costs may be as low as Rs 430, these are acknowledged to be generally higher in practice .

Cost recovery has been set at a limit that is politically acceptable. Originally, in Phase I, beneficiaries were asked to pay either a flat charge of Rs 200 to Rs 400 per ha or the cost of a pump operator's salary and electricity. The flat rate system also resulted in excessive pumping and wasteful application of water, and hence high electricity bills. After the political changes of 1990, many did not pay irrigation charges. Since 1993, a new arrangement has been adopted for operation and maintenance where the flat rate water charge has been cancelled, but the electricity cost for pumping is borne by the Water Users' Groups. This system is based on the principle that cost recovery should, at least, include operation and routine maintenance, while accepting that capital

investment is the responsibility of the State. Under the new arrangement, pumping hours are reported to have declined without affecting agricultural productivity, which suggests that water use is more efficient than before. To encourage users to accept the new system of payments, however, the government, in some cases, has had to cut off electricity or actually remove pumpsets. It has been said that only such “crisis” tactics have led beneficiaries to believe that the State would not subsidize them indefinitely.

The final stage of transfer involves giving farmers full responsibility for employing pump operators and for covering maintenance costs. To provide users an incentive to accept this, the systems installed in Phase I are being upgraded with brick-lined, open channel watercourses. PVC pipes are being installed in Phase II. Nonetheless, users are not eager to take over responsibility due to high operation costs. So far, only 93 tubewells have been handed over to users. Of the 64 pumps installed in the first phase farmers did not agree to take over 4 sets, which have, since been closed. Thirty-eight units were installed in the second phase, twenty were handed over, ten are being handed over, and the rest are being rehabilitated. Twelve of the 79 tubewells installed in the third phase have been handed over. In practice, the continued presence of the BLGWP helps provide a guarantee and a subsidy.

In the first two phases of the BLGWP, site selection was done on the basis of engineering considerations alone. Phase I of the project was initiated without farmers’ participation of any sort. Farmers were simply advised that a deep tubewell would be installed in their field. Consequently, unlimited free water was available

to the farmers. In 1989, when the third phase was being planned, the concept of participation was introduced. As a result, elements of farmers’ participation were included in the final part of the second phase to the extent possible, in cases where the deep tubewells had not yet been installed. Phase III of the project is designed based on farmers’ participation and development is expected to be driven by their demand. In many parts of the command areas farmers express dissatisfaction with the high cost of pumping caused by the high tariff as well as with difficulties in operation and maintenance. This makes it difficult to obtain their full participation.

In principle, the new demand-driven approach in the system, which comprises a dense underground network of channels and fine targeting on demand by each user should make operational cost recovery easier than it was with the MLIS. Increases in food production have taken place in some of the BLGWP schemes. However, construction costs are high and indigenous capacity for implementation and maintenance low. Moreover, various operational practices, such as turning tubewells on and off between delivery to different users, shorten pump life. Overall, it is not clear how well the pumps will be sustained after the aid agency leaves the area.

Other Tubewells

Possibilities for irrigation using deep tubewells exist in the area that may be served by the ILC. In Marchawar deep tubewell drilling started in 1998. Four electrically operated pumps have been installed and testing of one is ongoing. They are located in Amuwa, Kudsar, Rudalapur and Kataiya villages.

Shallow tubewells are common within the command area of existing surface irrigation systems.

Shallow tubewells in the Nepal Tarai are mostly owned by individuals with 5 HP pumps and installation costs are subsidized by Nepal's Agricultural Development Bank. According to Gautam and Shrestha (1997), in Rupandehi district 3,777 pumps have been installed with the bank's support. Many other private tubewells have probably also been installed in this section of the Tarai adjacent to the Dano and the Tinau, but the actual numbers are unknown.

Issues facing

BLGWP include:

- *institutional culture,*
- *deep tubewell management,*
- *erratic power supply, and*
- *farmer preferences for shallow tubewells.*

A survey during the field study identified 1,345 shallow tubewells. Of these, 460 tubewells are within the command area of the Marchawar Lift Irrigation System and 345 are in Uttar Pradesh, along the Kuda (Tinau) River between the Nepali border and Naugadh. The rest of the pumps are along the region dependent on the Tinau. Clearly these figures do not represent the actual number of tubewells. Because they are capped, they are difficult to count accurately. Incidentally, because the tail end command of the MLIS receives inadequate water for irrigation, the number of shallow tubewells there is widespread.

Key Issues

- In initiating the BLGWP, the institutional culture was guided by construction and engineering, and it was solipsistic regarding the fact that the region was close to one of the longest functioning irrigation systems in Nepal managed by farmers themselves. Despite their increased interaction with farmers the level of participation by central departments is still quite remote from grassroots concerns.
- Management of deep tubewells requires highly skilled manpower, availability of spare

parts, and cash expenditure. These are often unavailable and there is little use for unskilled local labour.

- Maintenance support is often unavailable and there is competition from Indian pump manufacturers. Users in India get pumps under subsidy and suppliers generally recommend pumps with higher a HP than required. This leads to market distortion in Nepal.
- The farmers think that water from deep tubewells is very expensive compared to that extracted from shallow, diesel-operated wells. It makes no difference to them that the deep tubewell gets water from a much deeper aquifer than do, the diesel pump operated tubewells. Farmers prefer shallow tubewells because of their flexibility and lower cost. The erratic supply of electricity and the frequent damage to parts are often mentioned as major problems while operating deep pumps.
- The efficiency of shallow tubewells is poor. In the lower Tinau region several shallow wells have gone dry, probably due to well interference, poor siting or drilling of wells. All pumps are diesel-operated and, because diesel is often mixed with kerosene, efficiency is lowered further. Most well drillers have received no training; consequently the wells are improperly drilled and poorly maintained.
- Overall, the extent of groundwater irrigation using shallow tubewells in the lower Tarai in Nepal is unknown, but clearly large. This could have significant implications for the willingness of farmers to participate in other, often more complex, schemes such as the MLIS or deep tubewell installations.

Case Study X: Kuda, the Tinau in India

Background

The Danab (Tinau) river is called Kuda after it enters Uttar Pradesh in India at Ramnagar until it joins the West Rapti River at Bedgaun, near Uska Bazaar of Gorakhpur Janapad about 30 km downstream of the Indo-Nepal border. Before the river joins the Rapti, it is fed by a number of smaller tributaries, including the Tellaar, Jamuar, Bilar and Ghangi.

System Description

Though use of groundwater is widespread, the water use systems along the Kuda River are not as well defined as those in the upstream region. The river is used for drinking, as well as for local lift irrigation. There are no flow records of these stretches of the river, but good low season flow is present, due to seepage. The major intervention by the State in water management along the Kuda consists of ineffective embankments for flood control.⁴⁸

The embankment system is highly disjointed. In some sections there are partial or parallel embankments on the same side of the river, which have been constructed by different politicians or Members of the Legislative Assembly (MLAs). During the monsoon season and heavy rains, the space between the embankments turns into a watercourse and villages are isolated. Since the embankments do not allow floodwaters to recede, village lands are waterlogged for as much as nine months of the year. A single crops can be grown only for the short duration of

the dry season in land that often used to grow three crops.

The lower Tarai region also contains a number of water bodies and lakes. They are formed on sections left by the meandering rivers. These lakes are home to birds and other aquatic fauna.

Through external (Dutch) assistance, a cluster tubewells development programme has been initiated along the Kuda. Development of the pump system has, however, been unsuccessful primarily because of the poor supply of electricity. Scarcity of drinking water is said to be critical in the upstream reaches of the Kuda River along the Indo-Nepal border although individual shallow pumps and handpumps are common.

Key Issues

- The key water issues along the river Kuda in India are flooding, waterlogging and groundwater use. The region, however, falls in the deep marginalized hinterlands of Uttar Pradesh where there is little accountable presence of the state.
- Transboundary water allocation could be a major issue in the years ahead if development affects flow on either side of the border.
- Lack of information and scientific understanding of water management systems is a particular concern in this region. Since the rivers change names – it may have different names along its length – and flows are not measured, there is little basis for evaluating water management options. Given large-scale flooding and waterlogging along with drinking and irrigation water scarcity, water management is clearly the emerging challenge.

The highly disjointed embankment system along the Kuda compounds the issues related to flooding and waterlogging.

- While flooding is a major concern in the region, embankments may have brought little benefits to the people. During the monsoon months when river stages are high embankments

serve as a place of respite, but these structures have led to large-scale land and agricultural degradation through waterlogging and drainage congestion.

Key Insights and Conclusions

Water resource systems are interdependent but management responses are generally fragmented.

The case of the Tinau River is that of an interdependent physical system, in which water management responses have evolved in a fragmented and independent manner. Interdependence is caused by a combination of hydro-geological, historical and social factors, and linkages in terms of the actual relationships and their implications remain poorly understood. These linkages are becoming important as the scale of water use and economic development grows. In some cases, specific constraints such as water scarcity and pollution in the dry season and flooding during the monsoon are causing clear stresses. That the system is naturally interdependent implies institutional overlaps both horizontal and vertical. A schematic diagram and chart of the inter-relationship between physical interdependence, technological choice, and water management systems is shown in Figure 9.

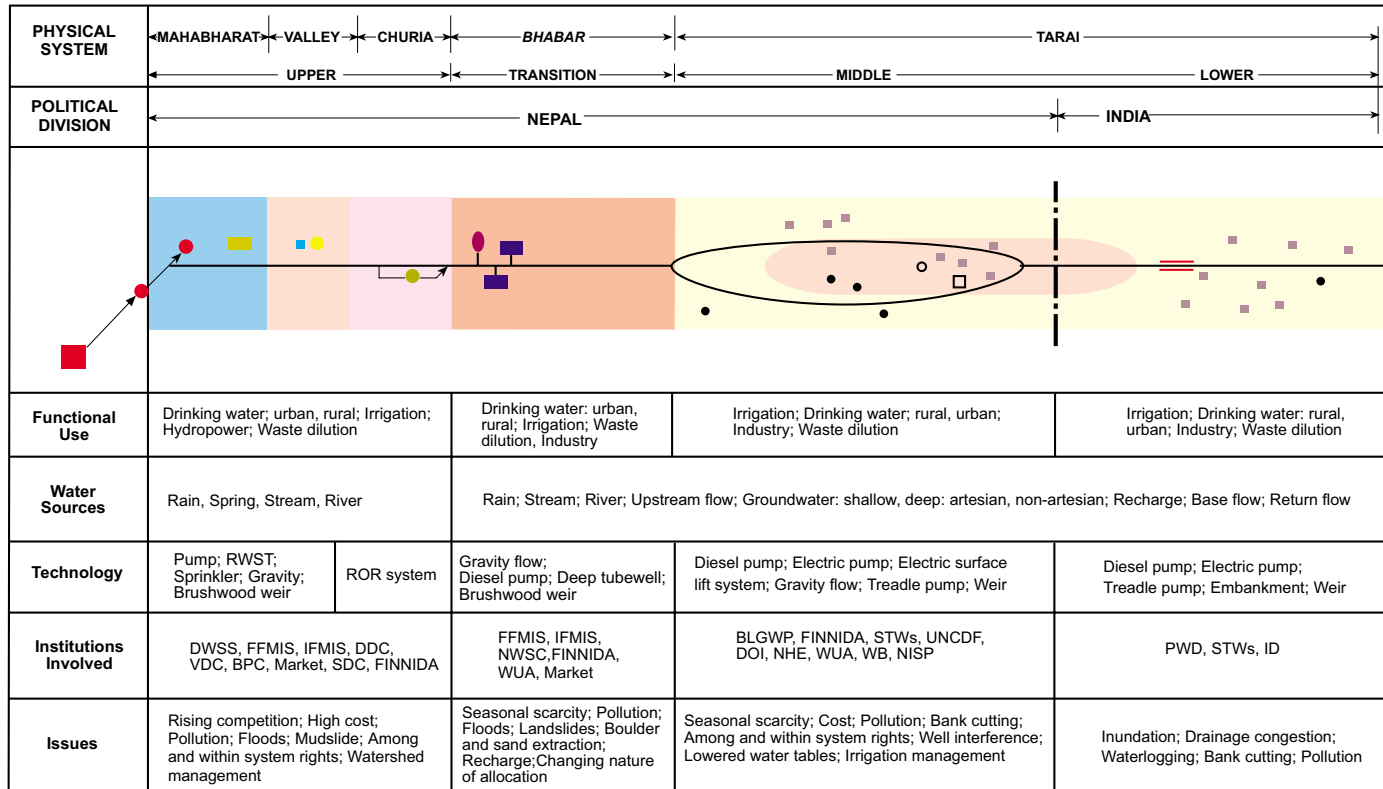
The story of system interdependency in the Tinau starts in situations where local water use patterns evolve in directions that ignore both upstream dependencies and downstream effects. It is not a new story, but it acquires increasing importance as the scale of human action significantly alters hydro-ecologic dynamics.

The core issue in the Tinau River is that fragmented institutions which oversee a complex

and interdependent system lead to counterproductive management interventions that should, with the benefit of hindsight, have been avoidable. Throughout the Tinau, water management is practiced as a dominantly household or very local activity. In the lower sections of the basin in India, embankments are constructed to protect specific areas from flooding with little thought given to the consequences of embankments for other areas not similarly protected or to how flooding might be mitigated by upstream management. Similarly, in upstream areas, diversions are created and waste returned to the stream with little thought of downstream users. As industrial development and urban living accelerates in the Nepal Tarai and in urban hill centres such as Tansen or Madan Pokhara, the consequences of waste disposal for water quality and use may be particularly significant.

Conceptually, water resource and use characteristics along different sections of the Tinau are interlinked. Water diversions and the development of complex hill irrigation systems have influenced flow dynamics throughout the upper basin, and may also have had an impact on the lower region. The dynamic, mobile character of the river channel, where the stream exits the hills, constrains possibilities for the development of permanent diversions for irrigation

Figure 9:
Sources, water management systems, technology, institutions and interdependence along a schematic transect of the Tinau River



Notes: - DWSS – Department of Water Supply and Sewerage; BPC – Butwal Power Company; DDC – District Development Committee; VDC – Village Development Committee; BLGWP – Bhairahawa Lumbini Ground Water Project, DoI – Department of Irrigation; WUA – Water Users’ Association; NHE – National Hydro Electric; UNCDF – United Nation Capital Development Fund; ID – Irrigation Department; WB – World Bank; SDC – Swiss Development Corporation; STW – Shallow tubewell; FINNIDA – Finnish International Development Assistance, NWSC – Nepal Water Supply Corporation, NISP – National Irrigation Support Programme, RWST – Rain Water Storage Tank, FFMIS – Formal Farmer-managed Irrigation System, IFMIS – Informal Farmer-managed Irrigation System

- Tansen water system, ■ Farmer-managed system, Madi *phaant* ■ Sprinkler, ● Rainwater tanks, ● Hydropower, ● Butwal drinking water, ■ Sorha-chhattis and Chaar Tapaha
- Deep tubewell, ■ Shallow tubewell, ○ Khadwa-Motipur, □ MLIS, — Embankments

As the scale of human interventions grows, the management of interdependent systems will become the single most important challenge facing the region.

uses. Return flows from municipal and other uses influence downstream water quality. Widespread development of groundwater through shallow wells by private farmers influences the large-scale surface and groundwater development initiatives by the government, necessitating serious considerations of conjunctive use. Embankments created in one area exacerbate flooding problems in other areas. These sweeping types of interactions are relatively easy to conceptualize. There is, however, no data for quantifying them and worse, no functioning institutional arrangements in place, which would provide proper overseeing of these matters as the scale of interventions grows. Interdependency and how to address it is the single most important challenge facing water management in the region.

From Interdependence to Action, Key Concepts Emerging from Case Studies

Recognition of system interdependence is important, but the evolution of practical management responses requires conceptual approaches that enable portions of the larger equation to be addressed as needed. From this perspective, the management situation found in the Tinau basin is highly fractured. In most areas studied as part of this research, resource development or management activities have been initiated with little conception of the larger system into which they fit. As a result, major problems regularly emerge due to unanticipated interactions. Collection of the data required to fully characterize the systems would be a major time-consuming and expensive process – one unlikely to be undertaken rapidly even in the medium watersheds of South Asia. Focusing on key constraints within a larger

qualitative conceptualization of the system would allow the development of more appropriate management responses and the progressive refinement of systemic understanding. In the Tinau, the insights on local water management obtained from this exercise are as follows:

The Mosaic Nature of Sub-Systems and Institutions

The Tinau river system can be viewed as a mosaic of smaller systems and institutions – all of which interact with other systems and are partially, but not fully, interdependent. Many management issues are dominantly local (that is, bounded within a given sub-system); others involve interactions at higher system levels or among sub-systems. The distinction between management “within” and “among” sub-systems is critical. Cost recovery and maintenance of a drinking water or irrigation system is a “within” sub-system issue – although it may be affected by external factors such as the cost of alternative supply sources. Groundwater pumping that affects surface flows and pollution are “among” sub-system issues. The “within system” issues can be addressed by institutions such as WUAs provided their capacity is strengthened through appropriate training. The “among systems” issues require more elaborate data, dispute resolution mechanisms and levels of organization that extend beyond local groups of users. Institutions capable of addressing these “among system” issues currently don’t exist. They will, however, be required as demand for water increases the scale of interventions and the impact of uses within sub-systems extends beyond individual sub-system boundaries. This is, for example, likely to be a factor if

groundwater extraction begins to affect regional water levels or as pollution grows.

shallow wells are higher in relation to the volume of water pumped.

The Dynamic Nature of Systems

The natural, institutional and use systems are dynamic, not static, and the changing nature of different components of these systems is not uniform. Surface systems, for example, have high seasonal and interannual variability. Groundwater systems, in contrast, are much more resilient because the stock portion is much greater than the flow. The dynamic nature of institutional and use systems is also important to emphasize – this is where the impact of social change has fundamental implications for traditional institutions, use patterns, and so on.

Many water management approaches are poorly adapted to the dynamic nature of systems. The extreme engineering example of this is the defunct Butwal barrage, which was bypassed in 1962 by the Tinaru when it shifted course. Institutionally, the decline of traditional systems when democratization reduced the ability of the rural elite in Marchawar to mobilize labour represents a similar example. Water management approaches are rarely designed with the dynamic nature of systems as a primary consideration. Efficiency is often a high priority but measures of efficiency rarely reflect the opportunity costs associated with flexibility. This may, for example, be the primary factor causing farmers to prefer shallow tubewells over deep tubewells in parts of the BLGWP and surface irrigation commands. Individuals owning shallow wells have much higher flexibility and ability to meet their own water needs than members served by larger deep wells, even when the operation and other costs of

Adaptation Versus Control

A third concept closely related to the dynamic nature of systems is that of adaptation. Many traditional systems are adapted to variability (that is, brushwood dams were designed for replacement after the monsoon) while modern systems often reflect attempts to control variability. Embankments and the establishment of permanent irrigation structures are primary examples of this. In contrast, the development of elevated surfaces for refuge from floods without attempting to confine rivers to their course would represent a more adaptive approach to flood problems. This would encourage drainage and the deposit of nutrient-rich silts while still enabling a degree of protection for residents against flood. In a similar way, temporary dams (perhaps not brushwood, but ones with an improved design) would allow river channels to change course without major damage to irrigation systems.

Adaptive approaches should not be viewed as being equivalent to “traditional” approaches. Groundwater development, for example, can be seen as an attempt to adapt by shifting dependence to a source with low natural variability as opposed to attempting to control the variability of surface sources such as rivers.

Key Challenges

In addition to the above concepts, the case studies highlight a series of water management challenges emerging throughout the Tinaru basin. The insights may find equal

The dynamic mosaic of management institutions necessitates recognition of the “among” and “within” sub-system issues.

resonance on similar situations faced in the marginal regions along smaller rivers of the Ganga system.

Social, Economic and Technological Transition

The introduction of new technologies is coinciding with major socioeconomic changes in the region. As a result, existing traditional institutions and systems are under stress. The case of Sorha-Chhattis Mauja is typical. The logs and tree branches needed for traditional temporary diversions are becoming difficult to obtain and river dynamics are changing due to continued extraction of boulders and sand from the river bed. The process is becoming complex because river boulders and sand are used by private individuals as well as the local government. Institutions like District Development Committees (DDCs), for example, use income from the sale of boulders as one of their sources of revenue.

As a result, the river water level at the intake is becoming lower than before and, although the committee at Sorha-Chhattis Mauja is able to mobilize the support of all the water users', re-erecting the intake is becoming an increasing constraint. A permanent intake would be expensive and, given river dynamics, faces a high risk of being washed away. Equally important, traditional systems face difficulty mobilizing labour due to the economic, political and social changes currently occurring in the region. Traditional institutions, as a result, need to innovate and to develop the capacity to respond to the new changes. Many (such as the new WUAs), however, lack the roots and social legitimacy to have an

immediate impact and are generally subject to the same social stresses as traditional institution. In addition, most new institutions focus on "within" sub-system issues while some of the most important issues are "among" sub-systems.

Intervention Magnitude and Intersectoral Impacts

The scale of modern interventions is much larger in relation to the stocks and flows within the natural hydrologic system than was the case with traditional water management interventions. The spread of groundwater pumping, for example, has the potential to change basic relationships between surface and groundwater systems. Traditional lift methods didn't. This is also the key difference between a large cement dam and a small brushwood one or the difference between the effluent discharge of villages and that from municipalities and industries.

Because of the eradication of malaria, opening of highways, the migration from the hills and the expansion of industrial activities, the population of the region has seen a steady increase over the past thirty years. This in turn has increased the need for water and has gradually created rising competition among the sectors. Industrial use is gradually rising and urban populations are growing. Irrigation is the dominant water use, with drinking water emerging as the next big competitive demand. As a result, disposal of untreated return flow and increasing downstream pollution are emerging as major regional issues. The situation is serious in the dry months, when the water system is stressed to levels of environmental insult.

Management approaches that respond better to variability are needed.

As the scale of interventions grows, there is an increasing need for fostering the social capability to address “among systems” issues. This is compounded by the overlay of the large-scale external interventions now occurring: water projects cutting across traditional systems, changed incentives for the members to invest in the maintenance of traditional systems, and regional development (markets, urban growth, etc.) all change the nature of use patterns and regional populations. The ability to address “among sub-system” issues is one of the major challenges facing water management systems in the region.

Uncertainty, Variability and Extreme Events

The natural system of the Tinau River basin exhibits uncertainty as a major characteristic. High intensity rainfall, landslides, mudslides, high sedimentation, fluctuations in river flow and bank cutting are all normal events in the basin. These events exacerbate floods, which lead to high loss of lives and property. Much traditional water management occurs in response to this uncertainty, and shows some ability to cope with the disruptions that these events bring. In contrast, many of the more recent interventions have increased the risks, and face greater susceptibility to bank caving. It is important to recognize that while the surface system is highly variable, the groundwater system is far less so. A key challenge is to reduce the risks associated with the high variability of the surface system (floods and droughts) without either reducing the benefits from that variability (groundwater recharge or sediment dispersal) or creating new problems.

Poorly Understood Systems and System Linkages

The Tinau system as a whole is poorly understood and no institutions exist that have an overall perspective or responsibility for it. As a result, management has focused on subsystems with little recognition of emerging “among systems” issues. Lack of information and understanding is likely to increasingly constrain the evolution of management options as “among systems” impacts and tensions increase. Improved understanding is central to identify the key points where systemic stresses are being faced. While data is important, it is, however, often unavailable. Thus something must be done even without detailed information on the resource dynamics throughout the basin. The starting point is to outline, at least conceptually, the inter-linked nature of water resource dynamics and use in the basin and then focus on key constraints – in this case probably flooding and rising competition in the dry season accompanied by water quality concerns. Limited sets of data can then be collected to address constraints, while the more complete understanding of the basin required for water resource monitoring to produce more reliable result is gradually developed over the decades.

One question that needs to be explored further is: what constitutes a basin? Though an attempt has been made to analyse the Tinau as a basin, the variable character of the resource in the hills and the Tarai, the role of return flows and the impact on surface water and groundwater need to be appreciated to understand how responses are made and how systems have become stressed in recent times. In the case of the Tinau, it is logical to consider its hilly region as a unit.

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The roles of local and national level organizations in water management need to be re-focused.

However, because the southern lower portion of the basin constitutes part of different contiguous formations, (*bhabar* and the Tarai, for example) it may be more logical to treat this portion as overlapping and thus with very different stress characteristics. These distinctions needs further conceptualization and research, especially where the concept of basin approach is considered central for the management of a river system as large as the Ganga basin. The insight of this study is that physical, social, and institutional complexity grows more marked as the scale becomes larger.

Potential Responses

Re-focus the Roles of State and Local Level Institutions

In Nepal, state institutions involved in water management have a long history of intense preoccupation with projects and the actual implementation of irrigation or other water related activities. This focus encourages state agencies to concentrate on sub-systems rather than on larger issues of water management at the scale of a basin or a region. In many ways, this focus conflicts with the increasing need for institutions capable of addressing “among-systems” issues. Rather than the details of management at very local levels, more attention needs to be devoted to “governance” and the larger, long-term regional vision. Local level problems need a locally rooted capacity to solve them.

Such an approach is intrinsically tied to the long running debate on decentralization being conducted both in Nepal and India. If

local units of governance such as municipalities and district or village units (VDCs in Nepal and *panchayati raj* institutions in India) were more empowered to manage the resources within their locales, immediate concerns could be better addressed. In this situation, local units could concern themselves with the conceptualization of meaningful projects, while higher units such as departments and ministries at the centre could focus on issues of governance, regulation and adjudication of disputes. Currently the situation is reversed: the central government focuses on donor-funded projects, while the local people their representatives and local government are left to adjust to and ameliorate the unintended aftermath of these projects, which tend to demonstrate top-down characteristics.

State and National Level Roles In Water Management

What might be the practical role of state and national level institutions in a reformed water sector? Institutional arrangements are needed to understand and resolve potential disputes between sub-systems as they emerge. They could include:

1. **Information/understanding/auditing:** A larger systemic perspective is required in order to identify when major changes within sub-systems are likely to have major impacts on other sub-systems. Institutions need to have the overall conceptual understanding of the systemic linkages among the various management options and the ability to guide the development of the information base essential for more detailed understanding. Enhanced local capacity should provide independent auditing of water management options.

2. **Arbitration/dispute resolution capabilities:** Institutions capable of arbitrating disputes among sub-systems (effect of urban or industrial pollution on agricultural users) are needed.

3. **Enforcement:** Institutions that are capable of enforcing management decision are needed as “among system” issues evolve into major disputes.

Decentralized Management for Sub-systems

Many management challenges are within sub-systems and can be logically resolved at this level. This is where “local” management initiatives are an increasingly important counterpart (rather than alternative) to the proposed role for state and national level institutions. In some cases, decentralization is already occurring, but it needs to have greater formal recognition and authority. The primary move toward decentralized management by the state has been the array of recent initiatives to turn over completed schemes to farmers’ groups for management and allocation of water. The new Policy on Irrigation (1992) provides a framework for the turnover of surface as well as of groundwater irrigation schemes to users’ groups for operation and arrangement.

Two issues are already emerging as lessons from these initial turnover efforts. First, since the initial choice of technology and design were imposed by external agencies, they

Conclusion

Even though a small river, the physical and social intricacy of water use and management systems in the Tinnau is extraordinary. Several water

rarely reflect local needs or operational considerations. Second, to overcome limitations, intense support for institution building through collective action is necessary. The initiatives of system turnover have to be sensitive to the new forms of stress that are introduced, by such factors as urbanization, education and commoditized labour.

Focus on Adaptive Technologies

Water management option that use surface water sources should respond to the variability by resorting to flexible diversion designs. A good engineer could develop low cost, “temporary” diversions that require less labour and material than the brushwood structures. Much could be learned from the *sayal* (flood irrigation) systems of the Middle East that “peel off” bits of the high flows for irrigation and recharge. But the extreme nature of the peak flood in the Tinnau calls for better adaptation to physical variability. Conjunctive water management could also be useful. One could, for example, develop gravel pits in the *bhabar* away from the stream and use a partial water diversion structure to channel peak flows into them for recharge during the monsoon. If done properly, the resulting deposition of sand could be mined during the dry season. This could reduce normal flood peaks, reduce the mining of the river bed, and increase dry season base flows plus groundwater availability.

management initiatives, some by the state and others by local units of governance or communities themselves, had been taken along its length

Management option need to better respond to variability.

independently of each other. With the intensification of urbanization and market agriculture, the level of water use has increased and is forcing these systems to take interest in the activities of others to ensure survival of their own water use patterns.

With the emergence of stress points within and among systems, the key to meeting future challenges to management in the Tinnau basin lies in effecting operational responses in three different styles – the hierarchic, the individualistic and the egalitarian along a scale that ranges from the capital city to the rural hamlets. While the hierarchic style of management is found at the top with the state agencies as well as at the bottom among larger, and traditional farmer-managed irrigation systems, the issue facing them is that of more effective decentralization, monitoring procedures including project financing and implementation. The top scale state organs like the Department of Irrigation will need to relinquish construction as well as operation and maintenance activities to bodies at the lower scale closer to the farmers. Governments need to focus on developing better governance functions such as adjudication among systems and promotion of scientific studies that help this process.

The individualistic style of management is growing rapidly within the Tinnau, from sprinkler-using vegetable farmers of Madan Pokhara to bullock cart-driven diesel pumps for tubewells in the Tarai. This management style is conducive to market measures and is capable of benefiting from its innovation and efficiency, but is rather notorious for a short-term perspective that is oblivious of environmental or fairness

considerations. It is a style appropriate at the scale of the household or individual farmers that cannot be banned to benefit hierarchic interests but needs to be given space within a framework of adjudicatory regulations, especially if management options are to benefit from its dynamism.

Besides the dualism of bureaucratic socialism and individualistic market liberalism is a third management style of egalitarian voluntarism found from villages to the national capital. In the traditional systems, some of it is found in the smaller farmer-managed irrigation schemes, while in the urban context this is the style adopted by many citizen groups and community-based organizations, including the activist-inclined intelligentsia. Market expansion and state interventions are crowding this style out of the traditional system, a style that owes its existence to failure of the other two styles in considering equity and long-term socio-environmental effects of their actions. It is making a comeback through national and district organizations of village headmen as well as water users' associations.

The systems of water management along the Tinnau have many surprises to cope with. They range from natural events such as droughts, cloudbursts and floods to disruptive interventions by state and municipality projects as well as the market. Pollution, sedimentation and shifting of rivers, local maintenance incapacity, land rights and tenancy conflicts, high cost of electricity and fuel, and many other issues keep cropping up at inopportune times to stress these systems. While decisions have to be made by system managers under conditions of uncertainty and imperfect

Pluralistic approaches allowing forces of entrepreneurial innovations, egalitarian caution and governmental regulation their due institutional participation may avoid many of the pitfalls encountered in the past.

knowledge, the role of cautionary activists serving as social auditors is crucial to ensure that economic and environmental equity issues are placed on the agenda. An egalitarian role needs to be played by research establishments and universities so that scientific analysis can ensure both economic efficiency and social justice.

While a hierarchic response to the emerging stresses may be to declare a “basin-wide authority” to manage water issues of the Tinau, an alternative pluralistic approach that gives space

to all three management styles with varying obligations at varying scales may be a less rigid and more stable arrangement. Allowing forces of entrepreneurial innovation, egalitarian caution and governmental regulation their due institutional participation may avoid the pitfalls of the past and provide more balanced interventions in an increasingly uncertain and stressful future.⁴⁹ The lessons are relevant not just for the Tinau River and water use systems depend on it, but for water management in general.

Cautionary activists should serve as social auditors to ensure that environmental, economic and equity issues are central on the agenda.

Notes

- ¹ For discussions on the complexity of Himalaya-Ganga see Gyawali and Dixit (1994).
- ² The concept of style and scale of management is based on Thompson (1997).
- ³ In 1998 August, after prolonged rainfall, a slope of the highly saturated Churia range came down as a mudslide that affected more than 100 houses in Butwal municipality. Because the local residents saw the incipient slide, they did not stay indoors during the night of the slide. There were, as a result, few deaths. The 1998 monsoon also saw devastating floods in the regions adjoining the Tinau. For details on the devastation see Special Issue of Seminar (1999).
- ⁴ The peak sediment concentration is also estimated to range between 6,000 and 12,000 ppm by Delft (1988).
- ⁵ Uprety (1989).
- ⁶ *Ibid.*
- ⁷ Nippon Koei (1978).
- ⁸ The calculation is based on the assumption that the demand for water is 12,000 m³/year/ha. The details, however, are not available. See Delft (1988)
- ⁹ The outflow calculation is only approximate, as it is based on estimates of gradients and transmissivities, while the overall authenticity and accuracy needs to be revalidated. See Uprety (1989). For a discussion on recharge along the *bhabar* see Duba (1982).
- ¹⁰ The four conventional land categories are (in descending order of quality of land): *abbal*, *doyem*, *sim* and *chahar*.
- ¹¹ The project plaque on a building close to the abandoned barrage at Butwal states that the irrigation command area is 64,000 acres.
- ¹² Information from Tazmul Musalman, Chairman of the Marchawar Water User's Association as well as other elders. The authors walked with the chairman along the remnants of the old canal starting from the "people-built" Gurbania weir.
- ¹³ According to local farmers, they repaired the old dam once, but the social disruption begun by the K. I. Singh revolt of 1951 was supplemented by the physical disruption wrought by the canals from the Butwal barrage. Marchawar degenerated into a "dacoit infested area" for the next two decades. Oral history during the interregnum needs to be explored to document the nature of the social change.
- ¹⁴ Of the 60+ ethnicities and caste groups in Nepal, summarized by Gurung based on the 1991 population census (See Gurung, 1998 and Salter and Gurung, 1996), at least a third of them are found in the Tinau basin. Of these, the traditionally dominant groups are the Bahun (hill brahmin), Chhetri, Magar, Gurung, Newar, and Damai-Kami in the hills, and Tharu, Yadav, Muslim, Kewat and Lodh ethnicities in the Tarai. The linguistic composition of Palpa is Nepali – 63%, Magar – 32%, Newari – 3%, with Gurung, Tharu, Maithili, Rai, Sherpa, Bhojpuri, Awadi, Tamang etc. forming the rest. In Rupandehi the percentage distribution is as follows: Bhojpuri – 43%; Awadhi – 29%; Nepali – 18%; Tharu – 3%; and Newari – 1% (NRA, 1982).
- ¹⁵ Palpa is located on the trade route that links the Indian heartland with Mustang Bhot. The route generally follows the Kali Gandaki River, which originates in Mustang, and is referred to as the Gandaki growth axis.
- ¹⁶ This was during the governership of General Pratap Sumsher. That Palpa was relatively independent even from Kathmandu is seen from the fact that during Nepal's 1950 revolution, which ousted the Rana oligarchy, the Nepali Congress planned to fly late King Tribhuban to Palpa in a helicopter and then to India. See Koirala (1998).

- ¹⁷ According to the census, in 1971, Tansen had a population of 6,434. By 1979 the population had increased to 13,500. According to municipality sources, in 1997 Tansen had a population of 14,289 (Tansen Municipality, 1997).
- ¹⁸ See Nippon Koei (1978).
- ¹⁹ In 1996/1997, operation and maintenance costs were Rs 8.5 million, while revenue was Rs 0.52 million (NESS, 1998).
- ²⁰ This valley floor of the upper Tinau with a total area of 36.36 km² includes the following wards of the VDCs mentioned: Devinagar # 3, 5; Jhadewa # 3, 4, 5; Humin # 2, 3, 4, 5, 6, 7; Chidipani # 3, 7, 6, 8, 9; Rupse # 1, 2, 3, 4, 5, 6, 7, 8, 9; Kaseni # 1, 2. Similarly, the Upper Majhar *khola* with a total area of 25.96 km² includes: Pokharathok # 1, 2, 3, 4, 5, 6, 7, 8, 9; Nayar # 1, 2, 3, 9; Chappani # 1; Chirtung Dhara # 1, 2, 3, 4, 5, 6, 7, 8; and Tansen Municipality #1, 2, 3, 8, 10, 15. The Majhar *khola* occupies an area of 34.09 km² of Madi *phaant* and includes the following: Kaseni # 3, 5, 6, 7, 9; Madan Pokhara # 1, 2, 3, 4, 6, 7, 8, 9, Tansen Municipality # 9, 14; Chirtung Dhara # 9.
- ²¹ Palpa became a part of the Gorkhali empire only in 1806 AD. Sen kings ruled Palpa from the 14th century until the Gorkhali conquest.
- ²² This phenomenon, wherein a landslide temporarily dams a river and then bursts, is known as *bishyari* in Nepali. These landslips occur with depths much greater than the rootzones of trees, and occur even in very well forested slopes. For details on *bishyari* on the Tinau see Sharma (1988).
- ²³ This is a special innovation of the Palpa Development Program that is becoming increasingly popular in the hills of Nepal. It envisages building hill roads in a manner that is different from the conventional practice of using heavy equipment, earth-cutting and dumping down hillslopes. Green roads first begin by opening a narrow track and initiating bioengineering measures, and widening the track over a four-year period allowing slope stabilization through incremental means.
- ²⁴ United Mission Nepal (UMN) is an international federation of Christian missionary groups.
- ²⁵ There are differences in the population figure. According to the publication by Butwal Municipality, the population of the town was 52,201 in 1994 and 44,271 in 1992. (BM, 1997).
- ²⁶ One of the organizations of the UMN was a Norwegian mission, which was able to arrange funding for the Tinau Hydropower Project partly through donations of second-hand electro-mechanical equipment and partly in cash from the Norwegian Agency for Development (NORAD). Some funding also came from His Majesty's Government, Nepal (HMG/N) and as a loan from the Nepal Industrial Development Corporation (NIDC).
- ²⁷ This HMG/N department was the previous form of today's Electricity Development Centre (EDC). This government department, under the Ministry of Water Resources, was merged with the Nepal Electricity Corporation (NEC), a wholly government-owned parastatal, in 1985 to form the Nepal Electricity Authority (NEA). This merger was a precondition of the multilateral lending agencies for their approval of a loan to construct the 69 MW Marsyangdi Hydroelectric Project. Subsequently, in 1995, the staff of the erstwhile Electricity Department, who had had themselves transferred to the Ministry of Water Resources as HMG officers rather than remain employees of a parastatal, were able to bring about a decision effectively resurrecting the Electricity Department under a new name. For a discussion see (Gyawali, 1997).
- ²⁸ In the industrial policy made by HMG between 1972 and 1980, there was a provision wherein the government could nationalize electric power generation and supply. The NIDC management at that time decided to take over the Bagheswari Electric Company (BEC) and eventually hand it over to the NEC. The management of the BEC, which was started by the landed gentry of west Nepal after the land reforms of 1964 made land ownership a risky proposition, was not competent enough to manage the power generation and supply business. There were serious concerns about the technical capability and the managerial skills of the BEC, with respect to providing uninterrupted electricity supply. There were complaints

against the BEC by significant sections of the business community of Nepalgunj, which viewed erratic power supply as a bottleneck for industrialization efforts in and around Nepalgunj. However, the take-over action should not have been pursued as the only appropriate solution: helping the company to acquire technical and managerial skill or, in the worst of cases, allowing other private parties to take it over, would have been better. Taking over a private company and handing it over to a government company was not the best of options, as the track record of the state utility suggests. As hindsight shows, this action did not solve the problem, but covered it up instead. (Personal communication from the then loan officer in the NIDC who dealt with the subject in the mid-1970s).

²⁹ While the Tinau Hydroelectric Project was being constructed, indeed when the second phase had been completed and the third was underway, the World Bank was engaged in putting together a loan for the Kulekhani Hydroelectric Project for HMG. Its “staff appraisal report” acknowledges the existence of BPC, but dismisses it, and the Eastern Electricity Corporation (EEC – subsequently merged by the government into NEC) in one short paragraph; “EEC, established in October 1974, has since taken over two private entities, the Morang Hydro Electric Supply company and the Dharan Electricity Corporation. It is owned up to 25% by NEC and the remainder by HMG. The Butwal Power Company is entirely a private company”. This tacit approval by powerful donors of nationalization is believed to have spurred government officials to discourage private sector involvement in electricity generation. (See World Bank, 1979). Even as late as 1987, when the Arun-3 Hydroelectric Project’s planning and promotion were in full swing, the NEA and the Canadian donors helping it prepare the feasibility report were reluctant to admit the existence of the BPC or of projects such as the Tinau Hydropower Plant. In a crucial study that justified Arun-3, the Tinau Plant is not shown or acknowledged in the system diagram but dismissed as small hydro. See (CIWEC and NEA, 1987).

³⁰ In Nepal, one of the legal provisions for the registration of non-governmental organizations (Nepali or international) is that their assets revert to HMG if they cease to function. The principle at work behind this provision is that such assets have been created as part of a public trust, which is not taxed. Hence, once the entity that is holding that public trust no longer functions, its assets ought to revert to another “public trustee” such as the government. However, in this case both the UMN and the BPC continue to function.

³¹ Mr. Odd Hoftun, the Norwegian electrical engineer of UMN who had the prime responsibility to establish the Tinau Plant, has worked in Nepal for over forty years and was honoured in 1996 by the Society of Electrical Engineers, Nepal, for his achievements. He provided comments on the above text and described the nationalization in the following words over email: “The only reason for handing over Tinau and the Butwal distribution system was the general feeling at that time that power generation and distribution belonged to the public sector. In fact, HMG wanted to nationalize not only the plant, but also the company as such because a private party involved in power generation or distribution was seen as an irregularity and an irritation. It was only after a prolonged fight that we succeeded in keeping BPC afloat as an instrument for possible future cooperation between UMN and HMG. In the case of Andhikhola it was laid down more or less clearly in the project document between UMN and HMG that BPC should own and operate the company in the future. But HMG then demanded that UMN hand over the corresponding shares in BPC. Jhimruk was a different case: BPC built this plant as a contractor for HMG. For practical reasons (tax etc.) NORAD funds were channelled through UMN as equity investment, and UMN maintained a majority shares in BPC during the construction and trial operation period. The project agreement stated clearly that the project on completion should be handed over to HMG by BPC without compensation. This was done, but HMG decided to turn the project back to BPC as equity investment in kind, resulting in HMG getting 97 per cent of the shares in BPC. This was done against strong protests from UMN, who suggested that UMN’s shares should rather be sold to private investors right away, with the proceeds reverting to HMG. In light of the complications involved in the ongoing privatization process, I guess many will now agree that HMG should have listened to this suggestion.”

³² For details also see Yoder (1994) and Stevens and Schiller (1993).

³³ The name of the programme has been changed subsequently to National Irrigation Sector Programme (NISP).

³⁴ See Reidinger and Gautam (1992) and Bhattarai (1994) for discussions on implementation issues related with the procedure and challenges of this method.

³⁵ UNCDF (1995).

- ³⁶ Like most voluntary migrants, the hill people are more open to innovation and aware of modern opportunities beyond their local, traditional, and social orbit than indigenous groups, who tend to be more locked into their culture and history (UNCDF, 1995).
- ³⁷ The farmer-managed system from the Gurbania weir was long in operation when the Indian aided Butwal barrage system was built without acknowledging its existence. The old system enjoyed the same legitimacy as other farmer-managed schemes, such as Khadwa-Motipur and Sorha-Chhattis systems.
- ³⁸ Such irrigation institutions may be referred to as hydraulically despotic, a term used by Karl Wittfogel to describe centralized and authoritarian arrangements that uphold a particular type of hydraulic intervention (Wittfogel, 1957).
- ³⁹ There is no record of how this decision was taken, either with HMG's Irrigation Department or with the Indian Embassy in Kathmandu. Interviews by the authors with old timers, including the Shuklas, hint at the possible hypothesis that it was instigated by the powerful landlords, who saw the permanent dam at Butwal as a means of bypassing the need to mobilize unruly post-democracy masses for the annual dam construction work at Gurbania.
- ⁴⁰ Personal communication with the Chairman of the Marchawar Water Users' Association.
- ⁴¹ According to local history the project had its genesis in the visit to Marchawar by HM the King in 1977. The locals appraised the monarch of the declining social and economic condition and requested an irrigation system. The conceptualization of the Lift Irrigation System followed. It is also argued by some that the MLIS grew out of the political pressure of the local member of the Rastriya Panchayat.
- ⁴² Evaluation in 1987 of Phase I of the project recommended initiating a pilot extension in a smaller area. In 1989 the FAO Project Formulation Mission revised the command area to 5,600 ha for Phase II. Net command areas of 3,685 ha in the lower command area and 1,915 ha in the area to be served by the Upper Link Canal were proposed for development. A subsequent reconfirmation of the decision was made to further constrain the command area to be developed under Phase II of MLIP to 2,815 ha. The detailed historical sequence of events to the present according to UNCDF (1995) is as follows:
- | | | | |
|------|----------|---|--|
| 1989 | November | - | Project Agreement signed for Phase II |
| 1990 | December | - | MoU on Phase II to HMGN MoF |
| 1991 | April | - | Project Documents for Phase II to HMGN for DoI |
| | | - | Pumps from Phase I begin operation |
| 1992 | June | - | Contract for Phase II from UNOPS to Euroconsult |
| | | - | First season's irrigation of Hardi Primary Canal |
| 1993 | | - | Construction begins Phase II: Total 616 ha |
| 1994 | | - | Total 1,351 ha |
| 1995 | July | - | Total 2,015 ha |
| 1996 | | - | Est 2,815 ha |
- ⁴³ *ibid.* Also see Euro Consult (1995).
- ⁴⁴ The private sector was represented by a consortium of East Consult from Nepal, Euroconsult and Delft Hydraulics.
- ⁴⁵ The share borne by the DOI is slated to decrease to 80%, 70% and 60% in the coming years. However, the WUA says it is unable to raise and collect the water fees needed to make this possible, more after the 25% electricity tariff increase of November/December 1999.
- ⁴⁶ The area expected to be irrigated was 7,680 ha (first phase), 4,600 (second phase), and 8,600 ha (third phase). The revised target of the third phase is 9,249 ha, with which the total area expected to irrigated will be 21,529 ha. See Olin (1992) and Tiwari (1997) for discussions on BLGWP.
- ⁴⁷ See DOI (1998).
- ⁴⁸ Activists campaigns describe how politicians promise that if they are elected, they will build embankments and there will be no need to pay land tax, water tax, or electricity charges. *Ibid* Seminar (1999).
- ⁴⁹ See Gyawali and Dixit (1997).

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C H A P T E R

3

**Conflicts over the
Invisible Resource in Tamil Nadu**

Is there a way out?

S. Janakarajan

Supported by K. Sivasubramanian, G. Jothi

Purpose and Objectives

Groundwater scarcity is a major constraint in Tamil Nadu.

This study analyses groundwater conditions in two river basins in Tamil Nadu and constraints to conservation of the resource. The study focuses on competition issues as one of the key factors that local management must address if communities are to develop mechanisms for conserving water and responding to scarcity. The purpose of this paper is to examine the nature and the sources of conflict in groundwater use in Tamil Nadu and their implications for both the

resource base and different sections of the rural and urban population. Constraints to water conservation due to competition emerge both from within village society and from external pressure. They are caused by the division of wells as land ownership becomes fragmented, competitive deepening of wells, unequal access to resources, and groundwater pollution due to the discharge of industrial effluents.

The study is based primarily on official publications, information gathered in 1997 and 1998 during a rapid field survey of villages in the Palar River basin and along four tributaries of the Cauvery River (Map 1), and on previous studies in the state. Structurally, the paper is divided into four parts: The first two sections discuss the conflict that occurs within rural areas and then the conflicts that arise out of the increasing industrial/urban needs for groundwater. The next section outlines institutional and technological responses arising out of the conflicts. Issues are summarized and policy implications are presented in the last section.

Documentation and analysis of groundwater conflicts has generated a number of insights. In particular it has highlighted the extent of scarcity created by competitive deepening of wells and pollution of groundwater via discharge of industrial effluent. While scarcity in the former case is reversible, the damage caused to groundwater and the resulting scarcity conditions caused by pollution are permanent. One of the key issues for further research is to analyse and document both the causes of, and responses to, groundwater scarcity.

Figure 1:
Tamil Nadu basin location map.



Groundwater Conflicts

Conflicts over the use of water have a long history. River courses are not constrained by administrative, ethnic or national boundaries and the impacts of upstream use fall upon downstream populations. As a result, disputes arise between groups and regions. Recently, groundwater has even become a source of conflict. This issue has attracted considerable attention from policy makers in India because surface water sources are approaching full utilizations and groundwater is widely perceived as the last major water resource that can be tapped to meet growing water demands. Tamil Nadu is among the most vulnerable states to water scarcity. While the state has 7 per cent of India's total population and 4 per cent of its land area, it possesses only 3 per cent of its water resources. Of the 1,261 TMC (thousand million cubic feet) of surface water available annually in Tamil Nadu, about 92% is utilized for irrigation, drinking and industrial purposes. Agriculture is by far the largest user, consuming approximately 1,050 TMC for irrigation. The remaining 105 TMC are used for drinking and industrial purposes. Groundwater extraction is also high. Approximately 1.5 million wells extract 425 TMC annually.

Water demand throughout Tamil Nadu has been increasing steadily due to population growth and associated increases in demand for food grains combined with economic expansion. Introduction of the "green revolution" package of agricultural technologies (high yielding crop varieties, chemical fertilizers, pesticides and energized pumping technologies) along with growing urban water demand for both industrial and domestic purposes have had a particular impact on

groundwater. Much of Tamil Nadu is underlain by hard rock formations with little water storage capacity (Figure 3). As in many other hard-rock, low rainfall regions (which constitute most of the arid and semi-arid zones of India), water tables have been receding progressively as a result of unregulated groundwater extraction. In many cases this has also caused the decline of traditional water sources such as tanks and baseflow diversion channels (locally known as springs).

Water demand has increased due to population growth, economic expansion and introduction of green revolution technology.

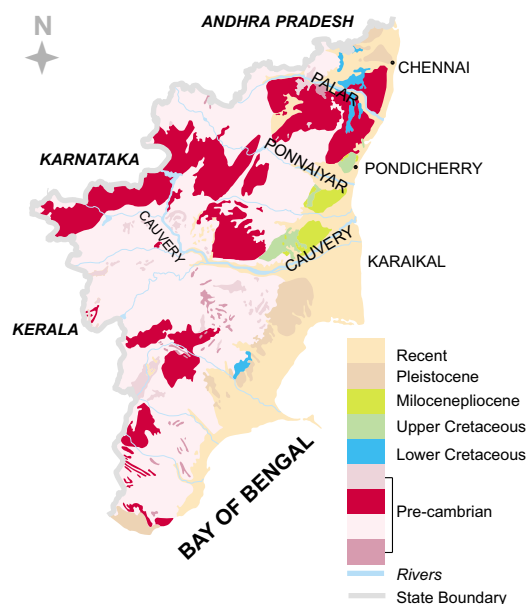
Figure 2:
Administrative map of Tamil Nadu.



Competition and conflicts are emerging between groups of farmers.

As competing demands for groundwater have grown in rural and urban areas, conflicting interests have emerged between these two major sets of users. Competition and conflict are not, however, just an urban-rural phenomenon but are also emerging within rural areas between groups of farmers and the owners of adjacent wells. Competition is a root cause of environmental degradation. Water table and stream flow declines, the drying up of traditional surface water bodies such as tanks and springs, and pollution by industrial effluents of surface water, groundwater and agricultural lands are all related to competition. Beyond competition, these factors have become both direct and indirect sources of conflict.

Figure 3:
Geological map of Tamil Nadu.



Conflicts in the Use of Groundwater Within Rural Areas

In India the right to construct a well and extract groundwater is attached to land ownership. As in the case of any other property, the owner of land with a well has a bundle of rights such as the freedom to enjoy, to sell, exclusivity and transferability. These rights over land and groundwater - the two most important productive resources in agriculture - confer immense power to individuals. The direct consequence is that groundwater is exploited only by landowners. The landless section of the population is excluded from access to groundwater, except where it has been developed for domestic uses through public wells. Even among landowners, access to groundwater depends on hydrologic characteristics (groundwater is not available in all locations). It

also depends on wealth. A landowner must have sufficient financial or other resources to be able to drill or dig a well in order to benefit from groundwater. For this reason, many resource-poor farmers are also excluded from access to groundwater. In addition, exclusion often occurs progressively as water levels decline through a process of competitive well deepening. Groups of well owners continuously deepen their wells in response to deepening by their neighbours, and associated water level declines. Only those who are able to afford the cost of continuous deepening (and the lucky few who strike high-yielding fracture zones that are unaffected by general water level declines) are able to maintain their access to groundwater. Inequality in access to this critical

productive resource, and the progressive exclusion of many farmers in the process of competitive well deepening, is a major source of conflict.

In many ways, conflict over groundwater is the reflection of ambiguous property rights. Landowners have the right to construct a well and extract groundwater – but they don't actually own the water and aren't able to conserve it for future use. The right to groundwater is a right of capture enjoyed by the well owners. The ambiguous nature of property rights has resulted in a number of forms of competition including:

- (a) fragmentation of wells into different shares as land and wells are divided through inheritance and the emerging conflicts between those holding shares in the same well;
- (b) competitive deepening of wells and the emerging conflict between well owners who share a common aquifer;
- (c) trading in groundwater and the emerging conflicts between water seller and water purchaser; and
- (d) unregulated pumping contributing to the drying up of the surface water bodies.

Each of these conflicting interests is discussed in detail below.

Fragmentation of well Ownership

Property rights over groundwater and the operation of the law of inheritance (under which land and wells are shared equally between

brothers) have created a problem of sub-division and fragmentation of wells into many shares along with land. Before entering into a discussion on the issues associated with fragmentation and the resultant joint ownership of wells, it is important to understand the extent to which it is occurring. Virtually no data are available at a macro level to indicate the nature and extent of joint well ownership. However, studies conducted by the author and others in river basins and villages in Tamil Nadu, indicate not only the magnitude, but throw light on the dilemmas and uncertainties associated with the management of joint ownership of wells.

Surveys of well ownership in the Vaigai and Palar river (Figure 4) basins indicate that between 20% and 47% of all wells are jointly owned (Figure 1).¹ A survey of eight villages in the Palar basin undertaken in collaboration with Dr. Barbara Harriss in 1993-94 (unpublished) showed the highest incidence of joint well ownership. In that survey the number of shares (or sub-divisions) in each well for different sections of farmers was determined (Table 1). At least four points are clear from this table:

- (1) Apart from a large number of landless agricultural labourers who are excluded from having any access to groundwater, approximately one-third of the land owners are also excluded from direct access to this precious resource.
- (2) The average number of wells owned in each size class increases at an increasing rate as the landholding size class increases. This indicates that better access to land is associated with better access to groundwater.

Property rights over groundwater and inheritance laws have fragmented well ownership.

Those who don't own land have no direct ability to own wells and therefore to access groundwater.

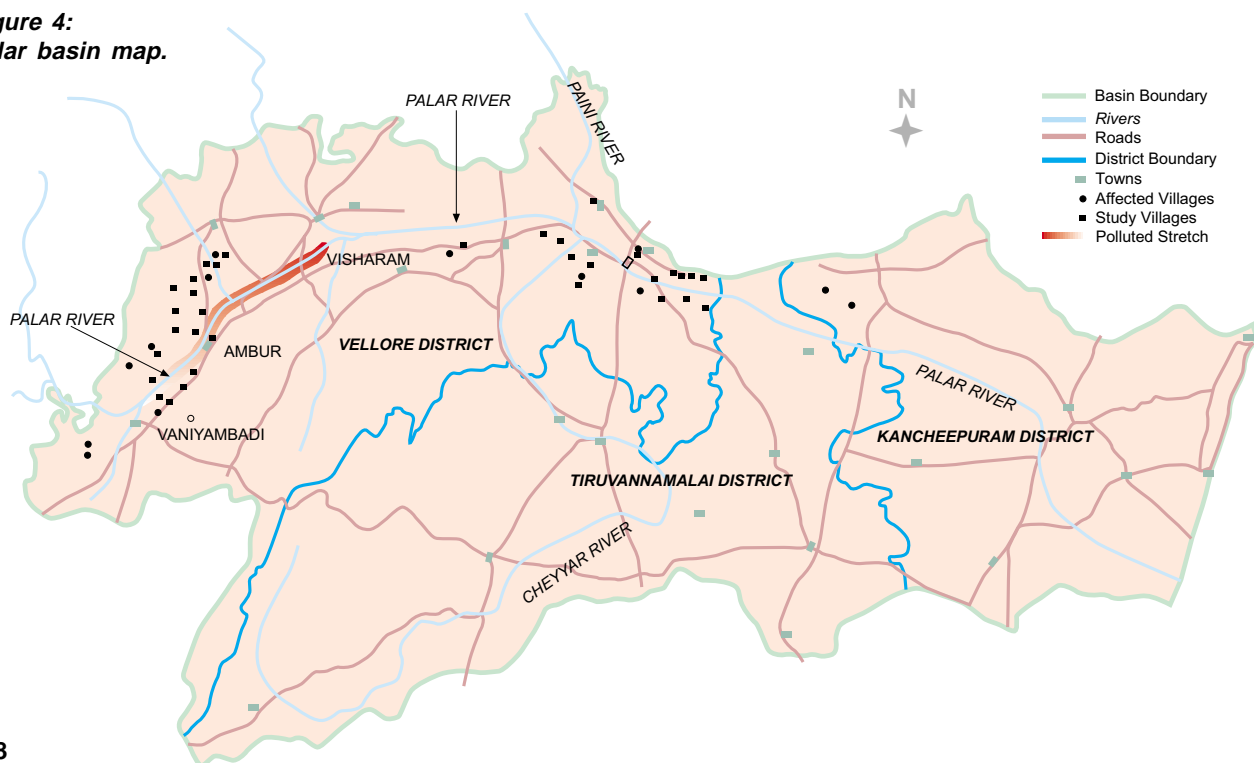
(3) There is a negative association between the landholding size classes and the number of shares in individual wells. In the two largest landholding size classes, there are hardly any shared wells. At the same time, few wells are owned by a single individual in the smaller landholding classes. This reinforces the point made earlier that the larger landowners consolidate their shares in a well, perhaps by purchasing shares from others.

(4) The frequency with which individuals own smaller shares in wells is relatively high in the lower landholding size classes. For instance, all 4 farmers owning less than 10% of a well, 11 out of 16 farmers whose share in a well is 10%, and 21 out of 25 farmers whose share in a well is 17-20% fall in the first three landholding size classes (that is, they own less than 2 acres). These groups often own unmanageably small fractions in wells. As a

result, they are particularly vulnerable to distress or pressure from richer landowners and often sell their well shares along with the land.

Although the management of jointly owned wells has not yet been studied in detail in the course of the current study, interviews conducted in these eight villages indicate that conflict between shareholders in wells is widespread. The practical difficulties involved in allocating water between shareholders are the most important source of conflict. The most common practice of joint well management seems to be to install a single pump set and run the motor in rotation for a fixed number of hours. The cost is shared equally among the shareholders. Problems, however, frequently emerge due to lack of cooperation or non-cooperation among the shareholders in sharing the costs as well as the available water/

Figure 4:
Palar basin map.



power supply. Unlike the case of the disintegration of the traditional tank irrigation communities, which is primarily due to the lack of motivation among the users for various reasons (Janakarajan, 1993), the lack of cooperation in joint well ownership is by and large due to financial constraints or a generally poor resource position. In such cases, those who have “not cooperated” are excluded from the use of a pump set. In addition, even if everyone agrees to share the initial costs of pump set installation, many disputes occur in the use and sharing of water due to the erratic power supply. These disputes are often settled by the village panchayats (informal village courts), but are not sustainable as they crop up again in the next period of scarcity.

Aside from rotation of available pumping time, another common mechanism for sharing water from a jointly owned well is for each shareholder to install his own pump set (either electric or diesel

operated). This often generates conflict as the available water is rapidly drained. The problem is inflamed when the shareholders install high-powered motors in a competitive manner with a view to extracting more water. The incidence of such disputes appears to be very high when farmers of different castes share a well.



Booster pump in a well: Tamil Nadu

Problems frequently emerge between joint well owners due to water scarcity, power unreliability, and differences over costs.

TABLE 1:
Extent and Share Ownership of Wells Across Size Classes of Farmers in 8 Villages of the Palar Basin

Size Classes (std.acres)	No. of Farmer Households	No. of Farmer Households with Wells	Extent of Share Ownership of Wells														Total No. of Wells in the Size Class		
			<.1	.10	.17	.20	.25	.33	.50	.67	.80	1.0	2.0	3.0	4.0	5.0		6.0	
<0.50	230	70	160	0	4	10	6	14	6	10	1	0	21	0	0	0	0	0	35.6
0.51-1.00	211	109	102	3	5	5	10	15	26	21	1	0	24	0	0	0	0	0	51.2
1.01-2.00	270	214	56	1	2	6	5	24	39	57	2	0	91	0	1	0	0	0	145.0
2.01-4.00	276	247	29	0	4	2	1	18	32	77	3	0	144	9	0	0	0	0	218.5
4.01-6.00	134	128	6	0	1	0	2	8	23	42	2	0	67	13	1	0	0	0	128.5
6.01-10.00	88	85	3	0	0	0	1	5	3	12	1	0	46	27	1	0	0	0	112.1
10.01-15.00	17	16	1	0	0	2	0	2	1	5	1	0	2	7	3	0	0	0	29.3
15.01-25.00	15	15	0	0	0	0	0	0	0	0	0	1	1	6	2	4	1	1	46.8
25.00+	4	4	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	1	14.0
Total	1245	888	357	4	16	25	25	86	130	224	11	1	396	63	10	4	1	2	780.8

Source: Survey conducted by the present author and Barbara Harriss - White in Tiruvannamalai and Vellore Districts (previously North Arcot District) in 1993-94.

Fragmentation of wells increases socioeconomic differentials by excluding resource poor farmers.

In many of these cases, the more resource rich shareholders purchase the shares of the less advantaged. This situation came to light in interviews carried out in Vengodu, Mappathurai and Sirungattur villages in 1993/94 of the former North Arcot district. In one case a single farmer who shared a well with 15 others bought up all the shares along with the land (Vengodu village). A large farmer in Sirungattur village adopted a similar strategy.

In many cases, when shareholders have different land holding status, individuals feel that benefits from deepening will go to the others and flatly refuse to cooperate. Conflicts in this environment are common and are referred to the village panchayats. One of the most common solutions extended by the village panchayats is to physically divide the disputed wells into as many shares as needed. This leaves the individuals concerned free to dig and deepen their delineated shares as they see fit. Such physically fragmented wells are common in all the villages surveyed. Although this is the widely adopted solution, it encourages competitive deepening even within individual wells. It also frequently results in individuals drilling borewells within their portions of the larger dug well. In such cases, shareholders whose resource position is weak rapidly find it difficult to survive. Eventually, the well tends to be dominated by the shareholder who has the best access to financial and other resources. The position of the resource poor farmers becomes especially vulnerable as they are excluded from the use of a well. In some cases, however, wells are completely abandoned due to the prevalence of too many shareholders. In this situation there may be too many disputes for any

solution to be effective. A typical shared well is shown in Figure 5.

Partition of wells between shareholders has important implications. It aggravates the precariousness of crop production (as many farmers have to share wells, with limited water supply). It inflames the problem of an already retreating water table due to competitive extraction as well as competitive deepening within individual wells. The most important implication, however, is that it increases socioeconomic differentiation by excluding resource poor farmers from the use of jointly owned wells and access to groundwater.

Conflict between well owners

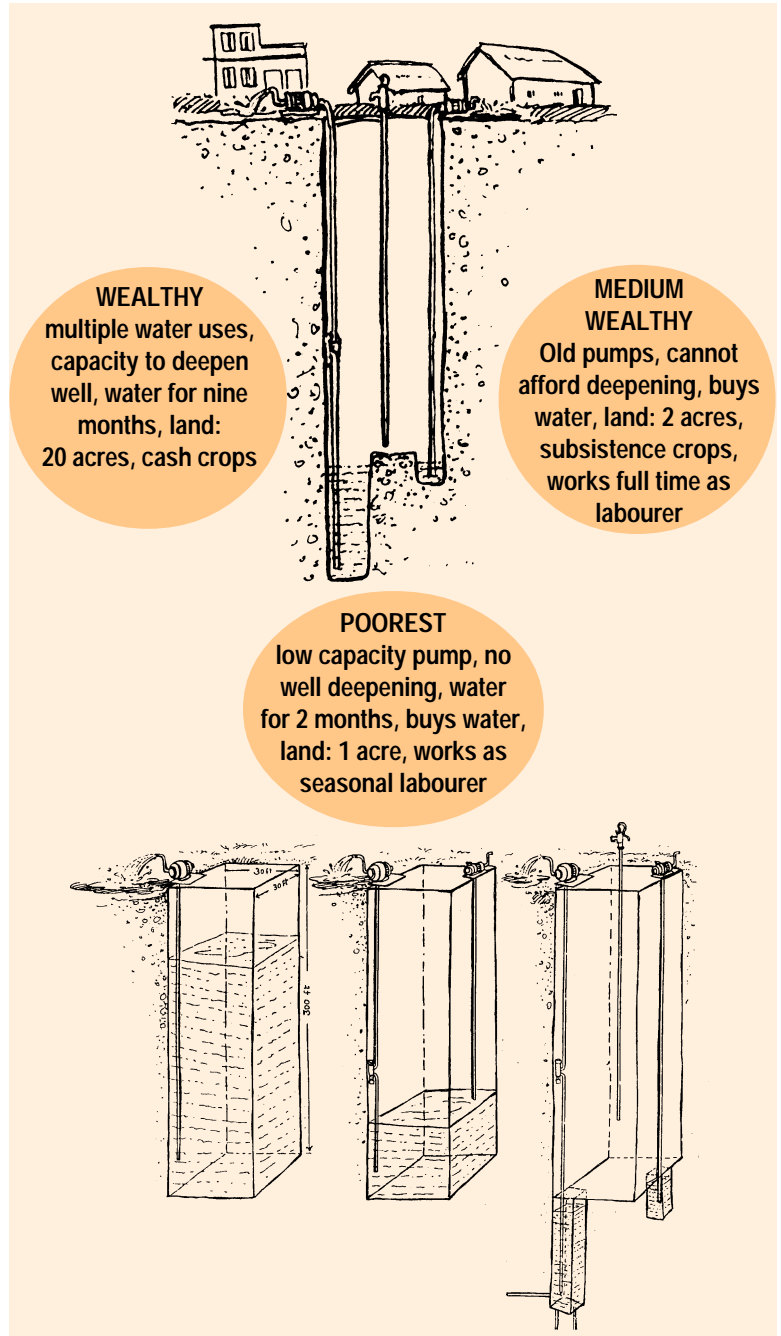
Rapid expansion of groundwater irrigation has resulted in the steady decline of the water table in many parts of India. Pumping rates exceed recharge and have resulted in secular lowering of water tables and the mining of groundwater (see, for instance, Bhatia, 1992, Rao 1993, Moench 1992, Vaidyanathan, 1996, Janakarajan 1997). Conflicting interests among well owners have emerged in this context. To determine the extent conflicts are likely to occur, the level to which the groundwater table has declined over a period of time is evaluated below within selected river basins.

The most appropriate way to evaluate the degree to which the secular lowering of the water table is occurring would be to document the change in the depth of wells, the change in the depth to the water table and the change in the volume of water extracted over a period of time. This information is not, however, available from any published source, nor is it possible to capture

through any survey. Instead, in a study conducted by this author and Vaidyanathan in 1997, an attempt was made to estimate the extent of the decline in the water table in the Vaigai River basin using a different, simple methodology. Two important pieces of information were sought from each sample well owner: (a) What was the depth of the well when it was originally dug? (that is, the “original depth”); and (b) What was the depth of the well at the time of the survey? (that is, the “current depth”). The difference between the “original depth” and the “current depth” for any given well illustrated the extent to which the water table had declined over a period of time. This study indicated that the decline of the water table was especially rapid in the sample wells located outside the canal and tank commands. In addition to this, a crucial finding was that the “original depths” of the sample wells dug at different points of time increased over time, implying that a newcomer has to have a well deeper than his predecessor (Janakarajan and Vaidyanathan, 1997). Case studies carried out in other river basins in Tamil Nadu, and secondary research, indicate that this pattern is widespread across the state.

Declining water levels have several consequences. First, deepening often affects neighbouring wells. The resulting situation is unusual in that an aggrieved party is unlikely to seek justice through the legal system because groundwater rights are ambiguous and indeterminate. There is, as a result, little recourse farmers can take except to deepen their own wells. Second, declining water levels affect the costs of construction of new wells due to the greater depth to which they must be dug. Third, deeper water levels increase pumping costs. This poses a

Figure 5:
Shared well diagram



particularly heavy burden on farmers who are unable to obtain electricity connections (since power is provided free of charge) and on society as a whole since power supply subsidies are supported by the state. Overall, falling water levels create a delicate situation and add tremendously to the costs of current users, while posing a heavy negative externality on future users (Janakarajan and Vaidyanathan, 1997).

Declining water levels:

- *affect neighbouring wells,*
- *increase the cost of new wells, construction*
- *increase pumping costs.*

The social and economic consequences of progressive lowering of the water table are a matter of great concern. Major questions exist regarding the extent to which wells that are dug and deepened in a competitive manner are sustainable, particularly in hard rock regions such as the Palar, Bhavani, Noyyal and Vaigai river basins. The cost of procuring groundwater is an important gauge of sustainability. A study of groundwater irrigation in 27 villages in the Vaigai basin indicated that the amount spent per acre of (net) well irrigated area works out to be much more than what has been spent to create one hectare of surface irrigation potential through major and medium irrigation projects nationally (Janakarajan and Vaidyanathan, 1997). According to the Report of the Eighth Plan, Government of India (1989), the average amount spent to create a hectare of irrigation potential during the Seventh Plan (1985-1990) in India was Rs 32,400. In the Vaigai basin, however, our study results indicate that farmers spent approximately Rs 80,000 per hectare of irrigation potential created from groundwater. This cost estimate would be even higher if such expenses associated with abandoned wells, trial bores and so on were also included in the calculations. All the investments in wells accumulate to pose a heavy burden on the community as a whole

as well as on individual farmers. This is particularly true because many of the investments are in failed wells.

Well irrigation has become a gamble. Not all those who invest in wells are successful. Many fail and lose in the race of competitive deepening. They end up selling their land or become trapped in debt. The direct consequence is the emergence of a new dimension of inequality between those who have been successful in the competitive deepening race and those who have not. The former are emerging as a class of water sellers and the latter are being reduced to the status of water purchasers. This is the subject of the next section.

Conflict between water sellers and purchasers

Groundwater sale in rural areas has come to be a common phenomenon throughout India.² Like joint well ownership, water markets in rural areas have emerged as a spontaneous institution to facilitate sharing of this scarce resource. Water market characteristics and their extent vary between locations depending upon the availability of groundwater, need, custom and conventions.

Exclusion of a majority of the agricultural population from direct access to groundwater for irrigation and the differential access to resources between water sellers and water purchasers are the principal sources of conflict between these two agents. A survey in the Vaigai basin indicated that more than three-fourths of the water purchasers are poor farmers whose landholding size is less than one hectare (Janakarajan and Vaidyanathan, 1997). In this author's study of the Palar basin, the extent of inequality in the distribution of land

across all the sections of farmers (excluding the landless population) was found to be extraordinarily high. In one village, where calculations indicate a Gini coefficient of concentration of 0.88, Gini coefficients calculated separately for the water purchasers and the water sellers, were relatively small – at 0.34 and 0.40 respectively. This indicates that the “between-group” component of inequality (that is, between water sellers and water purchasers) is far greater than the “within-group” component (Janakarajan, 1992). Moreover, most water purchasers belong to the socially deprived castes. Scheduled Castes, the most deprived group in the social hierarchy, constitute 27.3% of the water purchasers (Janakarajan and Vaidyanathan, 1997). This suggests that groups involved in the water deals are sharply polarized socioeconomically as well as and have unequal bargaining capacity.

There are two causes for the emergence of conflict between sellers and purchasers. The first is violation of an informal rule that water purchasers should purchase water only from the nearest well owner. If the concerned well owner agrees, water can also be purchased from the next nearest well owner. This rule is enforced to avoid conflicts that could otherwise arise as water is transported through the field channels belonging to others. Conflicts between water sellers and water purchasers due to the violation of this rule have been documented (Janakarajan, 1992). Even if all those concerned agree, purchasers must generally invest in hose pipes to convey the water to their fields. They are, however, often reluctant to make this purchase since there is no guarantee that a water seller would sell water regularly and investments

in pipes can be expensive for resource poor farmers (Janakarajan and Vaidyanathan, 1997).

Unequal trading relationships are a second cause of conflict. This results in exploitation of the weaker agent through non-competitive pricing for water purchased and through non-price measures. In some cases water sellers require water purchasers to provide free or under-paid labour services. Water purchasers cannot refuse this because the seller could cease to supply water in the middle of a season resulting in the purchaser losing his crop and all the investments he has made in it (Janakarajan, 1992). In the Vaigai basin survey, this author found that payments for water were often made through labour compensation and in several cases through output (grains). In this process, water markets become interlocked with labour, credit and product markets (Janakarajan, 1992 and 1997).³ In some cases, water purchasers are forced to lease their land to water sellers at terms dictated by the latter. This is a case of reverse tenancy in which a lessee is more powerful than a lessor. Such cases have been recorded in the villages surveyed in the Tiruvannamalai district in the Palar River basin (Janakarajan, 1992 and 1996).

Although instances of open conflict between water purchasers and water sellers are sporadic and infrequent, by and large the former are resentful of the latter. This is exacerbated in some villages where water sellers collude in fixing the price for water (Folke, 1996; Janakarajan, 1992). In order to understand the intricacies of conflicts in the water trade, a closer examination through a carefully designed field survey is in progress.

Groups involved in water markets are sharply polarized socially and economical with unequal bargaining capacity.

Conflicts emerging in surface systems due to increased groundwater use

Interaction between surface and groundwater is another important dimension where conflict is emerging. Groundwater pumping in prohibited areas, such as in river beds or their proximity, results in the drying up of surface water bodies and/or reduced downstream flow. This has occurred in the Palar Anicut System, an ancient surface irrigation system in which water from the Palar River is diverted via a weir through a network of unlined channels to 317 irrigation tanks. A survey of 27 of these tanks throughout the system showed that in 22 of them, spring channels (the local term for channels cut to divert subflow from river gravels) had stopped supplying water (Janakarajan, 1993). This suggests that a high portion of all the tanks in this basin are affected. Spring channels originate in the Palar River and are used to supply water for about 6 to 8 months each year. These were historically one of the most important sources of surface irrigation in the region. Now, most are unusable, being either heavily silted or encroached upon by farmers.

Another dimension of the competition between groundwater and surface water use concerns groundwater pumping in tank command areas throughout the state. Large numbers of wells are located in tank command areas. These wells derive most of their water through seepage or groundwater recharge from the tanks. As a result, the tanks are both losing their water and their place as an important source of irrigation (Vaidyanathan and Janakarajan, 1989). Some studies indicate a positive correlation between the

rapid growth of well irrigation and the decay of traditional tank irrigation systems. As the use of wells has increased, tank maintenance has declined. In a 1996 paper Lindberg shows how individual rationality conflicts with collective rationality. This eventually results in the erosion of common property resources. In the case of tanks, individuals rationalize disassociation from the collective maintenance of tanks and canals, because they can rely instead on groundwater. Indiscriminate pumping of groundwater, in turn, results in the progressive lowering of the water table. The problem is not only related to incentives for individual versus collective action. Large-scale rural electrification and the introduction of high yielding varieties have contributed as well. High yielding varieties require more assured, controlled and timely application of water and since the available tank water was inadequate to raise three short duration HYV crops, the growth of well irrigation in the tank command areas became inevitable. The government's policy of supplying free electricity to agriculture has aggravated this problem.

Environmental degradation is a major consequence of the above pattern. Water tables have declined and recharge may be declining as well due to the drying up of the surface water bodies such as tanks. Traditional institutions governing tanks were found to be defunct in 6 out of the 17 tanks studied in the Palar Anicut System. These were also the tank command areas in which well density was quite high. In one of the tanks, the tank sluices were permanently closed to facilitate the recharge of wells located in the tank commands. In other tanks, in which the well density in command areas was very low, the traditional system of irrigation was reasonably

The causes of conflict between water sellers and purchasers include:

- *violation of informal rules,*
- *unequal trading relationships,*
- *cases of reverse tenancy.*

unimpaired (Vaidyanathan and Janakarajan; 1989, Janakarajan, 1993). A similar result was obtained in a large-scale study, undertaken by the Tamil Nadu Agricultural University (Palanisamy, Balasubramanian and Ali, 1996) and several other village studies carried out in Tamil Nadu (Harriss, 1982; Janakarajan, 1986; Nanjamma, 1977; Janakarajan, 1996). The association between increases in well numbers and the decline of tank irrigation systems is not, however, uniform. A study on tanks in the Periyar-Vaigai system shows

that the spread of well irrigation in the tank commands does not lead to a total collapse of the tank institution although its degree of effectiveness does vary, according to well density (Vaidyanathan et.al. 1998). As tank irrigation systems decline, small farmers who do not have access to their own well irrigation are the most affected. This group is often reduced to the status of dependents on big farmers and water sellers for their irrigation needs. The net result is further polarization in an already differentiated society.

*Individual
rationality
conflicts with
the collective
rationality
needed for
water
management.*

Conflicts Arising Out Of Industrial And Urban Water Needs

Conflicts between rural and urban areas over water in Tamil Nadu have surfaced for two main reasons: (a) rapid urbanization and the ever increasing urban water needs for industrial and domestic purposes; and (b) pollution by industries, such as tanneries, textile dyeing units, and chemical industries, when they discharge effluent onto the surrounding land, streams or rivers. These two issues are investigated further in the following pages.

Conflicts due to increasing urban water needs

By most measures, Tamil Nadu is highly urbanized compared to most states in India. It ranks second in overall urbanization and first using a wider composite index calculated by including other important features of urbanization such as town density and degree of urbanization. In many districts, the degree of urbanization is higher than the all India average of 23% (Census

of India, 1981). The process of urbanization has been rapid and coupled with speedy industrialization. Together these factors have created enormous pressure on the provision of basic services in towns and cities, the most important of which is water.

In the last several decades, many industrial and commercial establishments in urban areas have met their water needs by pumping groundwater through their own deep wells or by purchasing it from external suppliers by tanker. Notable among the cities and towns in the state that depend upon the pumping of water from their rural neighbourhood are Chennai, the Coimbatore, Tiruppur, Erode Corridor, Karur and Dindigul (all these cities except Chennai, are in the Cauvery basin, which is shown in Figure 6). The sale of groundwater has become quite extensive in these areas. Although statistical data for these cities and towns is unavailable, it is common knowledge that a

large part of their water needs are met through groundwater pumping in adjacent rural areas.

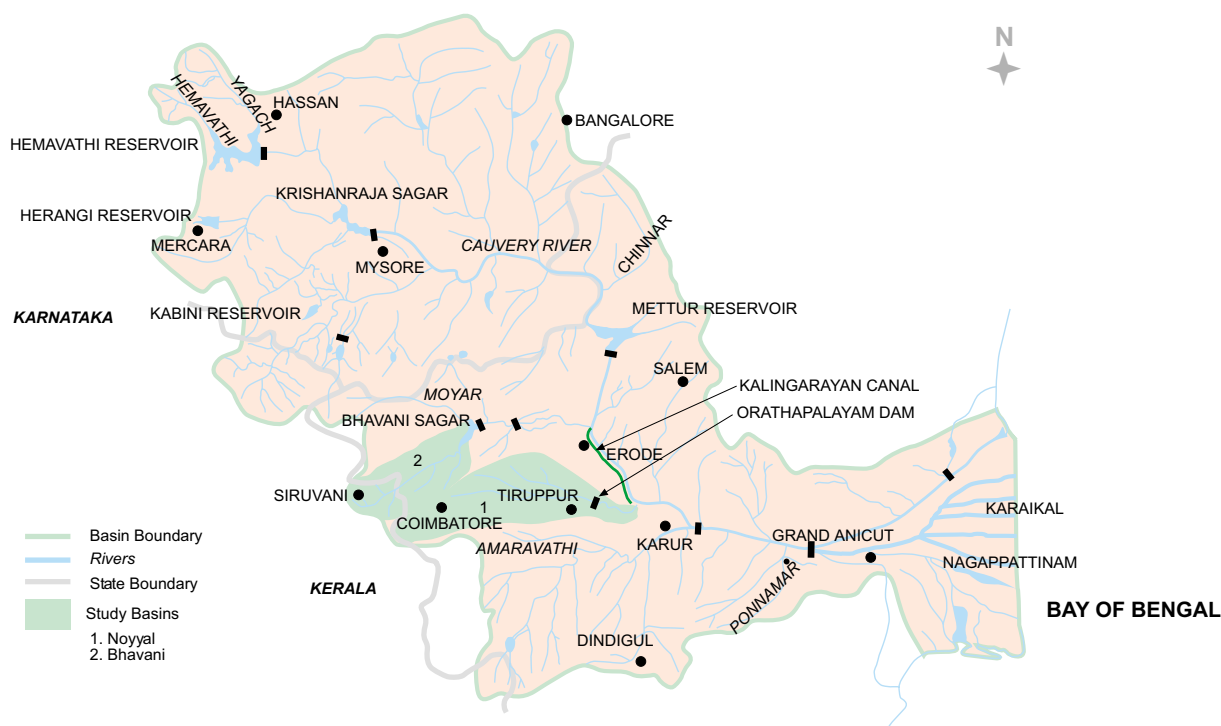
The case of Coimbatore and Erode districts, and particularly the town of Tiruppur in Coimbatore district is illustrative of the situation in the region. Tiruppur has earned a place on the industrial map of the subcontinent as one of the large foreign exchange earners due to a heavy concentration of knitwear industries in the town. There are about 752 dyeing and bleaching units functioning there whose operations depend heavily on high quality water. In the absence of any other source, these units have been transporting groundwater from rural areas by truck-tankers. Out of 93 million litres of water used per day (mld), private water supply alone contributes about 60 mld, or 64%

(Appasamy, 1994). It is transported by truck-tankers from several villages in a radius up to 30 km away. A rough estimate puts the number of truck-tankers which transport water to the town at 900 to 1,000, of which, according to a union leader in Tiruppur, about 90% are owned by the industry owners. While it is not surprising that a large number of farmers have resorted to selling water to the industries at Tiruppur, it is very surprising that the Tamil Nadu Electricity Board has authorized 230 agricultural wells around Tiruppur, Palladam and Avinashi to sell water by issuing them a separate service connection.

In the area around Tiruppur about 30 revenue villages are heavily affected by over-extraction of groundwater.⁵ Farmers report that until the 1980's

Industries bring affluence but their wastes pollute water.

Figure 6:
Cauvery and its tributaries.



water intensive, garden crop cultivation including the cultivation of coconut, banana, tobacco and turmeric was common but that it is no longer practiced in these villages. In the last 10 to 15 years agricultural wells have gone dry and inhabitants now face difficulties in meeting even their drinking water needs.⁶ They believe this is primarily because of the transportation of water from these villages to the town. Industrialists own many deep borewells in the villages. A few are also owned by local farmers, but financed by the industry owners.



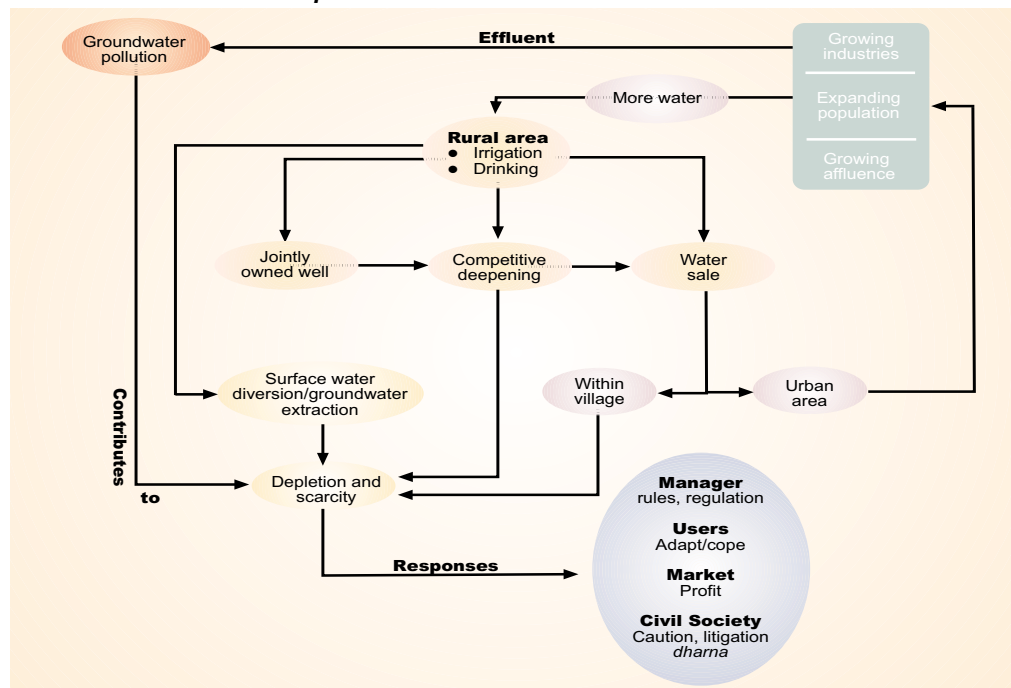
Rural water sale location: Tamil Nadu

When water scarcity problems became severe in the early 1990's, groups of local people started agitating and presented the issue to the revenue authorities. On several occasions in 1997 revenue officials had to mediate between water sellers and farmers. In June of that year an agreement was

signed in front of the Revenue Divisional Officer that no new deep borewells could be sunk and that groundwater could be transported to the town only from a few selected wells. Industry owners, however, are reported to have violated this

Water is pumped from rural areas and sold in urban areas.

Figure 7
Groundwater use and responses.



agreement within a month. Similar agitations and widespread demonstrations by farmers are also reported in many other areas within Coimbatore and Erode districts, especially on the Dharapuram – Tiruppur road, one of the main water transport corridors.⁷ Many women have participated in these agitations – a symptom of the fact that they have had to struggle hard even to get drinking water for their routine household needs.

Emerging water scarcity problems have led to widespread protests.

Extreme scarcity in the town of Palladam resulted in the sale of water even for drinking purposes at Rs 2 to 3 per pot. Most of the wells there are either dried or utilized for the sale of water to Tiruppur. Farmers, individually and collectively, have sent many memoranda to the concerned District Collectors and to ministers, urging them to ban the sale of water from agricultural wells to the towns. Since their petitions haven't yielded results, farmers and women have started detaining water trucks in several villages around this town.

Several farmers organizations have expressed the fear that the widespread sale of groundwater

to urban consumers has caused distress in agriculture. This is seen as causing an increase in rural unemployment, reductions in agricultural yield, large-scale migration from rural to urban areas and a shift towards non-farm employment. Now there is a large-scale shift towards non-farm occupations such as weaving, road construction or small business that seems to be essentially distress induced. These issues need to be examined more closely in the next phase of research.

An important dimension of the competition between rural and urban areas over water has to do with quality. Water transported for domestic and industrial purposes, although volumetrically less than irrigation use, is of high quality. As a result, transport tends to focus on the limited high quality supplies available in many rural areas leaving these rural areas with little or no high quality water for their own uses. Pumping is concentrated in selected villages where water quality is relatively better. As a result, the people living in these villages, particularly farmers, have become more sensitive to the depleting groundwater conditions.



Tankers supplying water to industry: Tamil Nadu

Conflict due to environmental damage

Conflict as a result of the damage to groundwater by industrial pollution is a major concern to the policy makers as well as the general public. A number of large-scale industries (such as tanneries, textile dyeing units, viscose, paper pulp, sugar, sago, oil refineries, fertilizer units and chemical factories) discharge effluent directly onto the surrounding land or into the rivers and streams. Contamination of groundwater has been

reported in parts of the state where tanneries and dyeing and bleaching units are concentrated. These include Pallavaram near Chennai, a stretch of about 100 km in Vellore district (including Visharam, Walaja, Ranipet, Arcot, Vellore, Ambur, Peranampet and Vaniyambadi), Dindigul, Erode and Tiruppur and its surroundings.

As most of these industries are highly water intensive in nature, they are concentrated along the river courses. This is not only to improve their access to water, but also to make use of the rivers for effluent discharge. Several important rivers in the state are very badly affected including:

- The Bhavani River in Coimbatore district, where viscose, rayon, paper pulp, sugar and distilleries pollute both surface and groundwater,
- The Kalingarayan Canal in Erode district, where tanneries and dyeing units pollute this age old canal system and groundwater,
- The Noyyal River in Tiruppur (of Coimbatore district) and the Amaravathi River in Karur District, both of which are heavily polluted by the high concentration of dyeing and bleaching units



Dyeing factory: Tamil Nadu

- The Palar River in Vellore district and the Kodaganar River in Dindigul district, which are both heavily polluted by leather tanning industries.

Aside from the Palar, which is in the northern Tamil Nadu, all the areas mentioned above are located in a contiguous set of sub-basin in the Southern portion of the Cauvery basin. These are highlighted in Figure 6. In the following section, damage caused to these areas is discussed in greater detail based on recent research under the Local Supply and Conservation Responses to Water Scarcity Project.

Bhavani River

The Bhavani River is the primary surface water source of a part of Coimbatore and most of Erode districts and is becoming polluted with chemicals and heavy metals. South India Viscose (SIV), one of the premier viscose manufacturing industries in India is the most water intensive and polluting industry on the river. SIV was started in the early 1960s in Sirumugai, about 50 KM from



Effluent discharged onto farmland and river banks: Tamil Nadu

Industrial demands focus on the highest quality water supplies from rural areas.

Pollution has greatly reduced drinking water availability. In some cases the poor must purchase water to meet basic needs.

Coimbatore. This industry meets 70% and 40% of South India's staple fibre and filament yarn requirements respectively and produces 180 tons of wood pulp per day. The latest available information indicates that the industry consumes an average of 40 million litres of water per day and discharges a roughly equal quantity into the Bhavani River, contributing significantly to pollution of the river especially in the dry season (Appasamy, 1994). Local farmers associations and The Bhavani River Environment Committee have expressed concern that the water stored in the Bhavani Sagar Dam, located 10 miles below SIV, is polluted with chemicals and heavy metals. They also claim that the polluted water is contributing to the salinity of groundwater in the area and that the area irrigated by the dam water is losing its fertility.

A study conducted by Stanley Associates Engineering Ltd. for the Tamil Nadu Pollution Control Board in 1994 revealed that SIV generates a large quantity of effluents containing chemicals like calcium, sulphite, nickel salts, soda ash and sodium hypochlorite. Despite treatment the effluent is dark brown and has a very strong sulphurous odor. The study concludes: "The large discharge volumes, the colour and odor form a potential threat for the water quality of the Bhavani river" (Asian Development Bank, 1994, Vol.III, p. 163). In the mid-1990's the Madras High Court ordered SIV to shut down its plants. Although the plant has been closed for brief periods, no major change has yet occurred. In addition to SIV, there are a significant number of other industrial units such as dyeing and bleaching units and sugar mills, which contribute to pollution of the Bhavani River. Notable among them are Tan India and United Bleachers.

Competing demands for surface water and surface water pollution, are well documented in this basin, but there are few studies to show that the effluent discharged from SIV or the other industries has contributed to the groundwater pollution in the region. Likewise, little research has been conducted on the effect of water pollution on agriculture and soils.

Kalingarayan Canal

Around 80 small and large tanneries are located along the 600 year old Kalingarayan Canal that runs parallel to the Cauvery River near Erode. Together these tanneries generate about 5,000 m³ of effluent a day, which is discharged into the canal. The Kalingarayan Canal Farmers' Association is concerned that these effluents have polluted the surface and groundwater supply resulting in yield reduction. This would seem to be a reasonable assertion that deserves further attention in the next phase of this study. Aside from these tanneries, 250 to 300 small and medium dyeing and bleaching units are located in vicinity of the canal, concentrated around Erode. These dyeing and bleaching units are reported to be discharging their effluent on the road and surrounding land. This probably has a significant impact on the local waterways, and ultimately on the nearby Cauvery River.

Although data are unavailable to show that the tanneries and dyeing and bleaching units in this region have contributed to groundwater pollution, the information provided by the Tamil Nadu Groundwater Board do indicate that groundwater pollution is significant in this region. A sample of groundwater has been tested biannually since 1985 from an observation well in an area of Erode

known as B. P. Agraharam where most of the tanneries are concentrated. The results are presented in Table 2. Although the data presented in this table do not show any steady decline in the groundwater quality since 1985, the sample tests do indicate that the groundwater quality is far from prescribed standards and that it is fluctuating from year to year. In addition, it is important to note that the tests focus on standard agricultural parameters and do not include many of the heavy metals (such as chromium) or other chemicals that would be expected as industrial pollutants.

Noyyal River

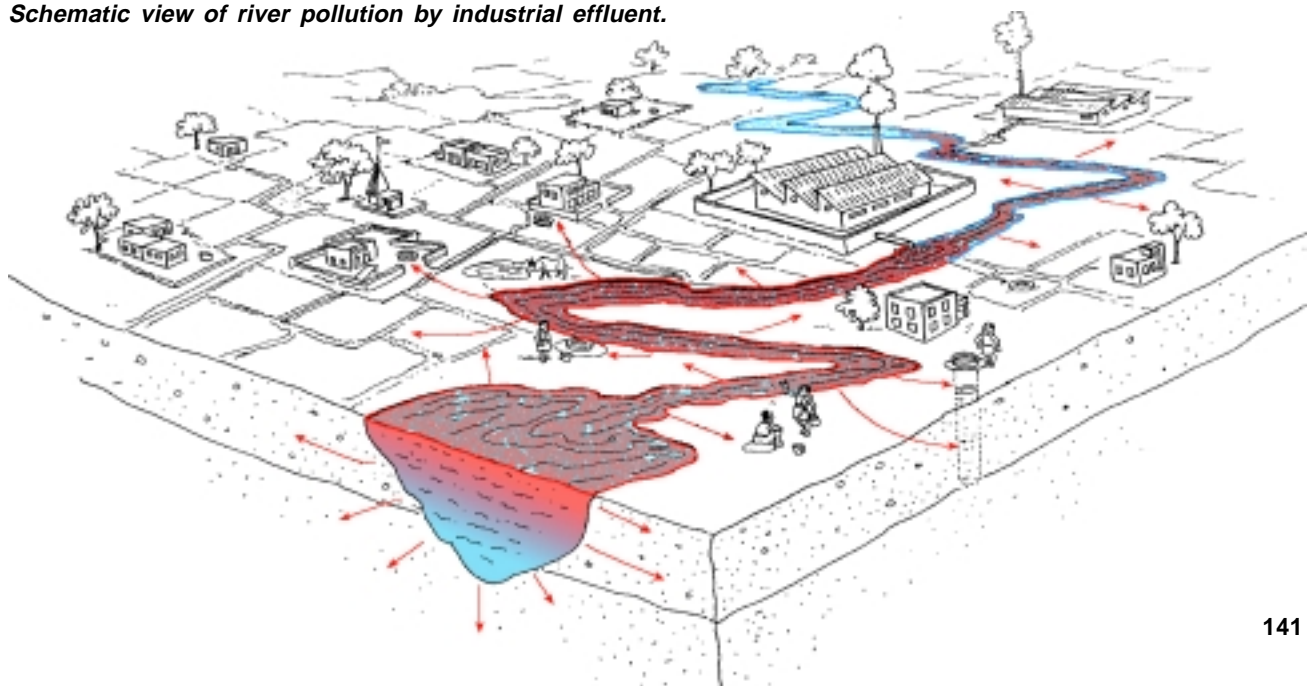
The largest town in the Noyyal River basin is Tiruppur, where the growth of the hosiery industry has been exceptional. The number of knitting mills in the town went from 22 in 1941 to 2,800 in 1991. Similarly, while there were hardly any dyeing

and bleaching units in the 1940s the Tamil Nadu Pollution Control Board indicates that 752 units were in operation in 1996. In addition, many unregistered units are reported to be operating about which no reliable information is available. The direct export value of hosiery products from Tiruppur has gone up tremendously from Rs 190 million (US\$ 5 million) in 1985 to about Rs 20,000 million (US\$ 530 million) in 1996. Tiruppur contributed 11.2% of the total value and 21% of the quantity of knitwear exported from India in 1984. By 1996, Tiruppur's share had gone up to 42% and 49.3% respectively. As a consequence, the population of the town has more than doubled from 80,000 in 1961 to a little less than 200,000 in 1991.

Dyeing and bleaching are important processes in the production of knitwear. These activities require an enormous quantity of clean water. Almost the same quantity of water is discharged

*Precise
knowledge of
pollution is
fragmented due
to
unavailability
of data.*

Schematic view of river pollution by industrial effluent.



There has been a dramatic rise in the number of dyeing and bleaching units over last five decades.

as effluent into the Noyyal River and other small streams such as the Nallar and Jamunai. Effluent discharged by these units is hazardous, causing serious health problems. This is evident from the type and extent of chemicals used in the bleaching and dyeing process. To process 100 kg of clothes the following chemicals are required: 500 grams of wetting oil, 4 kg of caustic soda, 750 grams of hypen, 4 kg of sodium peroxide, 8 kg of hydrochloric acid, 15 kg of soda ash, 3 kg of acetic acid, 10 kg of common salt and 2 kg of petroleum oil. The process also requires approximately 40,000 litres of water per 100 kg of clothes. On average, a dyeing unit can process 20 tons of clothes per month or about 700 kg per day and consumes about 8 million litres of water per month or 280,000 litres of water per day (Palanichamy and Palanisami, 1994). Discharge of these effluents has a tremendous impact on the Noyyal, particularly because it is not a perennial stream. During low

flow or dry periods, virtually all flow is industrial and other effluents.

The estimated water requirement of the bleaching and dyeing units in Tiruppur is about 94 million litres per day (mld) of which about 60% is met by groundwater transported by tanker-trucks from rural neighbourhoods. A roughly equivalent quantity of effluent is released into the Noyyal River and other streams. This has already caused permanent damage to the river, topsoil and, most important of all, to the groundwater. Even 30 years ago, the local textile operators confirmed that groundwater was contaminated in the areas where dyeing and bleaching units discharged their effluent. In the absence of any perennial source of surface water, the villages around Tiruppur depend entirely upon groundwater for agriculture. Since groundwater is contaminated, agriculture as the key occupation has been abandoned in many villages (Asian Development Bank, 1994, Vol.II).

TABLE 2:
Chemical Analysis of Groundwater from Agraharam Village, Erode

Year	Month	EC Micro CM at 25°C	pH	Ca	Mg	Cl	TDS	Total Hardness	SAR
1985	Jul	4,000	9.3	96	54	922	2,300	460	14.3
1986	Jan	2,000	9.2	76	49	808	1,795	390	12.7
1986	Jul	520	8.6	26	29	32	316	185	1.5
1987	Jan	3,790	9.2	16	68	808	2,195	320	16.8
1989	Jul	5,900	9.5	240	63	1,549	3,335	860	13.2
1990	Jan	4,170	8.7	80	331	1,078	2,213	1,560	2.5
1991	Jan	2,020	8.1	108	133	479	1,033	820	1.3
1992	Jan	3,510	8.8	24	83	688	2,028	400	13.1
1993	Jan	1,820	8.5	24	20	199	1,068	140	13.0
1993	Jul	720		20	15	57	393	110	4.8
1994	Jan	2,000		64	59	305	1,077	400	5.8
1995	Jan	1,450		44	59	206	830	350	3.8
1996	Jan	1,600		46	57	234	978	350	5.1

(Observation well No. 63247, range between two samples in the same year is presented as mg/l)
 Note: EC = Electrical Conductivity , Ca = Calcium, Mg= Magnesium, Cl= Chloride, TDS = Total Dissolved Solids, SAR = Sodium Absorption Ratio.
 Source: TNGB, 1996.

A Government Order (G.O. No.213, I) dated March 30, 1989 prohibits the establishment of polluting industry with in one kilometre of rivers. The Noyyal is one of the rivers notified in this order. The Tiruppur Dyers' Association wanted exemption from the order since, according to their claim, the Noyyal River is dry and any water that flows in the river is not used for irrigation. This claim may have had some merit at the time, but by 1992 the government of Tamil Nadu had built the Orathapalayam Dam. This was intended for irrigating about 8,000 hectares and located some 10 kilometres below Tiruppur. This dam's catchment is 2,245 km² and includes most of the area in which the bleaching and dyeing units are located.

The Orathapalayam Dam has never functioned well as an irrigation reservoir. Instead, it has become a storage reservoir for the pollution from Tiruppur and contributes significantly to pollution of the environment, especially groundwater. Water stored in this reservoir is substantially more than the natural flow in the river, because of the large quantity of effluent (about 92 mld/day) that is discharged by the Tiruppur dyeing and bleaching units into the Noyyal. This effluent contributes to the “additional storage level” of the dam.

The problem of polluted waters behind this dam was illustrated in an incident in February 1997. At that time there was no appreciable flow in the Cauvery, which the Noyyal joins some 32 kilometres downstream of the Orathapalayam Dam. Effluent was, however, accumulating behind the dam and threatening surrounding villages. In response to this situation the authorities decided to release the highly polluted water from the dam. As the river contained little unpolluted flow, and no public notice was given when effluent was released, this action resulted in considerable damage to crops, animals, soil and groundwater. The polluted waters continued downstream into the Cauvery. According to local reports, several hundred animals collapsed after drinking this water and petitions were filed in the High Court protesting release of the polluted water and claiming compensation for the damages. The situation was serious enough that the Tamil Nadu government released 20,000 cusecs of water from the Mettur Dam upstream on the Cauvery to dilute the pollution even though it was a scarcity period.

In all the villages all along the river course from Tiruppur to the Orathapalayam Dam, a

distance of about of 10 km, and in villages up to 20 km downstream of the dam, groundwater is reported to have been affected by the effluent.¹ Before construction of the dam, agricultural production was high and included major crops of tobacco, coconut, turmeric, maize, cotton and vegetables. At present, only dry crop cultivation is carried out in these villages and wet crop cultivation is limited to a few farmers whose wells are not yet polluted.

Field visits by Blomqvist in 1996 confirmed that the groundwater on both sides of the Noyyal River has become brackish and considerably harder in the last 10 to 15 years. The water quality is now unfit even for irrigation to depths of 300 feet. According to Jacks: “Downstream of Tiruppur at Orathapalayam, there is a newly constructed dam, aimed at arresting flash floods and utilizing them for irrigation. The water in the dam was brackish (7,000 mg/l TDS) and had a SAR (Sodium Absorption Ratio) in between that found in the effluent and that in the groundwater in Tiruppur town indicating a mixing of effluent from the

*Reservoir water
is also
contaminated
by effluents
from industries.*



Orathapalayam Dam: Tamil Nadu

Infiltration of polluted water has poisoned groundwater wells.

textile industries discharged directly into Noyyal and groundwater from Tiruppur town” (Jacks, et al., 1994, p.5). He also commented that: “Downstream of Tiruppur, however, the salinity was excessive definitively rendering the water unsuitable for almost any purpose” (Jacks, et al., 1994, p.4). Preliminary field visits for this study in the region confirm that the villages on both sides of the Noyyal River below the Orathapalayam Dam are quite badly affected by contaminated groundwater and people find it challenging even to meet drinking water needs.

What follows next is the case study of the village Veerapandi, a typical case where a high degree of groundwater contamination is reported:

Veerapandi is located 12 km from Tiruppur, on the Tiruppur – Palladam road. This is a big revenue village with a population of 25,000 (Census of India, 1991). One large knitwear industry along with its own dyeing and bleaching units and two other small units are located in this village. These industries were started about 20 years ago. All these units discharge their effluent onto the surrounding land and roads. Eventually the effluent ends up in the Noyyal River. Wells in this village have adequate water but it is completely polluted. As a result, agriculture has disappeared. Industries use most of the groundwater and have caused substantial pollution through effluent discharge. Due to the pollution, many industries now transport water from a nearby village. Inhabitants of that village now face major difficulties obtaining drinking water. In August 1997, about 3,000 people organized a procession and picketed the government offices to protest against the dyeing and bleaching units, which they held solely responsible for the pollution

of groundwater. The sub-collector intervened and negotiated an agreement between the villagers and industries. According to this agreement, the industries were to provide two tanker-loads of potable water (15,000 litres per load) daily to this village at their own cost. The agreement was complied with for about a month. Thereafter the industries stopped supplying water stating that they were under great pressure to erect their own treatment plants. Later on, the Panchayat Union started transporting drinking water in rotation to various segments of the village. Each household received water for two and a quarter hours, equivalent to about 100 litres once in 8 days. Soon it was realized that the water supplied by the Panchayat Union was inadequate. As a result, a local water market has developed in which a couple of farmers store lorry loads of water and sell it at 75 paise per pot. This rate increases to Rs 2 per pot at times of acute scarcity. Most people in this village use water for bathing only once or twice a week. The village population is now paying a high price for having let the polluters in.

Jacob’s study in 1996 clearly demonstrated the impact of industries on groundwater quality in the Tiruppur area. He measured a number of groundwater quality parameters. The important results are presented in Table 3. The information provided in this table suggests that the effluent discharged by the industries may have caused permanent damage to the groundwater in the region. Farmers from several villages along the Noyyal River complain about the hardness of the water and indicate that crop yields have declined.⁸ Reports in local newspapers indicate that people walk miles for drinking water in this region. According to dyers in the town pollution also affects industry (Blomqvist, 1996).

TABLE 3:
Effluent and Groundwater Quality, Tiruppur Area

Characteristics	For Effluent		For Groundwater	
	Tolerable Limit	Actual	Tolerable Limit	Actual
EC	<2,000 Ms	4,780 to 23,300 Ms	<2,000 Ms	2,910 to 16,400 Ms
TDS	2,100 mg/l	4,500 to 19,920 mg/l	1,500 mg/l	2,541 to 14,010 mg/l
Chloride	1,000 mg/l	3,750 to 7,273 mg/l	<1,000 mg/l	1,007 to 4,490 mg/l
Sulphate	1,000 mg/l	168 to 1,413 mg/l	<1,000 mg/l	156 to 821 mg/l
Magnesium	NA	NA	50 mg/l	100 to 766 mg/l
Sodium	NA	NA	200 mg/l	352 to 2,800 mg/l
BOD	30 mg/l	37 to 365 mg/l	Zero	1 to 128 mg/l
COD	250 mg/l	230 to 1,786 mg/l	NA	NA
Iron	NA	NA	0.3 mg/l	1.7 mg/l

TDS : Total Dissolved Solids, BOD : Biological Oxygen Demand, COD : Chemical Oxygen Demand, mg/l: milligram per litre, Ms : Microsiemens.

Source: Derived from Jacob, (1996).

On the whole, four important issues, all of which require further investigation, emerge from the foregoing discussion:

- (i) Groundwater scarcity is increasing and may be caused by the indiscriminate deepening and pumping of water by those who sell water to the industries;
- (ii) Agricultural problems are increasing due to declining or dried condition of the wells and groundwater pollution;
- (iii) Industrial effluents may have contributed to declines in soil quality; and
- (iv) Health hazards due to pollution may also be increasing.

Amaravathi River

As with the Noyyal River, the Amaravathi River and its basin are polluted due to the growth of

textile dyeing and bleaching units. Karur, near the confluence with the Cauvery, is particularly affected. Like Tiruppur, Karur is an important textile export centre that has grown rapidly over the last 15 years. In 1985, 100 bleaching and dyeing units were in operation. This number has now increased to 600 licenced units and an unknown but large number of unlicenced ones. Most units are located in a 17 kilometre stretch along both sides of the river and the Thirumanilayur Branch Canal. This area has substantial quantities of potable groundwater. However, since the entire industrial effluent goes into the surrounding environment and waterways, farmers in this region and the River Cauvery Protection Council have expressed concern that both groundwater and surface water are becoming polluted.

Dyers in this area claim that the large number of units is only one cause of the pollution. According to them a second factor is change in the demand pattern from foreign buyers requiring

Pollution has greatly reduced drinking water availability and in some cases the poor must now pay for it.

different input chemicals and a different dyeing process. The previous process used naphtha based chemicals, whereas the new process is a “reactive type” which requires 10 times more water and also contributes a greater pollution load to the Amaravathi River in the vicinity of Karur.

The switch from naphtha to reactive dyes has probably also occurred in dyeing units located in Tiruppur, but the damage caused in the Amaravathi basin appears to be less than in the Noyyal basin. This may be due to the fact that there is a reasonable flow of water in the Amaravathi River but very little flow in the Noyyal. Another point of difference between water use in these two towns is that there is little or no need for the sale of water in Karur. Unlike the Tiruppur dyers, most of those in Karur and its suburbs manage their water requirement from wells located within their premises.

One of the more polluted villages near Karur is Tanthonimalai. Groundwater there can no longer be used. In response to this, in 1995 the Consumer Protection Council filed a case against the dyers and bleachers in the High Court on behalf of the village. As a result of the case, the High Court issued a notice to all the polluters through the Tamil Nadu Pollution Control Board to close down all the units with immediate effect. They could open their units only if they had access to either their own treatment plant or to a joint one. As a result of this order 600 units have been closed since November 1997. Water treatment plants are also under construction, but progress has been slow and the High Court has constituted a committee comprised of lawyers representing the dyers, the Tamil Nadu Pollution Control Board and the original petitioners to conduct an inquiry into

treatment plant construction. On January 21st, 1998, textile industry workers picketed the District Collector's office protesting the dyeing and bleaching unit closures. Around the same time the inquiry committee constituted by the Court submitted its findings and recommendations. According to the committee, the dyeing units could not install their treatment plants due to lack of financing, a problem aggravated by closure of the units. Moreover, the committee found that the closure of units in Karur had affected the town economy badly. Therefore it recommended that the units should reopen under the condition that they install either their own treatment plant or to get access to a common effluent treatment plant (CETP) within three to six months. Since, however, many of the dyeing and bleaching units are small and have little capital, it is unlikely that they will install either their own treatment plants or get access to a CETP within the deadline prescribed by the Court. The process is ongoing and it remains to be seen what action will occur on the part of the court, government and unit owners. The key point, however, is that environmental and livelihood issues are coming into increased conflict. In addition, many of those affected by the environmental problems (farmers and town residents) are often different from those whose livelihoods are threatened (in this case, workers in the units).

Palar River

An Asian Development Bank study to assess the environmental condition in Tamil Nadu concluded that the Palar River is one of the most polluted in the state. It identified 3,226 small, medium and large industrial units, which primarily contribute to the pollution of the eight major river basins in

Closure of polluting industries is difficult due to the impact on local economies.

the state. Of these, 639 (or 20%) are located in the Palar basin. Table 4 gives estimated industrial pollutant loads discharged into the Palar River.

Probably the most polluted area in the Palar basin is between the towns of Visharam and Vaniyambadi (a stretch of about 100 KM on the Chennai-Bangalore national highway in Vellore district – Figure 4), where about 300 tanneries are concentrated along both sides of the river. These discharge effluent directly into the lakes, irrigation tanks, streams and the river. In addition, solid waste, such as lime, hair and leather are heaped near the tanneries and are washed into adjacent surface water bodies. Leather tanning is water and chemical intensive. Salt, wetting agents, lime, sodium sulphide, ammonium chloride and sulphate, enzymatic products, sulphuric acid, sodium carbonate, dyes and sulphonated vegetable oils are among the chemicals used. In addition, substantial amounts of chromium are used.

TABLE 4:
Estimated Industrial Pollutant Loads in the Palar River

Parameter	Pollutant loading (Kg / d)
Total suspended solids	29,938
Total dissolved solids	400,302
Chloride	101,434
Ammoniacal Nitrogen	3,034
Phenol	383
Oil and Grease	670
BOD	23,496
COD	70,990
Copper	4
Zinc	465
Total Chromium	474
Nickel	93
Cyanide	22

Source: Derived from Tamil Nadu Environmental Monitoring and Pollution Control, Asian Development Bank, Final Report, Volume-II, P.4.4, 1994.

Although the amount discharged in the Palar is not known, estimates indicate that as much as 75,000 to 100,000 tons of chrome sludge may be generated every year in the leather industry in India. This is particularly problematic because safe disposal mechanisms for chromium sludge have yet to be identified anywhere in the world (Thyagarajan, 1992, p.145). About 45 litres of wastewater is discharged per kilogram of semi-finished hide. The major pollutants in tannery effluent are alkaline effluent, lime, dissolved salts, sulphide, chromium and organic matter from hides and treatment agents.

A detailed study undertaken by the Soil Survey and Land Use Organization of Government of Tamil Nadu examined the impact of the tannery effluent on the region (Teekaraman, and Ahmad, 1982 and 1990). This study showed that tannery effluent disposal patterns are far from those prescribed by the Pollution Control Board. The 1982 study found that hardly any tanneries treat the effluent. Instead, effluent is discharged to earthen lagoons for evaporation. In most cases the number and capacity of these lagoons is not sufficient for the quantity of effluent generated. To quote, "...it is a common sight to see overflowing lagoons and the waste getting drained into the nearby fields. There are also large-scale breaches in the lagoons and the effluents seep and flow to stagnate later in the fields. Quite a large number of tanneries in Pernampet, Valathur, Vaniyambadi, Ranipet, Walajahpet, Arcot and Gudiyattam zones dispose of their effluent directly into lakes and tanks which in turn contaminate the water in the lakes and surrounding wells. A few tanneries in Pernampet, Vaniyambadi and Vellore let off their effluent directly into the Palar

Livelihood and environmental issues are in conflict. Those affected by environmental problems are different from those whose livelihood is threatened when polluting units are closed.

Poor disposal and management of effluents contributes heavily to groundwater pollution.

River, contaminating the potable water also.” (Teekaraman, et al., 1982 p. 15). The 1982 study identified about 16,000 hectares of affected land due to the tannery effluent in Vellore district using parameters such as soil quality and water quality (both surface and groundwater) to demarcate the affected area. The same study was repeated in 1990. It found no change in effluent disposal patterns and further damage to soils, surface and groundwater. Of 855 effluent storage lagoons inspected in the 15 centres from Visharam to Vaniyambadi, only 150 were concrete lined, 519 had broken structures, 696 were overflowing into open fields and only 67 could hold the quantity of effluent generated. Most of the channels carrying effluent from the tanneries to the lagoons were unlined, broken and overflowing. The above factors indicate that poor management of the effluents is likely to contribute heavily to groundwater pollution.

Studies by Narayana Murthy in 1987 documented the negative impact of tannery effluent on the environment in the Palar basin. According to Murthy, the number of tanneries in Vaniyambadi taluk alone increased from 108 in the 1960s to 240 in 1975. During the same period, land rendered unfit for use increased from 240 hectares to 6,400 hectares and the number of polluted wells increased from 48 to 520. The impact is continuing to grow. By 1984, the number of polluted wells exceeded 10,000. As a result of the pollution, agricultural yields have declined, drinking water scarcity has increased and cultivation has been abandoned in several villages (Narayana Murthy, 1987). Major health problems have also been caused by contaminated groundwater including cholera, skin ailments and gastroenteritis.

Groundwater quality sample tests conducted at various points in this region by the Tamil Nadu Water Supply and Drainage Board (TWAD), Government of Tamil Nadu in 1983, and quoted in Narayana Murthy (1987) show high BOD (biological oxygen demand) and TDS (total dissolved solid) levels. BOD levels in some cases exceed 20,000 mg per litre and as early as in 1983 TDS levels in the Ambur and Vaniyambadi region ranged from 3,710 to 5,350 mg per litre, whereas the safe limit for drinking water is considered to be 3 mg/l of BOD and 500 mg/l TDS. A more recent study carried out by the Water Resources Organization, Government of Tamil Nadu, also shows that discharge of untreated effluent by tanneries to the Palar River and adjacent lands over the past three decades have affected the groundwater quality (Rajarithnam and Santhanam, 1996). TDS levels in most sample locations ranged from 4,905 to 10,172 mg/l. The Central Pollution Control Board also conducted a study of groundwater quality in 12 locations in Vellore district, during 1994 (Central Pollution Control Board, 1995). Samples were taken from agricultural wells and all showed excess salinity with TDS values ranging from 2,529 to 10,674 mg/l. Since the natural aquifer was of a good quality, the excess salinity was attributed to contamination by tannery effluent. In addition, heavy metals including chromium, copper, zinc, iron and manganese were found in all except two sample wells. The high presence of chromium in 10 out of 12 sample wells in particular, indicates that the contamination of groundwater is primarily due to tannery effluent. Tables 5 and 6 present more detailed information pertaining to groundwater pollution in the Palar basin.

Many of the parameters in Tables 5 and 6 exceed normal limits for irrigation and drinking. In addition to the high chromium and TDS levels, the high coliform counts are characteristic of pollution associated with tannery effluent. They indicate that the groundwater in this region has high bacterial contamination. This, along with the heavy metals and other contaminants, is probably a primary cause of health problems reported in the region. Recently the Madras School of Economics has studied the impact of the tannery effluent on health in three sample villages located in the Walajapet taluk, downstream on the Palar River (Madras School of Economics, 1998). In one of the villages (Gudimallur) the effluent has entered the irrigation tank, heavily contaminating both surface and groundwater. Partly treated water passes through the two other sampled villages before entering the Palar River, causing enormous damage to the water bodies and resulting in serious health problems for both humans and animals. The most commonly reported health problems are related to respiratory ailments, skin allergies and diarrhea.

Remedies to tannery effluent pollution appear complex. Even if all the tanneries were to install the treatments or become a part of the CETP, the disposal of sludge remains an unresolved issue. On the order of 70 to 80 tons of sludge are generated by existing CETPs and individual treatment plants per day. This may increase to 140 to 180 tons per day when all the treatment plants become operational. The sludge, which is toxic and hazardous, contains chrome. At present it is stored within tanneries but during the rainy season it often washes into streams causing enormous damage to the environment and the human population (Sahasranaman, 1997).

Villages affected by tannery effluents (as reported in various studies) have been plotted on the Palar basin map. Most of the villages are in two clusters along the Palar River. One cluster is in the upper Palar (near Ambur, Vaniyambadi and Pernampet) and the other is downstream near Ranipet and Walajahpet.

Kodaganar Basin

Like the Palar River basin, the Kodaganar basin is severely affected by tannery effluent. Approximately 80 units operate in this river basin near Dindigul in the southern Cauvery basin. About 20,000 skins are processed daily, generating nearly 60 million litres of effluent. The untreated effluent stagnates in local pools and streams before it eventually joins the Kodaganar River. Many irrigation tanks in this region have been highly contaminated by effluent and two of them have been allotted as sites for the construction of Common Effluent Treatment Plants.

Groundwater samples show increasing contamination from heavy metals.

TABLE 5:
Mean Values for Heavy Metals in Groundwater, Palar Basin, 1994 (mg/l)

Well No.	Zinc	Copper	Chromium	Iron	Manganese
G1	0.078	0.026	0.143	0.150	0.132
G2	0.110	0.030	0.305	0.125	0.106
G3	0.081	0.031	1.120	0.100	0.114
G4	0.095	0.070	0.000	0.155	0.089
G5	0.071	0.027	0.290	0.200	0.490
G6	0.081	0.018	0.270	0.100	0.106
G7	0.103	0.023	0.120	0.150	0.152
G8	0.151	1.056	0.325	0.200	0.139
G9	0.098	0.025	0.620	0.133	0.472
G10	0.097	0.045	0.170	0.200	0.155
G11	0.085	0.016	0.640	0.100	0.407
G12	0.222	0.021	0.000	0.158	0.184

Source: *Groundwater Quality in Problem areas: A Status Report, Part-II, Chapter-6, pp.90-93, Central Pollution Control Board, Government of India, Delhi, 1995.*

Disposal of chromium contaminated sludge from tanneries is a major unresolved issue.

Sindalakundu village is one of the most severely affected villages in this region. This revenue village has eight hamlets and a population of about 25,000. The village has seven irrigation tanks with a combined command area of 2,500 acres. There are about 500 wells in the command area of these tanks. In addition, this village has 15,000 acres of agricultural land, some of which is dry and some of which is irrigated by about 1,000 wells. These originally supplied water for crops such as paddy, groundnut and vegetables. Pollution by the tanneries first became evident approximately 15 years ago. Now the village faces acute drinking water scarcity and, even though most wells outside tank commands, contain substantial water, they cannot be used due to the pollution. As a result, farmers have given up cultivation outside of tank commands and drinking water is fetched from distant wells located in the wet lands. These wells still have high quality water because they are located far on the other side of the river from the tanneries. Agricultural

activity has been heavily affected in this village as has livestock. Village respondents report that the cattle population has declined from 15,000 in 1981 to the current level of approximately 1,000 head. As a result, many farmers have migrated to towns and cities. In one hamlet (T. Puthur) only 4 out of an original 60 households remain. Some of them have sold their land during the past 10 years and others have left the land barren. The economic impact of the tanneries has not, however, been uniform with regard to all communities in the village. Approximately 60% of the 500 Scheduled Caste households in this village are employed in the tanneries. People of other castes, having lost their agricultural employment, prefer to undertake casual work in the town such as loading and unloading or construction work instead of seeking employment in the tanneries. A CETP has been constructed in the region. However, according to villagers it does not function satisfactorily, although its presence enables tannery operations to continue.

TABLE 6:
Mean Values for Major Chemicals in Groundwater, Palar Basin, 1994

Well No.	PH	EC Ms/cm	Total Hardness	Fluoride Mg/l	Chloride Mg/l	TDS Mg/l	Calcium Mg/l	Total Coliform mpn/100ml
G1	8.2	10.32	2,295	0.53	3,089	5,834	938	31,522
G2	8.2	11.92	4,135	0.59	3,781	7,117	1,331	7,913
G3	8.1	14.39	2,542	0.49	4,296	8,049	865	5,426
G4	8.0	15.00	3,937	0.48	4,763	8,292	1,788	8,460
G5	8.0	17.47	4,812	0.47	5,443	9,782	2,363	9,942
G6	8.2	4.87	1,574	0.64	1,249	2,718	763	7,714
G7	8.1	12.34	3,670	0.38	3,978	6,796	2,087	24,409
G8	7.4	14.87	3,994	0.40	4,809	8,251	2,167	8,453
G9	8.1	10.62	2,880	0.51	3,186	5,918	1,639	8,563
G10	8.2	10.72	3,374	0.62	3,277	5,861	1,205	13,727
G11	8.2	11.48	3,518	0.62	3,276	6,480	1,590	2,077
G12	8.2	4.08	921	0.64	1,061	2,334	533	3,765

Source: Central Pollution Control Board, Government of India, Delhi, 1995.

Responses And Emerging Issues

Responses

Groundwater scarcity in Tamil Nadu is increasing rapidly due to unregulated over-extraction and pollution. Where overdraft is concerned, there seems to be neither a concerted effort nor much collective thinking among the farmers in Tamil Nadu regarding how to address emerging problems. This contrasts with successful farmers' mobilization in Gujarat where the issue of overdraft and depletion of groundwater has resulted in the birth of a recharge movement known as "Swadhyaya." In Tamil Nadu, a number of NGOs are concerned with groundwater overdraft problems and have initiated work on the creation of percolation ponds and watershed management. Responses by the state government have, however, been minimal. Electricity for groundwater pumping is provided to farmers free of charge by the government. This provides a strong incentive for overextraction of groundwater. In addition, although a draft bill to enable groundwater regulation was prepared a few years ago, the government has yet to pass any legislation to regulate groundwater use in the state. The only point where large-scale investments are being made that could address groundwater overdraft is in the modernization of irrigation tanks. This has attracted considerable international support from the European Economic Community (EEC), the Japanese government and The World Bank (through the ongoing Water Resources Consolidation Project). Rehabilitation of irrigation tanks is likely to increase recharge and could have a significant impact on water availability in local areas.

Where pollution problems are concerned, social mobilization has been much greater than around overdraft problems. This has led to the array of protests and the court action discussed above. Numerous spontaneous actions (processions, demonstrations, hunger strikes and impounding of tankers transporting water from villages to urban industries) have also occurred. In most cases, women have participated in large numbers in these demonstrations because they are most affected by pollution problems. These actions have, however, had minimal impact on overall pollution levels. In addition, some sections of the population view water pollution as unimportant and feel that little would be gained by further opposition to it. This study indicates, however, that environmental damage to groundwater is not a sporadic occurrence and has major social implications. Groundwater pollution is severe in river basins such as the Palar, Noyyal, Bhavani, Kalingarayan Canal, Amaravathi and Kodaganar. As a result, it is essential to document the situation and raise public awareness regarding its consequences. In the long run, public awareness and concern should help catalyse government action to address pollution problems.

A key tension in developing widespread support for initiatives to address pollution problems is related to economic development. Initiatives to reduce pollution are widely viewed as conflicting with economic development objectives. Tanneries and other polluting industries generate substantial employment and many feel that attempts to control pollution are likely to reduce employment. Some political parties subscribe to this view and

*Pollution
displaces people
from agriculture
and triggers
migration.*

one national party protested strongly when some of the polluting industries were closed following the Supreme Court's directive. In addition, political parties in the region are often unwilling to oppose industrialists (who are an important source of support for political activities) or risk weakening their support bases among the workers employed in these industries.

Public awareness and concern can catalyse government action to address pollution problems.

Pressure by industry and worker interests has, to some extent, been counterbalanced by NGOs. Many NGOs are active in regions affected by pollution. They create awareness among the people, represent their cases to government authorities in court and assess environmental and economic damage due to pollution. The public interest litigation filed by the Vellore Citizens' Forum in 1991 is a case in point. This initiated major judicial intervention in Tamil Nadu. The case lasted five years before a historic judgement was passed by the Supreme Court in 1996. Under this judgement the central government was urged to create an authority, headed by a retired judge of the High Court, to assess damage and force polluters to pay compensation to affected groups. After this judgement, one NGO in the Kodaganar River basin identified 27 villages that had serious damage to land, houses, cattle and crops, as well as loss of employment and health problems. For all these losses, the total amount of compensation claimed was about Rs 104 million. This case is currently being taken through the courts with support from the NGO.

Public litigation cases filed by the individuals and supported by the NGOs, have led to the closure of the polluting industries like the tanneries and the dyeing and bleaching units in many parts of the state. On the whole, the pressure exerted on

the government by the people, NGOs and the courts has been substantial. Whether the government will take effective action, however, is yet to be seen. Currently most action is through the Tamil Nadu Pollution Control Board. Although it is supposed to control and monitor pollution, this board is far from effective and does little beyond issuing reminders or guidelines. Some of this may be due to ambiguous government policies: On one hand, the government strongly supports textile and leather exports to earn foreign exchange. At the same time, under the threat of court ordered closure of the polluting industries, the government has been trying to encourage and subsidize the installation of common effluent treatment plants. The government wants to avoid unpopular policy decisions such as closures that would lead to massive retrenchment of workers and undermine their support from industrialists. In sum, the government does not seem to have any long term policy to handle the situation. They neither collect any systematic information nor do they encourage any public debates on these critical issues.

Emerging issues requiring examination

The detailed analysis of the existing studies and the official data supplemented by a rapid survey in the basin areas, have helped to identify issues for research that are central to the question of local management. Some of these issues are listed below:

(i) To what extent are economic development and environmental protection goals actually in conflict with regard to both pollution and groundwater overdraft? If effective and affordable pollution control mechanisms can be identified, for example, incomes and employment associated with the

tannery and textile industries could remain high while the negative impacts of pollution are addressed. This would reduce the tension between environmental protection and economic development goals. It could also be a key factor breaking the deadlock between interest groups that has, so far, limited effective local responses to pollution. In addition, documentation of economic losses due to pollution (such as yield declines and health costs) could provide some perspective regarding the economic value of polluting industries and their critical role in regional development. Overall, economic and technical research to identify ways pollution can be addressed without reductions in income and employment, and to document economic losses due to pollution, appear central to any local management solution.

(ii) To what extent are emerging overdraft problems related to agricultural versus urban/ industrial uses of groundwater? Local farmers' associations often claim that agricultural wells are adversely affected by pumping for industrial and other uses. Quantification of different uses is essential to determine what types of action (improvements in agricultural use efficiency, limitations on industrial pumping and water transport, etc.) could have a significant impact on overdraft problems.

(iii) To what extent do local water markets represent equitable and efficient mechanisms for allocating scarce water supplies? A detailed analysis of water market characteristics and their functioning for drinking, agricultural and industrial uses is critical in evaluating the role they could play in water management at the local level. If they function in an inequitable manner

as part of interlocking agrarian markets the net effect could be socially negative. If, on the other hand, they enable access to water for low-income groups and the reallocation of water to socially high value uses, they could be key tools for water management. A comprehensive evaluation of the political economy of water markets in the study areas is needed.

(iv) Can institutional or other mechanisms be identified to address the problem of competitive well deepening? The dynamics of competition are relatively well understood as are the implications for present and future generations. How the vicious cycle of competition might be addressed is one of the core challenges that must be addressed by any management system.

(v) What institutional structures might enable effective management of both overdraft and pollution problems? Insights into this may be possible to gain through analysis of traditional irrigation institutions and the ways those institutions have responded to technology changes (the introduction of energized wells) and economic changes (the development of industries in areas that were once dominantly agrarian).

(vi) To what extent must management approaches address both surface and groundwater resources? Is there a positive association between the large-scale emergence of wells and the drying up of surface water bodies such as tanks, or have tanks declined due to reductions in maintenance, siltation and environmental changes throughout the basin?

(vii) A final key issue relates to monitoring. Given the high variability of groundwater conditions in

Addressing pollution in a meaningful manner requires sustained policy reform and public dialogue.

Reconciling environmental and development goals will require addressing overdraft, pollution and managing negative impact of imperfect markets.

hard rock zones and difficulties in monitoring extraction rates, the bi-annual water level measurements in drinking wells carried out by Central and State Groundwater Boards provide little indication of conditions in agricultural wells. Water levels often drop rapidly on a seasonal basis and extraction rates vary greatly even between adjacent locations. Farmers often experience extreme water scarcity even when official monitoring data show no long term water level declines. As a result, new data collection and monitoring systems are needed that provide information on conditions as experienced by water users. A key research question, therefore, relates to the types of information and data necessary to monitor groundwater problems and communicate them to local users and managers.

Summary And Policy Suggestions

This paper probes into the nature of conflicts over the use of groundwater and provides insights into the forces limiting the effectiveness of efforts to seek remedies.

Within rural areas, conflicts occur between users due to the inherent restrictions well ownership patterns create on access to this important productive resource. Conflicts also reflect the ambiguous nature of property rights to groundwater. Some of the dimensions of conflict in rural areas include:

(a) As land becomes fragmented, well ownership is also fragmented into shares creating managerial problems. Eventually disputes between shareholders arise and wells fall into disuse or are purchased by a resourceful shareholder.

(b) Conflicts between well owners emerge as water levels drop. This leads to a process of competitive deepening in which individuals with luck and sufficient resources who can afford the costs of digging can maintain access to water while others are gradually excluded.

(c) Trading in groundwater commonly leads to conflict between water sellers and purchasers. In many situations, the unequal trading relationship and relative poverty of water purchasers causes enormous friction.

(d) Unregulated pumping in tank command areas and near the river beds is affecting surface water sources such as tanks and spring channels. Studies indicate that the rapid growth of wells in tank command areas is a primary cause of the decline of traditional institutions for tank maintenance.

Conflict over groundwater between rural and urban areas occurs for at least two reasons: (a) The transport of groundwater from rural areas to meet increasing municipal and industrial water needs, and (b) the environmental damage to groundwater by industrial pollution. Farmers believe groundwater transport to urban or industrial areas is a major cause of depletion in rural areas and has caused a major decline in agricultural activities. In addition, untreated effluent from industrial uses is causing permanent damage to soil and groundwater aquifers.

Legal measures are essential in order to protect and regulate groundwater. Perhaps the most important factor would be to separate the right to groundwater use from land ownership. Attempts to define and clarify groundwater property rights

and remove current ambiguities are essential. In addition, some legal mechanisms are necessary to regulate water markets in rural areas for both agricultural and non-agricultural purposes. Over the short term, direct regulation of well depths, for example, may be a practical mechanism for addressing water level declines and reducing problems associated with competitive deepening. Finally, the official policy of supplying free electricity for agricultural purposes needs reform. A uniform electricity tariff for agricultural purposes should be evolved for all states to curb waste and misappropriation of subsidies as well as to

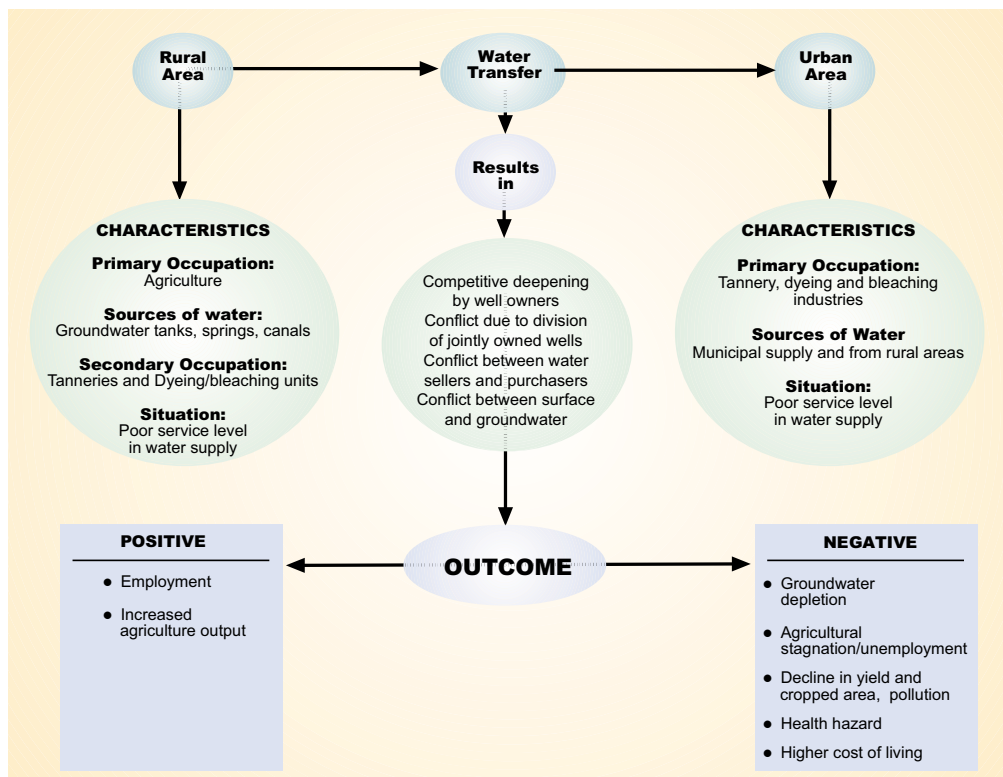
discourage use of electricity subsidy policies as political tools (MIDS, 1988 and Lindberg, 1996).

Where pollution is concerned, existing abatement laws are ineffective and need to be reformed to ensure that those who are responsible for pollution of the environment and groundwater can be held accountable. Damage caused by tanneries, dyeing and bleaching industries is permanent and imposes severe negative externalities on future generations. Those responsible for the pollution should not be able to absolve their responsibility by erecting

Disputes over groundwater are related to:

- *land fragmentation*
- *competitive well deepening*
- *groundwater trading, and*
- *the impact of pumping on surface sources.*

Figure 8
Dynamics of groundwater use and emerging conflicts.



Accountability lies at the core of addressing problem of over-exploitation and environmental degradation.

treatment plants that are often nonfunctional. In Tiruppur for instance, many dyeing and bleaching units started erecting the treatment plants reluctantly after being ordered to do so by the court.⁹ In fact, many only started after their operations were affected by groundwater pollution.¹⁰ For this reason, it is of paramount importance to devise legal measures that

enforce the “Polluter Pays Principle.” This could be used both to internalize the cost of externalities and to recover the cost of permanent damage already caused to groundwater and other environmental values. Finally, public education regarding the causes and consequences of over-exploitation and environmental degradation for the groundwater resource is essential.

Notes

- ¹ A survey of 1,100 sample wells in 27 villages of the Vaigai River basin (in southern Tamil Nadu) indicated that, on average, about one-third of the wells in that region are jointly owned (Janakarajan and Vaidyanathan, 1997). In a similar survey of 1,064 sample wells in 26 villages of the Palar River basin, the incidence of joint well ownership was 20 per cent (Rajagopal and Vaidyanathan, 1997). A separate unpublished report of a survey of 8 villages in the Palar basin carried out by this author and Barbara Harriss in 1993/94 indicated that a much higher percentage of wells (47%) were jointly owned.
- ² See, for instance, Shah, 1993; Kolavalli and Chicoine, 1989; Shah and Vengamaraju, 1988 and Moench, 1994. For more details on water sale in Tamil Nadu, see Janakarajan, 1992; Narayanamoorthy, Vaidyanathan and Janakarajan, 1989 and Janakarajan and Vaidyanathan, 1997.
- ³ For evidence in the other parts of the state, see also: Folke, Steen, 1996. Ruth Meinzen-Dick in her study of Pakistan found that the water purchasers in her study areas also enter into informal contracts with water sellers in the form of share cropping for water. Water purchasers were expected to bring fuel wood or provide other similar services in return (Meinzen-Dick, 1996).
- ⁵ These include Thongutti palayam, Kandiyankoil, North Avinashipalayam and Perunthozhuvu revenue villages.
- ⁶ A detailed investigation in this area by Blomqvist (1996) confirmed the scarcity situation. She documented that the water levels had fallen due to the extensive pumping by industrialists and that shallow wells had dried up resulting in the scarcity of water supply.
- ⁷ Blomqvist (1996) observes that the occasional sight of water tankers filled with good quality water in a drought affected, water starved region triggered demonstrations and the blocking of roads: "In 1993, a wave of agitation against the water lorries was organized along the road between Tiruppur and Dharapuram, one of the main water transport corridors" (pp70-71). Among the other areas where agitations are reported are Pongalur, Palladam, Sultanpet, Avinashi, Muthanampalayam, Nallur, Veerapandi, Mudalipalayam, Murugampalayam and villages around Dharapuram. Also, from another source: "Depletion of the groundwater level in villages near Tiruppur like Mandapam, Peruntholuvu, Orathapalayam has affected agriculture, and farmers have registered their protest against groundwater extraction for selling/industrial purposes (Tiruppur Consumers Council) (Appasamy, 1994, p 71).
- ⁸ Villages affected by groundwater pollution include Orathapalayam, Kodumanal, Pudur, Siviyarpalayam, Ramalingapuram, Thammareddipalayam, Namakkampalayam, Semman Kuzhipalayam and Kamatchipuram.
- ⁹ Only after the intervention of the Madras High Court in March 1997 did the dyeing and bleaching units in Tiruppur take up the issue of erecting treatment plants. The report submitted by the Pollution Control Board to the Madras High Court in June 1997 stated that many units had not taken steps to erect the treatment plants and were operating without the consent of the Board. Only 31 had fully completed the work. On 23rd June, 1997 the Madras High Court ordered the immediate closure of 44 units that had not begun to erect the plants. It granted four months time to complete the work to 708 others that had plants in various stages of construction (The Hindu, June 24th, 1997).
- ¹⁰ Detailed interviews carried out by Blomqvist (1996) with the owners of dyeing and bleaching units clearly reveal this point. Many owners expressed a deep concern about the polluted groundwater in Tiruppur and in the neighbourhood. One of the large dyers stated that, "All dyers are well aware that we are polluting. We know that we ourselves will get affected. We have invested in the industry here, and all those investments are going to be ours forever. If it is risky to live in Tiruppur, if it gives health effects, then what will be the use? Even now, people who can afford to send their children to school in Ooty will do so. My daughter goes to a school in Nilgiris. And when the children come back home for a vacation, they have to go the doctor week, which is not necessary when they are in school. If it is like that, everything will be in vain, all the hard work." (p. 156).

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C H A P T E R

4

**Historical Perspectives on
Conflicts over Domestic and
Industrial Supply in the
Bhavani and Noyyal Basins,
Tamil Nadu**

Introduction

Competition and conflict over water use between sectors, regions, and stakeholders has a long history in Tamil Nadu.

This chapter is an account of the history of conflicts between farmers, municipalities, urban residents, industry and the state over water in the Bhavani and Noyyal river basins, particularly the areas surrounding Coimbatore and Tiruppur, from the late nineteenth century (1890) to the 1970s. The information in this chapter is mostly synthesized from government orders and documents on board proceedings of the Tamil Nadu Water and Drainage Board (TWAD) found at the Tamil Nadu State Archives in Chennai.¹ The work represents a counterpoint to the more field-based work, undertaken partly in the same area, that has been presented in the previous chapters.

The chapter examines the nature of conflicts that emerged between different groups associated with diversion of water from the Bhavani and Noyyal Rivers for domestic and industrial water supply. It does this by attempting to answer a series of questions regarding conflicts and their dynamics in the course of everyday life. Was there any opposition to the municipality from urban people over fixing water tax? Was there any clash of interests between the municipality, farmers, the

public works department and the state? Did farmers protest against diversions? If so, how did the government address issues and what assurances were made to farmers in the basins regarding their concerns? What policy was adopted by the government to resolve conflicts? Answers to these queries increases understanding of the nature of water conflicts both between different sectors and with different governmental agencies in Coimbatore and Tiruppur.

In addition to the above queries the study also examines whether the government considered the importance of irrigation and the traditional rights of the farmers in the Bhavani and Noyyal rivers and their tributaries and channels between 1890 and 1970. This report consists of four sections in addition to the introduction. The first section deals with the history of drinking water supply to Coimbatore and Tiruppur, the second narrates the chronology of water diversion from the Bhavani River basin to the Noyyal River basin for agricultural purposes, the third analyses the conflicts, and the last contains concluding observations.

Domestic Water Supply: 1890-1970

The Problem

Diversion of water for purposes other than agriculture has been a major source of conflict. The concept of diverting water from the Bhavani and Noyyal river basins to supply Coimbatore and Tiruppur along with their

associated industries emerged at the end of the nineteenth century. It was implemented during the second quarter of the twentieth century.

Drinking water problems are often crucial for growing cities, towns and in some cases villages. In most areas, water needs are initially met

through local sources, such as wells and tanks, but growing urban demands often rapidly exceed supply from these sources. In both Coimbatore and Tiruppur problems of water supply were particularly intense.

Coimbatore faced water supply challenges compared to many other cities because drinking water was mainly extracted through the wells, and locally available supplies were saline and scarce. Since the late nineteenth century, Coimbatore's population has grown rapidly and the city emerged as a centre of industrial activity. As this occurred, the requirement for water assumed ever greater importance. The population of Coimbatore was 53,000 in 1901, by 1971 it had increased to 565,293 (figures for the 1981 city boundaries). The first textile unit was established by the British in 1888 and a local entrepreneur established a mill in 1907. Since then, a number of other industries have been established. In 1995, there were approximately 150 large-scale textile units, 350 small spinning mills, 20,000 powerless and 40,000 handloom units, 2,000 knitting units, 500 steel casting foundries, and 350 electric motor foundries in the city. In addition, many other industrial units were established. Due to population and industrial growth demand for water increased greatly. Consumption in 1931 was 11.3 mld, supplying 90,000 individuals at the rate of 126 litres per day. In 1971 this increased to 13 mld and by 1991 it went up to 85 mld and was distributed at the rate of 103 litres for 820,000 people. To meet the increasing demand, the municipality tried to extract water from tanks and streams adjoining the city. Due to the non-availability of good quality water in these sources, diversion of water from the Bhavani, Noyyal and its tributaries was actively considered at the end of nineteenth century.

The water supply situation in Tiruppur is also extreme. Tiruppur is known for its knitting industries and is located on the banks of the Noyyal River. Water availability problems have, however, been severe since the 1930s due to both population and industrial growth. The total population of Tiruppur was 6,056 in 1901 and rose to 128,228 in 1971 (figures for 1991 boundaries). The numbers of industries also have increased dramatically. By 1995 there were 8,437 units of which 713 were water intensive units and the requirement of water for industrial use was 90 million litres per day. Much of this was utilized by the 526 dyeing units present in the town.

History of Coimbatore Water Supply Schemes

Constituted as a municipality on November 20, 1866, Coimbatore is spread over about 10 square miles in 10 revenue villages (Coimbatore, a portion of Telungupalayam, Ramanathapuram, Krishnarasapuram, Sanganur, Anupparpalayam, Puliakulam, Kumarapalayam, Savaripalayam and Ganapathi). Though located near the Noyyal River, drinking water availability is limited. Rainfall levels are low (Table 1) and due to the low storage in underlying hard rock formations, groundwater is also scarce. The quality of water is also very poor. Groundwater in the region contains lime, probably also with magnesium and other salts. Because of its poor quality, available groundwater could not be used for industrial boilers, dyeing, cloth and other manufacturing purposes and was also poorly suited for domestic consumption. Tanks in and around the city are either situated in elevated locations not suited for drawing water from or are highly unreliable water sources. In addition to naturally occurring quality

Higher water demands in urban areas have been triggered by population and industrial growth.

TABLE 1:
Rainfall in Coimbatore:
1892/93-1908/09

Year	Rainfall (inches)
1893/94	22.43
1895/96	17.53
1897/98	13.44
1899/1900	24.89
1901/02	28.04
1903/04	31.83
1905/06	17.54
1907/08	19.87
1892/93	15.12
1894/95	16.24
1896/97	27.17
1898/99	25.11
1900/01	25.11
1902/03	32.01
1904/05	14.38
1906/07	33.32
1908/09	26.77

Source: G.O.No.145 Mis W PWD/B and RJ, 15-11-1917, Tamil Nadu State Archives, Chennai (hereafter TNSA).

problems, by 1890 much of the groundwater in Coimbatore was contaminated (see Table 2). However, the municipality did not consider any other sources of water supply for the town. Until the 1880s, the Coimbatore Municipal Council managed these problems through repairing the existing wells in the different parts of the city. No attempt was made to bring water from the rivers and other sources (G.O.No. 184 Mis, L and M [M], 14-2-1889).

As early as the 1890s, scarcity and poor water quality in Coimbatore led to interbasin transfer proposals.

Part of the apparent reluctance to develop alternative water sources was cost. Schemes proposed in the late 1800s were often prohibitively expensive. Part of the reluctance may also have been the limited nature of supplies available within the region. Towns and villages neighbouring the Bhavani and Noyyal rivers did not have sufficient good quality drinking water and were dependent upon nearby wells and public tanks. Groundwater in these regions, as in Coimbatore, was hard and its availability was very limited. Due to the growing population, industries and the process of urbanization, water problems were acute in most

of the towns and villages located along these rivers as early as the late nineteenth century. Insufficient and bad quality of water caused the spread of cholera and other diseases. For example, in Coimbatore 96 persons were affected by epidemics in 1926-27 of whom 59 died. In 1927-28, 86 of the 127 affected lost their lives (G.O.No.9 Mis LSG [L and M], 4-1-1932). Finally, the government initiated diversion of water from the Bhavani and Noyyal and their tributaries. A brief account of the different water supply schemes for Coimbatore is presented before analysing the other issues. The different schemes are listed in Table 3 and then discussed in detail in the following subsections.

Muthikulam Scheme

The Siruvani Project is the oldest in the history of Coimbatore Water Supply Schemes. The first record of it is in an inspection note by Colonel Montgomery in 1879 (G.O.No. 1453 W, PWD [B and R-Civil Works], 15-11-1917). The government did not, however, consider the proposal until the 1880s when the Coimbatore Municipal Council considered various possible schemes. In the late 1880s, the government proposed construction of a multi-purpose dam across the Bhavani at its junction with the Siruvani River, that is, a tributary of the Bhavani, for drinking water supply to Coimbatore and also to irrigate about 2,000 acres in the Noyyal basin. This was dropped in 1890 for two reasons. First, during low flow periods, diversion of water from Siruvani could affect the large irrigation channels which take off from the river between the towns of Mettupalayam and Bhavani. Second, supply across the chain of hills between Mettupalayam and the Noyyal River would require a huge investment for excavating or tunnelling. As a result, the

TABLE 2:
Chemical and Bacteriological Examination in Different Wells of Coimbatore: 1890.

	District Jail Well	Main Gate Well	Jail Garden Well
Total solids (grams per litre)	1.610	1.730	1.580
Volatile solids do	0.320	0.390	0.320
Chlorine do	0.398	0.390	0.355
Total hardness Clarks scale	49.000	49.000	49.000
Permanent hardness	15.750	26.250	22.750
Free Ammonia MI (grams per litre)	1.160	0.080	0.160
Albunminoid	0.120	0.040	0.080
Nitric acid	11.250	11.250	15.000
Apparent quality of the water as inferred from the results obtained on examination	Bad	Bad	Bad

Source: G.O.No.53 Mis L and M (M), 16.1.1893, TNSA.

TABLE 3:
Details of Different Sources of Coimbatore Water Supply Proposals/Schemes

Year Proposal Made	Name of the Scheme	Water Source(s)	Dropped/Finalized	Remarks
1888	Muthikulam Scheme	Bhavani River	Dropped in 1890	Prohibitive cost
1892	Noyyal River Scheme	Noyyal River	Dropped in 1893	Prohibitive cost
1901	Chitrachavadi Channel and Rajavaikkal of Noyyal River	Chitrachavadi Channel and Rajavaikkal of Noyyal River	Dropped in 1901	Bad quality of water
1907	Kistnambadi Tank Scheme	Chitrachavadi Channel of Noyyal River	Dropped in 1908	Protest from farmers, agri, farm and other downstream villages; and bad quality of water
1909	Sub-Artesian Springs, Singanallur Scheme	Sub-Artesian Springs, Singanurpallam Valley Singanallur Tank	Dropped in 1912	Prohibitive cost and poor financial conditions of the municipality
1912	Siruvani I	Siruvani River	Finalized in 1924	Best water at low cost of the scheme
1928	Anayar and Periyar Scheme	Anayar and Periyar Streams	Finalized in 1929 and 1930	Temporary water supply
1956	Siruvani II	Siruvani River	Finalized in 1970	Supply of water increased
1980	Bhavani River	Bhavani River	Finalized in 1989	Supply of water increased

government decided that diversion of the west flowing streams into the Noyyal basin was impracticable (G.O.No. 556 I PWD, 7-10- 1890).

Noyyal River Scheme

In 1892, the government explored the possibility of bringing water from the head sluice of the Kurumymookoor channels some miles above the Vellalore *anicut* (small dam/weir) of the Noyyal River. This proposal also did not take off because the proposed location of the filtration gallery had valuable coconut topes and lacked approach routes for delivering material for construction and fuel storage. Furthermore, a large amount of funds were required to compensate the owners of coconut topes and to establish the roads.

In addition, water quality in the Noyyal River was poor (see Table 4). Ultimately, the proposal was discarded due to the prohibitive cost (G.O.No.53 Mis. L and M [M], 16-1-1893).

Muthannankulam Tank Scheme

In 1901, Coimbatore Municipal Council proposed storing water from Chitrachavadi and Rajavaikkal canals (which drew water from on the Noyyal River) in the Muthannankulam tank for water supply to Coimbatore. This tank is located at the northern end of Coimbatore town. It is higher than the town and spread over about 9.75 acres. A proposal was made to enlarge the tank to store water for a period of 3 to 5 years. This proposal was, however, dropped

Difficulties in compensating users led to the rejection of several schemes for water diversion.

Contamination was a problem even in the early part of the century.

TABLE 4:
Chemical and Bacteriological Quality of Noyyal River Water: 1890. (grams per litre except as noted)

Total solids	0.540
Volatile solids	0.080
Chlorine	0.060
Total hardness-Clark's scale	28.00
Permanent hardness Clark's scale	0.700
Free Ammonia MI	0.200
Albumnoid	0.120
Nitric acid	0.450
Apparent quality of the water as Inferred from the results obtained on examination	Bad

Source: G.O.No.53 Mis L and M (M), 16.1.1893, TNSA.

because the tank received drainage from the outskirts of the town. In addition, objections were anticipated because the Noyyal River already had too many demands on it. Also, the quality of water at the tail end of Chitrachavadi channel was bad and unfit for drinking (Table 5). Finally, the scheme failed to take off (G.O.No.1490 Mis L and M [M], 10-10-1901).

Kistnambadi Tank Scheme

In 1907, the government proposed construction of a tank near the Kistnambadi tank, where the Chitrachavadi channel from Noyyal discharges. This scheme was proposed in order to harness surplus water from the Kistnambadi tank that was being discharged into rivers, the Selvambadi tank, and ultimately the Kumarasamy tank. A surplus weir is present in the Kumarasamy tank and the whole amount of water flowing over this weir would, in theory, be available for the proposed new water supply tank (G.O.NO.1664 Mis L and M [M], 9-10-1908).

This proposal received stiff opposition from the government agricultural farm and the farmers of the Chitrachavadi channel and other downstream villages (G.O.NO.1664 Mis L and M [M], 9-10-1908).The agricultural farm objected to it for the following reasons:

- (i) the proposed storage tank would utilize lands that would otherwise be used for the farm, the institute and the residential buildings for the staff.
- (ii) more than half of the wetlands acquired for experimental work by the government farm would be taken away; and
- (iii) water supply for the wetlands would be affected in bad years (G.O.NO.1664 Mis L and M [M], 9-10-1908).

TABLE 5:
Chemical and Bacteriological Examination of Chitrachavadi Channel Water: 1906. (parts per 100,000, except as noted)

Total solids	38.00
Total hardness parts per 1,00,000	28.00
Permanent hardness	8.500
Chlorine	4.970
Free Ammonia	0.009
Albumnoid Ammonia	0.008
Nitric acid (NO ₂)	Nil
Oxygen absorbed (Tidy's process)	0.068
Nitrates	Present
Sulphates	Present
Phosphates	Nil
Iron, Poisonous metals	Nil
Opinion of water	Contaminated

Source: G.O.No.1337 Mis L and M (M), 27-6-1907, TNSA.

In addition to the objections of the government farm, 86 landholders of the Chitrachavadi and other villages submitted a petition stating that they had been suffering on account of inadequate rainfall and uncertain supply of water from the Chitrachavadi channel for their paddy crops and topes. This had forced them to leave large areas of land fallow for several years. In addition, the farmers requested a reduction in the land assessment rate or an exemption from any increase of assessment for the next two settlement periods. As a result, they asked the government to reconsider the proposed storage tank for the Coimbatore water supply scheme (G.O.NO.1664 Mis L and M [M], 9-10-1908). Finally there was the question of water quality. As with other sources, water in Kistnambadi tank water was contaminated (Table 6). In addition to the above complications, the project was expensive. The storage reservoir would have to be enlarged at considerable cost to hold twelve months supplies.

TABLE 6:
Chemical and Bacteriological Examination of Krishnambadi Tank Water: 1906. (parts per 100,000, except as noted)

Total solids	39.00
Total hardness	20.00
Permanent hardness	0.50
Chlorine	5.325
Free Ammonia	0.010
Albuminoid Ammonia	0.012
Nitric acid (NO ₂)	Nil
Oxygen absorbed (Tidy's process)	0.108
Nitrates	Present
Sulphates	Present
Phosphates	Nil
Iron, Poisonous metals	Nil
Opinion of water	Contaminated

Source: G.O.No.1337 Mis L and M (M), 27-6-1907, TNSA.

TABLE 7:
Cost and Maintenance of Schemes Investigated in 1912

Scheme	Probable Cost	Probable Annual Initial Cost in Rs (lakhs)	Maintenance, pumping charges, etc.	Total annual maintenance
		Siruvani bund on ½ the capital cost at 5.96% for 30 years		
1. Siruvani River Water supply	15.95	47,530	5,000	0.52
2. Sub-artesian supply	7.50	22,147	161,500	1.84
3. Bhavani River	21.00	62,770	402,000	4.65
4. Singanallur	26.25	72,353	57,000	1.30

Source: G.O.No. 381 W PWD [B and R-Civil Works] 23-2-1915, TNSA.

Even then there was no guarantee that supply would be sufficient throughout the year (G.O.NO.1664 Mis L and M [M], 9-10-1908). As a result of these factors, particularly the cost, the government decided to abandon the scheme.

Proposed schemes were often rejected due to multiple factors.

Sub-artesian springs and Singanallur Scheme

In 1908, the government considered undertaking a detailed study of the possibility of securing sufficient water supply from newly discovered artesian springs near Coimbatore. It invited suggestions for other moderately priced schemes with a supply source other than the Noyyal River. (G.O.No. 1664 Mis L and M [M], 22-7- 1909). By 1909, the Sanitary Engineer had found possible sources as: (a) sub-artesian springs, (b) Sanganurpallam valley, and (c) Singanallur tank. This resulted in a request to the government to investigate schemes (a) and (c) (G.O.No. 1151 Mis. L and M [M], 22-7-1909).

In addition to cost, common problems with proposed schemes included water quality, land acquisition issues, and questionable supply reliability.

In 1910, the government deferred the study on the sub-artesian sources of water supply until the financial conditions of the council had improved (G.O.No.1 Mis L and M [M], 3-1-1910), and in 1912 the investigation of the Singanallur tank scheme was abandoned owing to its prohibitive cost and unreliable prospects of water supply (G.O.No. 1435 M L and M, 5-8-1912). In the same year, the government ordered an investigation of the Siruvani and Bhavani rivers as sources of water supply to Coimbatore.

Siruvani Scheme - I

In 1912, a preliminary investigation was conducted for four possible schemes: the Siruvani River, sub-artesian supply, the Bhavani River and Singanallur tank (G.O.No.381 W PWD [B and R-Civil works]).

The Siruvani River water was reported to be of excellent quality and the best among those examined in connection with the investigation (see Table 8). This water was uncontaminated except by wild animals in the hill areas (G.O.No.2158 Mis LSG (PH), 23-10-1925). Considering the many advantages, the Sanitary Engineer recommended the Siruvani River scheme to the Coimbatore Municipal Council for consideration.

The Coimbatore Municipal Council reported that the high cost of the proposed Siruvani water supply scheme could not be met with their own resources. They recommended looking into the feasibility of a combined hydroelectric scheme which would be financially viable. In 1913, the Sanitary Engineer submitted an alternative approximate estimate for a water supply scheme for Coimbatore, combined with a hydro-electric project and some irrigation. The new scheme was designed to provide water to 70,000 people in Coimbatore and to another 20,000 people in the Podanur railway shops and colony. Power generated would be for electricity supply to Podanur workshops, colony, Nilgiri Railways, Coimbatore colony and industrial concerns, and electrification of at least Coimbatore, Wellington and Ootacamund. The project would also increase the area of wet cultivation in the Bodampatti valley and indirectly benefit cultivation under the Noyyal River basin system (G.O.No. 1453 W PWD [B and R-Civil works], 15-11-1917). This combined project remained under consideration at least until 1915, although the power component was dropped subsequently (G.O.No.381 W PWD, 23 2-1915).

TABLE 8: Bacteriological and Chemical Examination of Siruvani Water: 1923	
Bacteriological Examination	
Total colonies per c.c. on agar at 37 IC	120
Lactose fermenters present in how many C.C	1 C.C and upwards
Result of Vibrios test	No Vibrios in 100c.c
Nature of lactose fermenters isolated and number of species	Two of class II and 8 of class III. 3 species
Chemical Examination	
<i>Physical appearances:</i>	
Colour and transparency	slightly yellowish but clear
Smell	No
<i>Quantitative:</i> <i>(in parts per 100,000)</i>	
Total solids	4 - 6
Temporary hardness	Nil
Permanent hardness	1.0
Chlorine	0.3
Ammoniacal Nitrogen	Trace
Albuminoid	0.0

Source: G.O.No. 2158 Mis LSG (PH), 23-10-1925, TNSA.

In 1919, the Sanitary Engineer submitted independent plans and estimates for the Siruvani water supply scheme. This proposal envisioned

irrigation of 2,000 acres in the Noyyal River basin, continuous water supply to 100,000 people at the rate of 20 gallons per head per day and 375 gallons per minute per day for industrial concerns. In 1924, the government sanctioned Rs 4,100,000 on the basis of cost sharing at a 50:50 ratio with the municipal council. The foundation stone for the scheme was laid by Hon. Viscount Goschen of Hawkhucs, Governor of Madras on October 10, 1924. Work on this scheme was started in 1925 (G.O.No. 4452 Mis LSG [L and M], 14-11-1930). As a special case, the government was willing to allow its grants to be spent first and ordered that the expenditure would be incurred on the schedule shown in Table 9.

Although the government was willing to allow its share to be spent first, it warned the municipal government that any costs above the initially estimated amount should be met entirely from the municipal funds, otherwise the scheme would be stopped (G.O.No.2246 Mis LSG [PH], 5-11-1925). In 1926, the government indicated that the Coimbatore Municipality did not need to pay any charge for drawing water from the Siruvani River for drinking water supply until irrigation could be initiated under the scheme (G.O.No. 1814 I PWD, 29-11-1926). In 1930, the government revised the estimate of the scheme's cost to Rs 43,74,808 and agreed that this was to be shared, with the government paying Rs 2,357,024 and the municipality paying Rs 2,017,784 (G.O.No.2094 Mis L and M [PH], 28-8- 1930). In 1932, the government sanctioned revised estimates amounting to Rs 4,641,650 for the complete scheme relating to Coimbatore water works (G.O.No.2320 Mis W PWD, 7-11-1932). The Siruvani scheme was completed in 1931 and

drinking water supply has been available to the city through it since then.

In addition to municipal water supply from the Siruvani, the farmers of Palladam and Coimbatore at various times proposed diverting surplus water from the Siruvani to the Noyyal River basin for agricultural use. In 1949, the government sanctioned Rs 67,660 for raising the height of the Siruvani dam by 4 ft under the 'Grow More Food' scheme. The storage level was increased facilitating discharge of more water into the tunnel for irrigation purposes in the Noyyal basin. During September 1950 and June 1951 25 to 40 cusecs were released (G.O.No. 790 Mis PWD, 2-3-1955). This was mainly used by the *ayacuts* (command area) under the Chitrachavadi channel. In July 1951, following damage in the tunnel supply of water for the Noyyal basin, irrigation was stopped by the municipality.

Anayar and Periyar Scheme

Before the Siruvani scheme, drinking water scarcity was severe in Coimbatore. As a result, in 1928 the government ordered water supplies to be arranged from government sources on the Anayar and Periyar rivers (G.O.No.2211 Mis Public Health 19-10-1928). In 1929, the government sanctioned Rs 36,240 for this scheme (G.O.No.2560 W PWD, 9-9-1929), and it was further hiked to Rs 40,485 in 1931 (G.O.No. 132 Mis PW and L W, 17-3-1931). Water was diverted from the Anayar River into the gravitation main by means of a temporary dam which was supplemented by the Periyar River. This scheme was expected to supply 5 gallons of water per head per day for a population of 70,000 (G.O.No.4452 Mis LSG (L and M), 14-11-1930). From March 2, 1929 water was drawn from the

As early as the 1890s cost sharing was prevalent between government and municipality.

TABLE 9:
Expenditure on Siruvani Water Supply Scheme

Year	Amount (Rs in 100,000)
1924-25	0.50
1925-26	7.50
1926-27	14.75
1927-28	12.25
1928-29	6.00
	41.00

Source: G.O.No. 1277 Mis, LSG (PH), 6-9-1924, TNSA.

Anayar and from April 18, 1927 from the Periyar River. The total quantity of water drawn from both the sources was about 300,000 gallons per day (G.O.No.1189 I PW and L, 11-4-1930).

Siruvani – II

After the reorganization of states in 1956, the Tamil Nadu government approached the Kerala government to divert more water from the Siruvani for drinking water purposes and also for extending irrigation in the downstream villages. The Kerala government, however, refused permission (G.O.No.2393 Mis E and PH [H], 21-9-1960). The subject was then included in the agenda for the meeting of the Southern Zonal Council held in April 1960 where it was decided that the Chief Ministers of both the states should settle the matter between themselves (G.O.No.2393 Mis E and PH [H], 21-9-1960).

In the meanwhile, in 1956, the Chief Engineer, PWD (GI) in Tamil Nadu prepared a proposal to increase storage capacity in the scheme from 2.4 MCF to 425 MCF to meet the increasing demand for more water for Coimbatore, irrigation of downstream villages and the Noyyal basin through construction of a new dam across the Siruvani. The approximate cost was estimated to be Rs 14,400,000 [11,400,000 for drinking water supply and Rs 3,000,000 for irrigation] (G.O.No.2393 Mis E and PH [H], 21-9-1960). In addition, an agreement was made between Tamil Nadu and Kerala for Kerala to provide 1,300 million cubic feet of water every year, that is 223 million gallons daily (TNSAR 1983-84, p.257). Based on this new supply agreement, a new scheme for augmenting the Siruvani water supply (at a level five-fold over that of the then present rate of

supply) was inaugurated on September 15, 1970 at a cost of Rs 6 crores (Tamilarasu,² October 1970, p.35). In 1977-78, the government sanctioned Rs 161,600,000 towards the initial cost and Rs 3,500,000 for annual maintenance (Tamil Nadu State Administrative Report 1977-78, p.334). Part of the works of this scheme costing Rs 70,100,000 in Kerala were executed by Kerala PWD with the Coimbatore Municipality bearing the entire amount. The remaining works in Tamil Nadu which cost Rs 91,500,000 were undertaken by the Tamil Nadu Water and Drainage (TWAD) Board. The "Siruvani Water Supply Improvement Scheme" of the TWAD Board was estimated to cost Rs 22 crores. This was taken up with loan assistance from the LIC and state government's resources (Tamil Nadu Administrative Report 1984-85, p.209).

Pillur Scheme

In 1989, the Pillur Reservoir Project was constructed across the Bhavani River to generate electricity as well as to extend water supply to Coimbatore, 20 towns and 523 hamlets situated in 99 village panchayats.

History of Tiruppur Water Supply Schemes

The water problem in Tiruppur is an acute one despite the fact that the Noyyal River runs through the town. There are two main reasons for this. First, there are about 31 irrigation *anicuts* across the Noyyal above Tiruppur, which divert large portions of the river's flow. Second, the available water, what little there is of it, was contaminated even in the early twentieth century (G.O.No.660 Ms L and M [M], 22-4-1918). Water problems were

Water became a point of competition between Kerala and Tamil Nadu soon after the States were separated during state reorganization in 1956.

particularly severe during the summer. The average annual rainfall from 1909 to 1929 was only 25.72 inches (see Table 10), and most of this occurred during the monsoons.

Until the 1920s, the water for Tiruppur was supplied mainly through seven public wells (G.O.No.4965 Mis LSG [L and M], 14-11- 1937). Every year, the Tiruppur municipality spent a certain amount on repairing the wells so that it could provide the maximum water supply possible through them. Attempts to provide adequate water supply could not, however, meet the demand of the growing population of the Tiruppur municipality and until the 1920s the government did not initiate any steps towards providing sufficient drinking water.

In 1919, Koilveli valley water was examined and found to be hard and bacteriologically not hygienic (Table 11). Despite the low quality, this source of water was recommended for the Tiruppur municipality water supply scheme because of the absence of any other perennial supply (G.O.No.2353 Mis E and PH [PH], 15-8-1936).

In the 1920s, the government proposed supplying water from the Koilveli infiltration gallery about five miles from Tiruppur. This scheme would supply only 20,000 people at 5 gallons of water per head per day (G.O.No.3089 Mis Health, 16- 11-1954). It consisted of two stages: 1) construction of an open infiltration gallery and collecting wells and a full power test; and 2). construction of a gravitation main, service reservoir and distribution system, (G.O.No. 725 Mis PW and L [W], 10-3-1928). In 1920, the Sanitary Engineer recommended that the first part of the scheme be taken up first and, depending on its

viability, decisions could be made regarding the later part (G.O.No. 725 Mis PW and L [W], 10-3-1928). In 1923, the cost of first part was estimated at Rs 105,000 and in 1927, the government approved an approximate estimate of Rs 67,000 (G.O.No. 725 Mis PW and L [W], 10-3-1928). Before sanctioning this scheme, the government issued an order to confirm the viability of the water supply scheme by ‘full power test’ and in 1928, sanctioned Rs 51,000 for the purpose (G.O.No. 725 Mis PW and L [W], 10-3-1928). In 1931, a revised estimate of Rs 64,300 was sanctioned for a full power test (G.O.No.809 Mis PW and L [W], 23-3-1931). In 1937, the government finally sanctioned Rs 184,000 for the Koilveli water supply scheme (G.O.No.4068 Mis LA, 30-10-1937)

TABLE 10:
Rainfall at Tiruppur Station 1909-1929

Year	Rainfall (inches)
1909	25.77
1910	31.45
1911	17.82
1912	26.74
1913	17.74
1914	17.08
1915	32.60
1916	23.72
1917	31.20
1918	25.16
1919	23.88
1920	22.75
1921	26.70
1922	36.08
1923	16.69
1924	24.24
1925	27.20
1926	16.70
1927	20.49
1928	27.78
1929	22.52

Source: G.O.No.316 Mis LSG [PH], 10-2-1933.

Large-scale river water diversion for irrigation combined with contamination of available sources added to water scarcity in Tiruppur in the early 20th century.

TABLE 11:
Chemical Examination of Koilveli Springs

Physical appearances colour and transparency	-slightly yellowish but clear
Smell	-none
Quantitative (parts per 100,000):	
Total solids parts per	45.0
Temporary hardness	17.5
Permanent hardness	10.0
Chlorine	1.420
Free ammonia	0.003
Albuminoid ammonia	0.003
Nitric nitrogen	
Qualitative:	0.225
Nitrates	Nil
Sulphates	Present
Phosphates	Nil
Iron, poisonous metals	Nil
Microscopic exams of suspended Matter	Practically no deposit

Source: G.O.1327 Mis LSG (PH), 8-8-1923.

Numerous potential sources were investigated for Tiruppur water supply.

but this scheme was kept under suspension until a drought season (G.O.No.4965 Mis LSG [L and M], 14-11-1934). Later, the scheme’s expenditure was reduced to Rs 1,82,370, of which, Rs 9,1185 was of share the government and the rest as municipal contribution (G.O.No.908 Mis E and PH [PH],3-3-1941).

The Koilveli water supply scheme provided only 75,000 gallons of water per day distributed through some 20 public taps. This was inadequate and did not serve even one-third of the water demand of municipality (G.O.No.4203 Mis E and PH [PH], 28-11-1949). Consequently, Tiruppur looked for additional schemes to increase water supply.

In 1949, the government sanctioned investigation of a water supply scheme with the Bhavani River as the source to serve Tiruppur and seven nearby villages: Pogalur,

Kurukkalaiyampalayam, Annur, Karavalur, Nombiyampalayam, Avanasi and Tirumuganpundi (G.O.No.844 Mis HELA [H], 3-3-1956). Later, Karamadai, a nearby village also was included under this scheme (G.O.No.2012 Mis Health, 27-5-1953) and the Tiruppur municipality agreed to adopt it (G.O.No.4203 Mis E and PH [PH], 28-11-1949). In 1949, the Sanitary Engineer also recommended provision of supply from the Coonoor River as the most suitable and economical scheme. He estimated the cost at about Rs 10,600,000 with an annual maintenance charge of Rs 1,38,000 (G.O. No.1520 Mis HELA [H], 7-5-1956). As a result, although supply from the Bhavani appeared feasible, attention shifted to using the Coonoor as a source.

In 1953, the Sanitary Engineer of Coimbatore reported that the minimum flow of the Coonoor River was 56 cusecs and that only 5 cusecs were required for the Tiruppur water supply. His analysis indicated that diversion of the 5 cusecs would not affect riparian interests in the Coonoor River and the irrigation interests under the Lower Bhavani Project (LBP) (G.O.No.844 Mis HELA [H], 3.3.1956). He further reported that the estimated cost of the scheme would be Rs 9,125,000. Based on these recommendations the Tiruppur water supply scheme was sanctioned in 1955 with the Coonoor River as the source (G.O.No.1520 Mis HELA [H], 7-5-1956). This scheme was inaugurated by the Chief Minister on 7-7-1955.

Progress on the scheme did not, however, last long. The Chief Engineer (Irrigation) indicated that, based on results of gauging conducted in the Coonoor River, it was not possible to tap water from the river for the municipal water supply without it being detrimental to irrigation (G.O.No.

844 Mis HELA [H], 3-3- 1956). Consequently the government suspended this water supply scheme. As a result of the suspension, the people of Tiruppur municipality protested against deferring the execution of the water supply scheme, particularly after work had been inaugurated. The municipality pressured the government to proceed with the work with the Bhavani River at Mettupalayam as a source. According to them, even

after the change over to the Bhavani River, the portion of the scheme beyond the Bhavani bridge would remain the same as designed and approved for the scheme that originally had the Coonoor as the source (G.O.NO.1520 Mis HELA [H], 7-5-1956). Finally, in 1956, the government recommended the scheme be continued and a loan of Rs 2,500,000 was also sanctioned (G.O.NO.1520 Mis HELA [H], 7-5-1956).

Industrial Water Supply: 1900-1970

The Problem

Until the early twentieth century, water from the Bhavani River and its tributaries was used only for irrigation and was never diverted either for supply to towns and villages or for industrial concerns. During the early twentieth century, only small amounts of water were diverted to Coimbatore Municipality and to some extent to the Railways and other industries. However, in the second half of the twentieth century, diversions to small towns, villages and industry increased substantially.

Whether diversion of water to the industries created any scarcity for agriculture is an important question. It is also important to have a comprehensive understanding of the adverse impact on the environment that discharge of industrial effluents created. These basic factors are an essential part of the context in which to evaluate the government's policies and the role of the judiciary towards effective water management in the Bhavani River basin. Reactions of local inhabitants are also a core part of that context. Information on the extent of farmers protests and the measures taken by the government to protect

the farmers' interests and water quality in the Bhavani River basin is central to understanding water management and environmental problems.

The main objective of this section is to understand government policy regarding industrial water supply in a historical perspective between 1900 and 1970. This section focuses on the history of water diversion to the Railways, water supply to industrial concerns and the attendant environmental issues in the light of the government policies.

Water Supply to the Railways

When water from the Bhavani and its tributaries was diverted for the Railways at the end of the nineteenth century, the government did not visualize any major implications for the agricultural sector. Initially, the government collected water charges from the Railways at a flat rate without considering the quantity of water taken. Starting in 1898, the South Indian Railway Company diverted water from the Kallar River at Kallar in Coimbatore district through pipes (Letter No.2979 Mis, PW and L, 28-11-1931). From 1902 onwards, it also took 4,000 gallons of water per

*People protested
against
delaying the
implementation
of water
projects.*

day to the Mettupalayam railway station from the Odanthorai channel in Coimbatore district and paid 6 rupees-10 annas-6 paise per annum to the Revenue Department (G.O.No.3010 Mis PW and L (I), 23-10-1929). The Railway company was informed that supply of water would be stopped at any time if it affected irrigation of the *ayacut* under the channel (BP. No.1880 Mis, 24-3-1902). In spite of this, there was no indication of any resentment among the farmers against the diversion of water to the Railways.

Railways were competitors for water.

The governmental authorities neglected collection of the minor water charges from the Railways until 1926. In 1927, the government changed the mode of collection and fixed the tariff according to the actual quantity of water, thereby replacing the earlier flate rate. Under the new system, the Railway Company was charged Rs 3 per 1,000 cubic yards for drawing water from the government sources (G.O.No.2183 (I) PW and L, 28-9-1927). The rate was based on that already established by the South Indian Railway Company for drawing water from the Odanthurai channel (G.O.No.3010 Mis PW and L (I), 23-10-1929). It was estimated on the basis that the 3 inch pipe would irrigate about one acre of land. It was further stated that this rate would be continued for the Railway Company subject to modification in every decade (G.O.No.1307, PWD Mis, 16-4-1948).

Beginning in October 1898, the South Indian Railway Company began diverting water from the Kallar River through pipes. The government meanwhile ordered that the water charges should be collected from company starting at the beginning of 1898. The railway company did not, however, oblige. Nothing much was done until a

government order was issued in 1928 indicating that, although the government had ordered the Railway Company to pay in 1909, it has never charged as no agreements had been entered with it (G.O.No.1784 PW and L (I), 19-7-1928). The company, however, requested the government to waive the balance due. Consequently, in 1931, the government ordered that tariff on the South Indian Railway Company should be levied only from September 28, 1927 and waived the earlier dues (G.O.No.2903 Mis PW and L (I), 19-11-1931). This history shows that the government consistently neglected the need to regulate water supply to the Railway Company until the first quarter of the twentieth century. At the same time, it must be recognized that in those days, the Bhavani River water was diverted only through old channels such as the Arakkankottai, Thadappalli and Kalingaroyan canals. As such, diversion of water to the railways may not have posed a serious threat to the agricultural sector.

Even though there was no representation from the farmers' side regarding the water diversion to the Railways, the government did hike the water charges further in 1948. The government raised the rates for water drawn for the Railway Company from irrigation sources and navigation channels to Rs 6 per 1000 cubic yards, subject to a minimum of Rs 100 per annum (G.O.No.1307 Mis, PWD, 16-4-1948).

During the second half of the twentieth century, water supply to the Railway Company was regulated by installing meters and other measuring devices. In 1954, the government proposed to fix meters or other suitable devices to measure the quantity of water and maintain them at the government's cost. The Railway was responsible

for the proper housing and safe custody of the installed devices. Rent for the meters and cost of repairs or replacement due to the negligence of the Railway would be adjusted in the accounts of the Railway. The Railway was also responsible for maintaining a log book containing daily entries of the quantities of water drawn.

Water Supply to Industries

Traditional industries have utilized Bhavani waters in small quantities since historical times. Originally, the water diverted for industrial uses probably did not create any issue inviting the government's policy attention. In Karnool district of Andhra Pradesh, for example, factories drew water from the Karnool-Cuddapah canal for up to 40 years before 1927 without paying any charges. Since the Bhavani River basin was also part of the Madras Presidency similar practices may have been common in the study area as well.

Different kinds of water charges for industries were introduced in 1909. At that time, the government fixed the rate for industrial water supply at Rs 3 per 1,000 cubic yards if taken by means of sluices or pipes and Rs 80 for the same amount taken by hand. Both types of diversion were subject to a minimum charge of Rs 50 per annum unless the industries were specially exempted or concessional rates allowed by the government (G.O.No.441 PWD (I), 19-10-1909 and G.O.No.1200 Mis, PW and L, 1-6-1927). Following non-compliance of the 1909 Government Order directing the authorities to collect the outstanding tariff, in 1928 the government again advised them to charge the industries for taking water from government sources (G.O.No.1784 PW and L (I), 19-7-1928). Available historical records to this

point suggest that diversion charges were imposed solely to increase government revenue. They do not suggest that water supply to industries was regulated due to objections raised by farmers or that the water tariff was imposed to ensure constant water supply to farmers or for environmental protection from industrial effluents.

During the second quarter of the twentieth century, water demand for the industries increased substantially in the Bhavani River basin. For instance, in 1925, the Sanitary Engineer estimated that about 50,000 gallons of water per day were utilized by factories in Coimbatore and could generate revenue worth Rs 9,000 per annum at a rate of eight annas per 1,000 gallons (G.O.No.888 Mis, PWD (W), 26-6-1925). Rates were not, however, increased. In 1940, when the Chief Engineer (Irrigation) proposed raising water charges, the government deferred implementation due to the Second World War (G.O.No.2093 Mis PWD, 6-8-1945). Until 1945, the minimum rate was only Rs 3 per 1,000 cubic yards. In 1945, the government did accept the recommendations of the Chief Engineer, though implementation was further postponed until normal conditions were restored after the Second World War (G.O.No.2093 Mis, PWD, 6-8-1945).

Until 1946, water charges were collected at different rates based on the method of lifting and the quantity of water. Finally, in 1946, the government modified the earlier rules for supplying water to the industries from government sources. The entire quantity of water actually used for boiling purposes was to be charged at the rate of Rs 3 per 1,000 cubic yards. If used for cooling purposes, without exceeding the permitted quantity, the rate was one-fourth of this full official rate.

The government regulated the supply of water to railways.

Different rates were charged for supplied water.

To obtain this rate, the company was required to return the same quantity of water into the channel or river. The government order further stated that all expenses connected with meters and other devices should be borne by the company and that penalties of Rs 8 per 1,000 cubic yards would be charged if companies drew more than the prescribed quantity. Charges for the estimated quantity of water required by the company were to be paid in advance (G.O.No.2538 Mis, Revenue, 19-11-1946).

In 1948 the water charges were increased to Rs 6 for 1,000 cubic yards (G.O.No.1307 Mis, PWD, 16-4-1948). This rate applied to water from streams, government irrigation systems and navigation channels and to all types of industrial uses including rice mills. Users were also subject to a minimum charge of Rs 100 per annum (G.O.No.1307 Mis, PWD, 16-4-1948). In the case of water taken for cooling purposes and returned undiminished and unpolluted to government sources, a concessional rate was fixed at the rate of one rupee and eight annas per 1,000 cubic yards. If the water was not returned to the channel the water cess was to be at the basic Rs 6 per 1,000 cubic yards rate applicable to all industrial purposes. These requirements and those for diversions for cooling represent the first indication of environmental considerations.

Aside from the nascent emphasis on water quality and protection from pollution, the government imposed some restrictions on industries, which reflected the importance of irrigation for agriculture along the river and its channels during the second half of the twentieth century. In 1950, for example, Solar Industries and Traders Ltd, Punjai Lakkapuram, Erode,

approached the Executive Engineer, PWD, Erode, seeking permission to take water from the Kalingarayan canal. They were refused permission on the grounds that the canal water was intended only for irrigation purposes. The government, however, granted permission to take water from the channel in the same year at the rate of Rs 6 per 1,000 cubic yards under the following conditions (G.O.No.4801 Mis, PWD, 26-11-1951).

- 1) Pumping was not to be done directly, but with the help of a cistern to be built by the company at its own cost.
- 2) Cisterns were to be supplied by a 6" diameter sluice with a headwall tube built at the site to be selected by the PWD.
- 3) The sill level of the sluice would be kept about one foot above the bed level of the channel
- 4) The company was to agree to pay water charges fixed by the government
- 5) During scarcity and closure periods, water would not be allowed to be used for industrial purposes.
- 6) The company should not change or modify any of the arrangements fixed initially.
- 7) In the event of infringement of any of the conditions the pipe sluice would be blocked permanently and no diversions of water from the channel would be permitted.

The above conditions show that the government had initiated certain measures to regulate industrial water supply in order to protect the

farmers. A similar situation also occurred in the case of the United Bleachers Ltd. factory, which was located on the right bank of the Bhavani, close to the railway bridge in Mettupalayam. This factory required about one cusec of water. The company accepted payment of the usual cess of Rs 6 per 1,000 cubic yards for the water consumed and the government permitted it to draw water for 10 years from March 1, 1954 by sinking borewells in the riverbed with the following conditions:

- 1) the company was not to use the water for any purpose other than processing in the factory.
- 2) the company was to pay charges at the rate of Rs 6 per 1,000 cubic yards subject to a minimum of Rs 100 per annum or any other rate fixed by the government from time to time.
- 3) After processing the effluent, water was to be treated properly before being let into the river.
- 4) the meters installed by the company at its cost should be open at all times for inspection by the officers of PWD or the Revenue Department.

Conflicts over Water supply

Disputes and conflict over allocation of water have been seen in both Noyyal and Bhavani river basins since the beginning of the century. The following section discusses the history and nature of the conflicts.

Debates over Interbasin Diversions

During the same period that demands for water supply to the municipalities of Coimbatore and

5) the company should bear the cost of drawing water and also for letting it back.

6) the company was not to claim right to draw water and the permission was liable to be cancelled at any time (G.O.No.1797 Mis, PWD, 17-5-1954).

Since Independence, successive governments have paid little attention to interest of the farmers and water quality, while allowing water diversions for the industries. Until 1977, no separate act was enacted to minimise or control the discharge of effluents by industries. In 1977, under the Water (Prevention and Control of Pollution) Cess Act 1977 (Act No. 36 of 1977), water charges were fixed for industrial purposes at a rate of three-quarters of a paise per cubic metre for cooling, spraying in mine pits or use in boilers; 2 paise per cubic metre for processing in which the water becomes polluted but the pollutants are easily bio-degradable. The rate was higher – two and half paise per cubic metre – for processing whereby water becomes polluted and the pollutants are toxic and not easily bio-degradable.

The government initiated measures to regulate industrial water supply in order to protect farmers' interests.

Tiruppur were increasing, lack of water supply in the Noyyal River basin forced the farmers of Palladam and Coimbatore taluks to demand more water for irrigation (G.O.No.496 PWD [I], 9-9-1890). As a result of these increasing demands, the idea of diverting Bhavani water into the Noyyal basin emerged during the last quarter of the nineteenth century. The proposal did not, however, proceed within the government due to the prohibitive cost (G.O.NO.127 PWD [I], 1-3-1890). Farmers constantly made representations to

reconsider the decision not to proceed with the proposal, but the government refused to do so (G.O.No.496 PWD [I], 9-9-1890).

Although the proposal was not being pursued by the government, it remained under discussion by farmers and other institutions. In 1923, a proposal to utilize surplus water in the Bhavani by diverting it through a tunnel into the Noyyal basin for irrigation was developed. This proposal has been under consideration ever since. Under this proposal, it was expected that excess Bhavani water could be diverted through this tunnel between June 1, and December 15 and would be sufficient for direct irrigation of 1,600 acres of paddy. This irrigated area could be doubled if a storage facility could be developed in the Noyyal basin (G.O.No.2339 I Mis PW and L, 14-10-1927). Meanwhile, the Siruvani water supply scheme (discussed above for Coimbatore municipal supply), was finally implemented in 1931. After meeting the drinking water needs of Coimbatore, this scheme was believed to have substantial excess water that could be diverted through its tunnel into the Noyyal valley.

Aware of the importance of utilizing any surplus water passing through the Siruvani tunnel for irrigation, but uncertain as to the amounts actually available, the government issued a memorandum to the Coimbatore Municipal Council. The memorandum stated: “the Coimbatore Municipal Council is informed that the Chief Engineer for Irrigation has reported that sufficient reliable information is not available as to the quantity of water which may be drawn through the tunnel and as to the surplus quantity which will be available for irrigation in the Noyyal valley and that in order to divide the area for

which water would be available for direct irrigation, the gaugings of the stream for two years have been ordered. He has also reported it is only after the results of the two years’ gaugings of the Siruvani have been received and the Superintending Engineer has submitted his report on the investigation of a channel in the higher reaches of the Noyyal that it will be possible to formulate proposals for the most profitable use of the surplus water passing through the tunnel for purposes of extension of irrigation” (G.O.No.2112 Mis, LSG [P.H], 26-10-1927). The debate over water availability continued, and diversion for irrigation did not take place until 1944. Until then, the government was considering various alternative proposals and decided to postpone the diversion of Bhavani water into the Noyyal basin until a decision on the Lower Bhavani Project was reached (G.O.No.3936 Mis, PWD, 22-10-1949).

In September 1944, the PWD diverted Siruvani water into the Noyyal basin for irrigation purposes. This was done for 14 days without the previous consent of the Coimbatore Municipal Council. Taking offence, the municipality claimed that the government should compensate the city for the diversion (G.O.No. 2544 PWD, 1-10-1945). This was turned down by the government on the grounds that “there was no occasion to agree to the request for payment of compensation to the municipality for diversion of water from the Siruvani reservoir into the Noyyal basin for irrigation purposes.” The government’s communication further said: “It is not, however, obligatory on the part of the government to consult the Municipal Council in regard to the utilization of the surplus water of the reservoir after meeting the requirements of the town water supply” (G.O.No.2544 PWD, 1-10-1945).

Proposals for interbasin water transfer to meet irrigation needs in Palladam and Coimbatore were made during the 1890s but rejected due to cost.

The question of diversion again cropped up after the Lower Bhavani Project was finalized in 1946. In 1946, farmers who had been pressing the government demanded that: 1) The usual flow of water in the Chitrachavadi channel should not be restricted, and 2) sufficient water should be allowed through the tunnel in the Siruvani River for storage in irrigation tanks in and around Coimbatore. In the same year, the Executive Committee meeting of the Madras Chamber of Agriculture passed a resolution urging implementation of the farmers' demands (G.O.No.3936 Mis PWD, 22-10-1949). The Executive Engineer reported, however, that the free flow of water in the Chitrachavadi channel was not disturbed except from April 1 to 21 in every year and that this disturbance was essential in order to complete annual repairs. In addition, he indicated that it was not possible to interfere with operation of the Siruvani drinking water supply scheme. Finally, he indicated that there was a separate proposal for diverting the Siruvani River itself into the Noyyal basin for irrigation purposes (G.O.No.3936 Mis, PWD, 22-10-1949).

While this was all going on, members of the Madras Legislature and the Central Legislative Assembly from Coimbatore district were discussing development of an irrigation scheme for utilizing the Bhavani water in Avanashi, Palladam and Dharapuram taluks. Various alternative proposals were examined and it was finally decided to postpone the scheme until a decision was reached on the Lower Bhavani Project. In 1947, V. C. Palanisamy Gounder, MLA, wrote a letter to the PWD Minister requesting him to issue very urgent instructions to the chief engineer for irrigation have the

proposed plans for raising the Siruvani dam estimated expeditiously and sanctioned at an early date (G.O.No.3936 Mis, PWD, 22-10-1949). After finalizing the LBP, the government decided to increase the height of the Siruvani dam by 4 feet to divert the water through the tunnel for the Noyyal basin. In 1949, the government issued the necessary order with a view to enhancing water supply to an existing *ayacut* of 3,500 acres under the Noyyal River (G.O.No.3936 Mis, PWD, 22- 10-1949).

In 1948, the Coimbatore Municipality passed a resolution allowing diversion of surplus water through the Siruvani project tunnel between June and September for irrigation purposes subject to the following conditions:

- (i) The diversion were required to be without prejudice to the rights of the municipality for the supply of 35 gallons per head per day;
- (ii) The municipality reserved the right to stop the diversion if and when it was found that the supply had prejudicially been affected.
- (iii) The government was required to investigate and ascertain the stability of the dam's foundations before the scheme was put through.
- (iv) The government could pay a contribution to the municipality towards the maintenance of the water works out of irrigation funds; and
- (v) Should there be change to any portion of the water works including the tunnel consequent on the release of the surplus water, the government was required to reimburse the municipality all expenses (G.O.No.3936 Mis, PWD, 22-10- 1949).

The state had a major role in making decisions over water allocation.

The above conditions were substantially accepted and the scheme was implemented. Only conditions four and five remained to be settled (G.O.No.3136 Mis, PWD, 4- 9-1954).

After the completion of the works to raise the dam's height, the municipality permitted the diversion of between 20 and 40 cusecs of water through the tunnel from September 1950 to June 1951. This water was mainly utilized by the existing *ayacut* under the Chitrachavadi channel. In July 1951 slight damage occurred in the tunnel leading to a temporary breakdown of water supply for Coimbatore. Consequently, the municipality refused to allow water through the tunnel for irrigation purposes stating that the water supply for the town had been disturbed due to increased draw through the tunnel (G.O.No.790 Mis, PWD, 2-3-1955).

To achieve the objective of ensuring water supply for irrigation and to reach an agreement with the municipality, the two outstanding conditions were examined in consultation with the Chief Engineer, Sanitary Engineer, and the Municipal Council as well as the Health and Local Administration Departments. They suggested that the Siruvani dam, approach channel, tunnel, and associated works could be taken over by the PWD and certain safety measures be carried out in the tunnel to prevent any possible collapse. They also suggested that the average annual expenditure of Rs 23,000 incurred on maintenance works should be recovered from the municipality as its contribution towards the cost of maintenance. The government realized that if the PWD took over the maintenance of the tunnel, difficulties in diverting water for irrigation purposes could be solved (G.O.No.3136 Mis, PWD, 4-9-1954). In 1955, the

District Collector discussed the surplus water diversion at the district board meeting and the board had approved the inclusion of the scheme in the Second Five-Year Plan (G.O.No.4182 Mis, PWD, 7-11-1955).

The above history indicates that, while the concept of inter-basin water diversion had emerged by the end of the nineteenth century, no diversions were implemented until the water supply scheme was launched for Coimbatore City. Both the farmers of Noyyal basin and the elected representatives of the Coimbatore region had discussed the possibility of inter-basin transfers for almost for half century. During that period, the concept of transfers did not generate much debate even in the source area. There were no major objections by farmers of the Bhavani River to the diversion of water into the Noyyal basin. It was only when Coimbatore municipality actually diverted Bhavani water for drinking water supply that issues associated with inter-basin diversion began to be discussed extensively. Even then, the conflict that erupted was not generated by users in the source area. Instead, it centred around the diversion facilities (tunnel capacity, etc.) and irrigation revenue. Debates over revenue occurred between the municipality and PWD over the municipality's demand for a certain amount of the irrigation revenue in return for allowing its facilities to be used to divert surplus water.

The inter-basin water diversion debate continued until the early 1950s. Nothing was resolved due to the conflict between the municipality and the state. By the time decision was arrived at on diversion, there was no surplus water left due to the increasing population growth and industrial development in the town of

The cost of maintaining water systems was recovered from municipalities.

Coimbatore. After this, attention shifted to municipal water supply schemes.

Conflicts Between Municipalities and the State Government

As water diversions increased in the study area, conflicts emerged between municipalities and the state government. On the surface, these conflicts were related primarily to the sharing of project costs and water charge income. On a deeper level, however, they reflect tensions over the government's claim of ultimate ownership and authority over water resources. The history in Coimbatore illustrates these tensions.

Conflicts regarding contributions for irrigation benefits

As proposals for the Siruvani water scheme to divert water from the Siruvani to the Noyyal basin for Coimbatore water supply progressed, tensions emerged between the municipality of Coimbatore and the government. These conflicts were not directly over water but related to the contribution of funds for the water supply scheme. The Coimbatore Municipal Council demanded that the government contribute a certain amount from the "irrigation funds" for the Coimbatore water supply scheme on the basis that the Siruvani water would be used for irrigation purposes. The government refused this demand and pointed out that there was nothing new in Siruvani water being made available for irrigation as it was only a diversion from the Siruvani to Coimbatore. Furthermore, the government pointed out that no storage would be provided for irrigation. In this context, the

government categorically stated that no contribution would be given from the irrigation funds (G.O.No.1746 Mis PH, 27-11-1924). Later, in 1926, the Coimbatore Municipal Council insisted that the government pay reasonable costs from "irrigation funds" for the diversion from the Siruvani to Noyyal. This too was turned down (G.O.No.1787 Mis LSG [PH], 7-10-1926). In 1927 the municipal council again sought a reconsideration of the government's decision. The government responded that, "a contribution from irrigation funds can be considered only if and when it is found that irrigation is benefited by the water supply scheme" (G.O.No. 93 Mis LSG [PH], 19-1-1927). The dispute simmered on until 1945 when the Coimbatore municipality claimed compensation for the diversion of water from the Siruvani reservoir into the Noyyal basin for irrigation. Again the government refused saying, "there is no occasion to agree to the request for payment of compensation to the municipality for diversion of water from the Siruvani reservoir into the Noyyal basin for irrigation purposes" (G.O.No.2544 Mis PWD, 1-10-1945).

The conflict between the municipality and the state government regarding funds stemmed from the government's approach towards the local bodies. When a local body demanded a share from the "irrigation funds", the government refused stating that the scheme was not meant for irrigation. But, when it found surplus water, the government appropriated it for irrigation purposes without paying any amount to the local bodies. It thus treated the local bodies as "secondary citizens" as far as the sharing of irrigation funds and compensation for the surplus water diversion was concerned.

Conflicts over water reflect tension between the state's claim of ultimate ownership over water resources and the perspectives of municipalities.

Conflicts Regarding Water Charges

Until the 1860s, the question of taxing water supplied from government sources for drinking water supply had not arisen in the Madras Presidency (G.O.No.1433 I PW and L, 14-5-1930). Furthermore, once the principal of taxing water supplies had been established there was little uniformity in the rates for water supplied to local bodies from government sources. A few municipalities and the Madras Municipal Corporation paid on the basis of quantity, others paid only a fixed amount irrespective of the quantity drawn and yet others paid nothing (see Appendix - 1). In 1868, charges were fixed for the very first time at Rs 1 for 1,000 cubic yards for the Madras Corporation. This rate was arrived at by dividing the quantity of water required for maturing a crop on an acre of land (estimated at 7,000 cubic yards) with the then current water-rate of Rs 7 per acre (G.O.No.1433 I PW and L, 14-5-1939). The same rate was also adopted in the case of Cocanada, Masulipatam, Ellore and Chidambaram municipalities. In some other municipalities, such as Berhampur and Karnool, a fixed charge was made irrespective of the quantity of water taken (G.O.No.1433 I, PW and L, 14-5-1930). In 1930, the government passed an order stating: "so far as existing water supply schemes of local bodies are concerned, no charge for water taken from government sources shall be levied where none has been levied hitherto. But, in fact any future time, in connection with improvements to existing schemes or carrying out of new schemes, any considerable quantity of water has to be diverted from irrigation sources, it will be open to the government to decide what, if any, charge shall be levied on that account" (G.O.No.1433 I PW and L, 14-5-1930).

The state government treated local bodies, such as municipalities, as "secondary citizens" when making water allocation decisions.

Charging water rates for the urban supply to Coimbatore was not discussed while considering various sources between the 1890s and the early 1920s. In 1926, the government passed an order stating that "the Coimbatore municipality will, for the present, be permitted to take water from the Siruvani river for its water supply scheme, free of charge, but if and when irrigation is affected the question of charging for the water will be considered" (G.O.No.1814 I PW and L, 29-11-1926). The municipality refused to accept the government order and pointed out that the question of charging for the water supply had never been indicated by the government right from the inception of the Siruvani scheme. The municipality contended that even while finalizing the scheme the government had not mentioned it (G.O.No.168 I PW and L, 24-1-1927). When the municipality requested reconsideration of the decision, the government responded that when such a contingency arose the council representations would be considered (G.O.No.168 I PW and L, 24-1-1927). In 1934, the government issued an order stating that "if a local body getting its supply free of charge from a government source and sells water for non-domestic purposes, it should pay to the government one-third of the total amount realized by it every year from such sales" (G.O.No.1297 I PWD, 15-6-1934). The municipal council did not, however, accept this. As a result, in 1935, the government indicated that Coimbatore's rate concession was given only for the time being and there was no reason to exempt the council from the payment of water charges (G.O.No.1297 I, 15- 6-34) (G.O.No.1698 Mis I PWD, 30-7-1935).

This led to a long running dispute over water charges by the government to the municipality.

The municipality claimed that while sanctioning the Siruvani scheme, the Chief Engineer had accepted that the cost of maintenance could be met from income derived through the sale of water for non-domestic purposes so long as it did not affect irrigation. Since irrigation had not been affected at present, the government, it said was not entitled to levy a charge on the water sold for non-domestic or industrial concerns. Therefore, the council considered filing a suit seeking a declaration that the Government of Madras was not entitled to claim any share of the revenue from the sale of water for non-domestic consumption. This prompted the government to direct the Collector to take appropriate steps in case a suit was filed (G.O.No.1784 Mis, PWD [I], 31-3-1937). Consequently, the municipality gave up the litigation and paid the amount to the government (G.O.No.106 Mis, PWD I, 16-1-1946).

Conflicts between Urban People and the Municipality Regarding Water Tax

In order to meet the cost of the Siruvani water supply scheme, Coimbatore Municipality proposed hiking the property tax from the 7.5 per cent prevailing in 1924 to 15.5 per cent. This would be implemented as a consolidated rate based on the annual rental value of all buildings and the land within the municipal limits and would start from October 1, 1925. In addition, they proposed that the existing property tax of two annas for every 80 square yards would be increased to four annas. These increases were to be allocated as water and drainage taxes respectively. Social organizations and the public at large protested against the proposed increases. Meetings of tax

payers were held in 20 wards of city between February and March 1925. Eighteen wards completely rejected the proposed hike for the Siruvani water supply scheme and two wards accepted it with certain conditions (G.O.No.821 Mis LSG [PH], 28-4-1927). Six public meetings were also held in different places of the city. Petitions containing thousands of signatures were sent to the chairman of the municipal corporation from the wards protesting against the tax increases. Several suits were filed in the District Munsif court challenging the hike, and a lower court as well as an appellate court held that the council levy was illegal (G.O.NO.1845 Mis LSG [PH], 23- 9-1927).

Those protesting the tax increases for the water supply scheme mainly demanded that: (1) either the government should bear the entire centage charges; (2) it should bear three-quarters of the cost of the scheme; (3) interest on the loan should be reduced and the repayment period extended to 50 years; (4) the agriculture and forest colleges, police recruitment school and central jail should be included in the municipal limits and made subject to any taxes; and (5) the water tax on annual income should be reduced to 5 per cent (G.O.No. 1792 Mis LSG (PH), 26-8- 1925). The government refused to concede to these demands, except for reducing the centage charges, and pointed out that water and drainage tax in Coimbatore were very low when compared to the prevailing rates in 14 other municipalities (Appendix -2). If these charges were reduced below 8 per cent, the municipal council would not be in a position to finance its share of the cost of the scheme (G.O.No.1845 Mis LSG [PH], 23-9-1927).

In 1927, the government issued an order

In 1925 proposals by the government to raise water taxes were opposed by social organizations and the general public through public meetings and legal actions in Coimbatore.

Tension over water rates represented a continuing source of conflict between the government and the municipality.

indicating that if the municipal council undertook the proposed drainage works, the tax rate would be increased with a final level determined after finance requirements for the scheme had been considered (G.O.No.525 Mis PH, 25-3-1927). This led to public protests, and the municipal council passed resolutions clarifying that there would be no need for additional taxation. To substantiate its stand, the council noted that property values were steadily increasing leading to increased tax revenues at the then current assessment rate. Overall income from the property tax, for example, had increased from Rs 46,662, in 1915/16 to Rs 1,03,000 in 1926/27. Increases of this type, it was argued, would be sufficient for completion of the water supply scheme with no change in rates. Overall, tensions over rates represented a continuing source of conflict between the government and the municipality.

The above types of tensions were common between the government and municipalities. A situation similar to the one in Coimbatore developed between the government and the Erode municipality. At the inception of a major water supply scheme for this city the government did not mention anything regarding the payment of water charges for taking water from the Kalingarayan channel and the Cauvery River. The only condition on water diversions was that no damage would be done to the channel. Starting in 1919-20, the municipality drew water from the Cauvery River without paying and without the government demanding any charges. In 1930, however, the government ordered the municipality to pay water charges from 1920 to 1929 at a rate of Rs 1 per 1,000 cubic yards. The municipality requested the government to withdraw the charges stating financial hardship. In the end, the

government agreed that no charge need be levied from the Erode municipality for water drawn either from the Cauvery or the Kalingarayan channel (G.O.No.2269 I PW and L, 25-1-1930).

Water Conflicts between Farmers and State Government

Water diversion for domestic water supply created conflicts between farmers and the state in the Bhavani and Noyyal River basins. The government did not support farmers' protests against water diversion, but mostly favoured drinking water supply schemes in the towns and villages of these basins. The farmers of Chitrachavadi channel protested diversion of water from the Anayar and Periyar rivers to supply Coimbatore. Disregarding the farmers' objections, the government passed an order in favour of the Coimbatore municipality. They also decided to supply the water without any levy. The municipality was warned, however, that if there was any adverse effect on irrigation, the government might at any time cancel the permission granted to tap the sub-soil water from the Anayar and Periyar rivers (G.O.No.1189 I PW and L, 11-4-1930).

In a similar situation in 1949, the government proposed diversion of water from the Coonoor River to provide drinking water to Tiruppur. Opposing this, the farmers of Nellithurai, Thekkampatti and Odanthurai villages requested the government to abandon the scheme fearing that it would affect irrigation (G.O.No. 844 Mis HELA [H], 3-3-1956). According to their protest, about 2,000 acres of paddy and betel nut groves would be affected and about 2,000 agricultural labourers would be

deprived of their employment. In addition, the farmers indicated that shortages of irrigation water were already causing suffering. Consequently, in 1956 the government ordered that work on the Coonor River water supply scheme should be suspended. The government also ordered the Chief Engineer, PWD (GL) to report on the availability of water for the Tiruppur water supply scheme from the Coonor River (G.O.No. 844 Mis HELA [H], 3-3-1956).

In April 1956, representatives from the municipality and the government participated in a conference held at the Assembly Chambers. The conference proceedings stated that “the requirements of the municipality being only 3 cusecs, about 100 acres of the tope can be purchased by the municipality and the water to be utilized by this, diverted for water supply” (G.O.No. 1520 Mis HELA (H),7-5-1956). As a result, the government decided to proceed with the Tiruppur municipality water supply scheme stating that the small quantity of water required would not affect irrigation.

Conflicts over Industrial Water Supply

No conflicts between farmers and industries concerning water diversion for industrial uses are present in the historical records examined. As in the case of municipal supplies, most conflict occurred over water charges. As previously noted, in 1924 the government specifically stated that the maintenance cost of the Coimbatore Municipal Water Supply Scheme could be met from the proceeds of the sale water for industrial purposes (G.O.No.1267 Mis PWD I, 28-5-1936). In 1934, it

changed its position and stated that if the local body received supply free of cost and sold it for non-domestic purposes, the local body should pay one-third the amount of the total received through sales every year to the government (G.O.No.1297 Mis, PWD (I), 15-6-1934). Although the Coimbatore municipality protested this, the government emphasized that the municipal council could not be allowed to enjoy the entire income from the sale of water for industrial purposes (G.O.No.1267 Mis, PWD (I), 28-5-1936). It also indicated that if the municipality drew water partly from government sources it had to pay proportionally (G.O.No. 3066 PWD, 7-1936). In 1937, the municipal council countered that ‘the government was not entitled to levy any charge whatsoever on the water sold by the council to individuals, non-domestic or industrial concerns’ (G.O.No.1784 Mis, PWD (I), 31-8-1937). Based on this, the council intended to challenge the government in the court. The government too directed the Collector to take steps to meet the threat from the municipal council (G.O.No.1784 Mis, PWD (I), 31-8-1937). In 1940, the Coimbatore Municipal Council gave up the litigation and paid the sum of Rs 6,263 due to the government (G.O.No.106 Mis PWD (I), 16-1-1940).

Overall, until Independence and even after, the government considered water supply to industries only from a monetary point of view. Conflicts seldom arose in the agricultural sector against diversion of water to the industries. Only from the 1970s onwards did issues concerning industrial pollution come into the picture in the Bhavani River basin.

*Farmers
protested
against
diversion of
water from
irrigation for
municipal use
as early as
1930.*

Conclusion

In the Bhavani and Noyyal river basins, the concept of inter-basin water diversion to augment domestic water supply emerged at the end of the nineteenth century. Since then, water has been diverted from agriculture to non-agricultural sectors. These diversions, along with pollution, represent the fundamental continuing point of tension between agricultural and non-agricultural users.

Pollution represents a continuing point of tension between agricultural and non-agricultural water users.

Initial conflicts focused primarily on cost sharing for water supply schemes and water charges and their allocation between local bodies and the state government. The situation in Coimbatore in the 1930s typified these tensions. When water was diverted for the Coimbatore water supply scheme the people who demanded drinking water were not ready to pay the cost and complained that water charges were too high. The municipality was in a bind. It had to impose the tax on the water users to generate the resources essential for maintenance, for payment of its share to the state and for recovery of investments in the water supply scheme. Conflicts over the quantity of water diverted emerged gradually and were not as prominent initially as these financial tensions were. Only in recent history have tensions over pollution as well as water availability dominated conflicts over finances and project control. Water diversion for the Coimbatore water supply scheme was first envisioned in the 1890s when the water diversion for the Noyyal basin was also discussed. In the early twentieth century, a small quantity of water was diverted for the Railways and industries. At that time, neither the quantity of water nor the quality of water was an issue.

Lack of coordination among the government departments also led to unnecessary conflicts in water distribution, management and project sustainability. Although the municipality accepted the terms and conditions of the state government relating to domestic water supply, it refused to supply surplus water to the agriculture sector. When the government demanded diversion of surplus water for irrigation, the municipality protested and pointed out that the government had not paid a share of the expenses for the domestic water supply scheme. This led to conflict between the municipality, the PWD and the state government. This shows the importance of coordination among the government departments and different stakeholders for enabling efficient water management.

As time passed and diversions increased, conflicts over supply availability between urban and agricultural interests gradually increased. In general, the municipalities won most of these conflicts. In the Coimbatore case, for example, although the government placed conditions on municipal water supply schemes stating that water supply for domestic purposes would be restricted if agricultural operations were affected, when actual shortages occurred municipal supplies were maintained despite farmers' protests against the diversion and scarcity. The government did not seriously consider those protests, indicating that only a small quantity of water was diverted for domestic purposes. On the whole, the diversion of water supply did affect cultivation. This was not taken into account either by the municipality or the state. The problem is not, however, just

associated with diversions for municipal uses. In the agriculture sector increasing demand for water arose due to changing cropping patterns and the mechanization of water lifting devices. This also contributed to water scarcity. In addition, discharges of industrial effluent affected the quality of water. In this situation, how to accommodate new demands in the dynamic processes of economic transformation involving multiple stakeholders is an important question.

In the case of water use for industry and the Railways, initially they both used river water without restrictions. Neither the farmers nor the government considered industrial water use an issue until the second half of the twentieth century. In addition, during the second quarter of the twentieth century the government's main concern was revenue and it completely neglected environmental problems. Only after Independence did the government attach some importance to the protection of water quality in the Bhavani River. In short, until the 1970s, the government failed to give much attention to the diversion of water for industries and the discharge of effluents into the river and its channels. This was not, however, just a lapse on the part of the government. Farmers also were oblivious of the long term effects of

industrial water supply and effluent discharges in the Bhavani River and its tributaries.

History suggests that an effective approach to water management would be to allocate equitable shares in the available water among the stakeholders and, within that proportion, increasing demand should be managed. This could prevent the emergence of conflict due to increasing demand on scarce water resources. In addition, the government should encourage and educate farmers to cultivate less water consuming crops in water scarce areas. This would help society to meet the increasing demand both in the non-agricultural sectors and within the agricultural sector. The government should also frame scientific norms ensuring equitable distribution of water among the different sectors for efficient water utilization. At the same time, it should consider constructing tanks to harness remaining surface supplies and improve plans for effluent and drainage treatment. Unless treatment is accomplished, the constantly increasing demand for water from the domestic and industrial sector with the attendant effluent and drainage discharges will not only reduce water supply available for irrigation, but will also pollute remaining fresh water resources.

History suggests that an effective approach to water management may be to allocate equitable shares among stakeholders.

APPENDIX - 1
List of Local Bodies, Sources of Water Supply and Rate of Charges in Madras Presidency, 1927

Name of the Local Bodies	Sources of Supply	Rate of Charges Rs 1,225/1000 c. yds
Berhampur Municipality	Ichapur canal	do
Cocanada	Samalkota canal	do
Masulipatam	Bandar canal	do
Ellore	Kistna-Ellore canal	do
Madras Corporation	Red hills tank	do
Karnool	Karnool-Cuddapah canal	do
Anantapur Municipality	Wells excavated in the Bed of Pandameru River	do not pay any charge
Adoni	Gangalamanchi tank	do
Bellari	Wells excavated in the Bed of the Hagari River	do
Chengalput	Wells excavated in the bed of Palar River	do
Canjeeveram	Wells excavated in the bed of Vegavathi River	do
Tanjore	Vennar	do
Mannargudi	Vadvar Municipal channel	do
Nagapatam	Vettar	do
Chidambaram	North Rajan Channel	do

Source: G.O. No. 1845, MIS Local Self-Government (PH), 10-2-1927.

APPENDIX - 2
Property Tax and Water and Drainage Tax in Different Municipalities in Madras Presidency: 1926 (in per cent)

Name of the Municipality	Property Tax	Water and Drainage Tax	Total
Cuddapa	8 ¾	8 ¾	17 ½
Rajamundry	8 ½	8	16 ½
Masulipatam	9 ½	9	18 ½
Nagapatnam	8 ½	8 ½	17
Coonoor	10	8	18
Tanjore	8 ¾	8	16 ¾
Tuticorin	8 ½	5 ½	14
Trichinopoly	8 ½	9 ¾	18 ¼
Vellore	7	8	15
Otacamund	9	6 ½	15 ½
Conjeeveram	8	8 ½	16 ½
Ellore	8 ½	8	16 ½
Vizagapatam	8 ½	8	1 ½
Tirupathi	8 ½	7	15 ½
Bellari	9 ¾	6 ½	16
Berhampur	8 ½	8	16 ½
Kumbakonam	9	5 ½	14 ½
Nellore	9 ½	7	16 ½
Dindigul	7 ½	6	13 ½
Cocanad	7 ½	6	13 ½
Chidambaram	8	8	16
Gudur	10	5	15
Coimbatore	7 ½	8	15 ½

Source: G.O. No. 1845, MIS Local Self-Government (PH) 23-9-1927.

Abbreviations

BP	- Board Proceedings
E and PH	- Education and Public Health
G.O.	- Government Order
HELA	- Health and Local Administration
LA	- Local Administration
LBP	- Lower Bhavani Project
LIC	- Life Insurance Corporation
L and M	- Local and Municipal
LSG (PH)	- Local Self-Government (Public Health)
LSG (LM)	- Local Self-Government (Local and Municipal)
MLA	- Member of Legislative Assembly
PH	- Public Health
PW and L	- Public Works and Labour
PWD	- Public Works Department
PWD (B and R)	- Public Works Department (Buildings and Roads)
PWD	- Public Works Department
PWD (I)	- Public Works Department (Irrigation)
PW and L	- Public Works and Labour
TNSA	- Tamil Nadu State Archives
TNSAR	- Tamil Nadu State Administrative Report
TWAD	- Tamil Nadu Water and Drainage Board

Notes

¹ Unless otherwise noted all government orders and TWAD board proceedings and letters referred to in the text are from the Tamil Nadu State Archives, Chennai.

² Tamilarasu is an official magazine published by the Government of Tamil Nadu.

C H A P T E R

5

Addressing Water Scarcity

***Local Strategies for Water Supply
and
Conservation Management in
the Sabarmati Basin, Gujarat***

Summary and Findings

Water scarcity is emerging as a major source of conflict in Gujarat due to groundwater depletion and pollution.

The Sabarmati River, which flows from Rajasthan into Gujarat, plays an important role in the socioeconomic development of the state in general and the basin area in particular. The basin's water resources serve the agricultural, industrial and household needs of the 9.94 million people living within it. Competition between water use sectors – rural and urban domestic uses, industry and agriculture – within the basin is great. Increasing population, urbanization and industrialization are putting pressure on the limited water resources. This, coupled with depletion of groundwater resources and increasing pollution of surface water bodies, is causing water scarcity to emerge as a major source of conflict. Water problems are a threat to the sustainability of local communities, the environment and the region's economic development.

This paper presents preliminary results of research being carried out by VIKSAT as part of an ongoing networked project to evaluate local water management options. The purpose is:

1. to investigate water scarcity and pollution problems in the Sabarmati basin in Gujarat, India;
2. to evaluate responses by local populations to emerging water management problems;
3. to analyse the potential role different supply and demand based water management strategies could have on water availability, water demand and water quality within the basin under current conditions and in the future; and

4. to identify institutional arrangements through which water management could be implemented.

The study involves extensive fieldwork throughout the Sabarmati Basin. Preliminary results presented here relate primarily to bullets 1,3 and 4 above. Chapter six documents the major farmer movement to recharge groundwater. For the research here, a first-cut analysis of water management alternatives was undertaken using the Water Evaluation and Planning (WEAP) modelling system developed by the Tellus Institute, the Boston office of the Stockholm Environment Institute. WEAP is a mass balance "accounting" system that allows comparison of water management scenarios involving broad arrays of new supply development and demand side management options. Institutions which could potentially play major roles in water management were also investigated. The major findings are presented below.

Emerging Water Related Problems and Issues

■ **Groundwater overdraft is leading to increased costs and a decline in quality and quantity throughout the basin, but is especially strongly felt in the rural areas:** Groundwater is the major source of water in the rural areas of the basin. In alluvial areas, long term declines in water levels, resulting from excessive pumping of groundwater reduce well yields, increase in pumping costs, increase in fluoride and salinity levels in groundwater and a reduce availability of water for irrigation. The middle and lower

portions of the basin, which includes all the major urban centres, are in the alluvial zone. In the hard rock zone, that is the rural areas of the upper part of the basin, excessive groundwater pumping causes rapid seasonal declines in water levels, which result in acute seasonal scarcity of water, in turn causing a major obstacle for agricultural production.

■ **Declining water table and increased gross supply, but decreasing per capita supply of water to Ahmedabad and other centres of population:**

In Ahmedabad, as the population and industry have expanded, municipal supplies have been expanded greatly by an exponential increase in groundwater extraction through tubewells and, somewhat more recently, by further augmenting municipal supplies with diversion of water from the Dharoi – a reservoir built to supply water for irrigation in Mehsana and Sabarkantha districts, drinking water for Ahmedabad and Gandhinagar cities and for Sabarmati and Gandhinagar thermal power stations. In spite of this, the per capita water supplied by the municipal corporation in Ahmedabad declined from 197 litres per capita per day (lpcd) in 1971-72 to 125 lpcd in 1996-97. On top of this, there has also been an indiscriminate growth in the number of privately owned tubewells in the city, with their added impact on the declining water table.

■ **The quality of the resource is declining due to its pollution and depletion, leading to a further decrease in the effective supply:** Industries located in and around Ahmedabad dispose of the untreated effluents in the river bed downstream of Ahmedabad and upstream of the Vasna Barrage. Untreated municipal sewage is also discharged directly to the river. Both of these cause serious

problems of pollution of river water. The water contaminated by effluents also pollutes the agricultural fields, which are irrigated by the Fatehwadi canals that take off from the Vasna barrage. With continued large investment in the industrial sector expected in the future, the threat to surface and groundwater bodies from pollution is great. Furthermore, effective groundwater depletion is increased with the contamination by fluorides and salts that make the resource either a health hazard or unfit for many uses, or both.

■ **Overdraft of groundwater in Ahmedabad is leading to increased urban/rural competition:** With little scope for the further augmentation of supplies in Ahmedabad, the municipality is increasingly looking for rural supplies to meet their demands. This has led to reductions in allocation for irrigation in the command of reservoirs such as Dharoi in the upper Sabarmati basin and become a source of conflict between urban and rural users.

■ **No single institution in Gujarat has the expertise needed to plan and implement an updated water resource management strategy:** Generally, the more centralized institutions have the technical skills that would be required, but lack the social science, or social engineering, skills. Members of local cooperatives, on the other hand, often have a very clear sense of local conditions and needs, but may lack the technical skills and political power to implement a strategy. There are some good research and training institutions in the basin that can provide a link between these institutions.

■ **The WEAP analysis shows the urgent need for water management interventions:** A first-cut analysis of future water supplies and demand using

Municipal demands are encroaching upon irrigation water supplies.

Water management challenges are related to institutions, equity and increasing competition.

WEAP shows that, in the absence of water management interventions, the gap between demand and supply (the actual supply requirement) could increase to 1,017 MCM by 2,020 and to 1,875 MCM by 2,050.

■ **Less equitable distribution of the resource:** In addition to the above issues, the issue of equity also needs to be addressed. From the available information, resource access appears inequitable. This is reflected in the increasing competition leading to increased frequency and intensity of conflicts between different sectors of water use caused differential allocation. Equity issues are of fundamental importance and will form one of the focus areas for research in the future.

The above issues in the Sabarmati basin will lead to an increasing gap between demand and supply. This is confirmed by the WEAP analysis base case scenario. In order to address this base case scenario, four Water Management Options have been examined, again applying WEAP. The following section describes the Options and the findings in brief.

Water Management Options

The alternative water management options analysed through the study are: local recharge using excess run-off within the basin; adoption of efficient water use practices and reduced conveyance losses; conjunctive management using imported water supplies; and a combination of efficient water use and local recharge activities. The results show that:

■ Local recharge on its own would be quite insignificant in reducing the gap between demand

and supply anticipated by 2020 and 2050 A.D. WEAP modelling results indicate that implementation of this option would cause a reduction of less than 1 per cent.

■ The extent to which demand side options could help address the water scarcity gross situation in the future is quite large. This would require large-scale adoption of efficient irrigation water use technologies such as drips, sprinklers and efficient conveyance systems in the fields, and efficient water use technologies in the domestic and industrial sector. WEAP modelling indicates that these interventions could reduce the gap between supply and demand by 324 MCM and 1,005 MCM in 2020 and 2050 respectively. In other words, this means that this option could make good roughly one-third of the gap projected for 2020 and more than half the projected gap for 2050.

■ The modelling also indicates that conjunctive management of groundwater could be another option to consider. This option would entail the recharge of surplus monsoon flows diverted from the Sardar Sarovar reservoir. The available supplies due to this option would increase by 157 MCM and 156 MCM by 2020 and 2050 respectively. While this is less than what could be achieved through demand management, it still represents a significant contribution towards addressing water scarcity problems.

■ In the final analysis, the modelling suggests that a combination approach incorporating demand management, network improvement to reduce conveyance losses and conjunctive management would have the maximum potential to address water scarcity problems.

This combination of improvements should be investigated further in detail.

It must be emphasized that none of the above options is adequate in isolation. The existing institutions are too inadequate in themselves to address the issues. It is essential therefore that the institutional arrangements involve all the stakeholders throughout planning, implementing and monitoring stages. The following section details some of these measures.

Institutional Arrangements for Water Management

There are a large number of rural and urban institutions in and around the Sabarmati basin, which have major stakes in the way water is managed. They could play significant roles in basin water management in the future. Institutions that could either oversee or direct the whole process are, however, lacking at present. There is also no single coordinating institution that could define links between existing institutions. Water management institutions that might serve the above purpose are proposed below:

- **A Sabarmati Basin Water Management Society (SBWMS)** is proposed as a lead institution for coordinating management. As envisioned here, a wide array of technical, scientific and management institutions, and the municipal corporations of major urban centres would be members of the society. The society would have legal/statutory powers to enact regulations to affect water management decisions. Its mandate would be to lead the evolution of broader water management perspectives for the basin, while ensuring sustainable and judicious resource allocation and

use among user groups. Linked to this institution would be the ones described below:

- **A stakeholders forum** is proposed, which would have representation from various interest groups in the basin. The forum's mandate would be to orient the basin water management society on water management issues concerning the multiple stakeholders, to suggest management priorities and their ways of implementation, and to ensure effective participation by stakeholders in the design and implementation of water management plans. Identifying the stakeholders and representatives would be accomplished in conjunction with the regional, village/watershed level and urban level institutions described further below.

- **Village and watershed level institutions** are proposed at local levels and would have the mandate to identify local resource management issues, identify potential management initiatives, and implement the same with support from regional institutions.

- **Urban water management institutions** are proposed in urban areas. They would have a mandate to implement water management plans applicable to their respective urban areas including direct and indirect management interventions. These institutions would be entrusted with legal powers to enforce legislation, regulations and acts.

The regional institutions proposed above would have a cross cutting mandate to identify areas suitable for local water management interventions and to assist proposed local institutions in planning and implementation. Regional institutions would also be responsible for ensuring that the area has access to financial and technical

New institutions are needed to involve stakeholders and coordinate water management.

resources to implement management plans. Technical support for this would be provided by the basin water management society. In addition, establishment of tradable water rights and promotion of water markets are suggested as institutional mechanisms to achieve the

larger goals of sustainability, equity and efficiency in water use. These institutional mechanisms can take care of the water allocation and maintenance of the system in a way that is compatible with the prevailing social and physical context.

Introduction

Water scarcity problems are regional in nature and emerge from physical, social, economic and institutional factors.

In Gujarat, as in several other semi-arid parts of India, groundwater overdraft, coupled with increasing scarcity and pollution of surface water supplies, threatens ecosystems as well as many of the advances in agriculture and domestic water supply made over recent decades. Gujarat has also been the focal point for major debates over inter-basin water transfer involving water from the Sardar Sarovar (Narmada) project.

The Sabarmati River basin, which is one of the inter-state river basins in Gujarat, plays an important role in the socioeconomic development of the State in general and the region in particular. The basin is one of the water scarce basins in Gujarat and is characterized by a number of competing uses – rural domestic and irrigation, urban domestic and industrial uses. Pressures are increasing on limited water resources due to the lack of state laws and policies for water management, demographic trends and industrialization. In addition some state policies, including those promoting industrialization exacerbate pressure on available water supplies. This coupled with depleting groundwater resources and increasing pollution of surface water bodies, is leading to increasing conflict. The emerging scenario poses serious threat not only to the sustainability of the communities but also to the region's overall economic progress.

In Gujarat, as well as the rest of India, community based local water management initiatives are increasingly being recognized by NGOs, researchers and academics as a major strategy to address the growing water scarcity problems (Moench and Kumar, 1993). These local management initiatives are undertaken either by local communities or the NGOs.

Almost all NGO and community based responses to water scarcity and pollution problems – in Gujarat and other parts of India as well – focus on augmenting the available supplies of surface and groundwater in the locality (Moench, 1995). Efforts to address the issues related to demand management are ineffective and inadequate in these efforts. Further, these initiatives are highly localized with little potential to have an impact on the regional water situation. However, water scarcity problems are often regional in nature and emerge from a range of physical (such as hydrology, geology and climate), social, economic and institutional factors.

In general, experiences with comprehensive approaches to water management are scarce in India. As a result, there is a paucity of knowledge and information on the extent to which local water management interventions, which includes both supply and demand side management,

could address emerging problems of water scarcity and pollution in a region or basin. With water management issues posing a major challenge to food security and economic growth in the region, understanding the natural science and social science of basin level water management will be critical to framing water resource development and management policies for the next century.

Current water management debates in India are polarized between big dams and local management by communities. This polarization leaves little space for experimenting with the variety of other institutional arrangements, such as combinations of quasi-governmental institutions, private institutions and rural institutions. Such gaps in thinking mainly stem from a lack of clarity regarding the type of institutions which could address water scarcity and pollution problems at local, regional or basin levels.

Developing comprehensive and effective water management perspectives for a basin requires a detailed analysis of the impact of each of the

diverse interventions on the overall water supply, demand and water quality situation. It also requires analysing the extent to which each intervention should be implemented in order to balance the supply and demand, considering the economics of each intervention as also the probable future changes in the demand and supply within the basin.

Institutional issues are central to all water management debates. Being a social activity, water management decisions should reflect the needs and priorities of direct users and other stakeholders. These often conflict. Therefore, achieving larger water management goals requires compromise on the part of each one of the stakeholders with decisions being arrived at through consensus. Hence, stakeholders will find their due place in the development of management institutions. However, the types of capabilities are different for different stakeholders. Their capabilities – technical, organizational, social, legal and financial – to deal with water management issues need to be examined to suggest their potential future role in water management.

Water management decision-making is a social activity reflecting the needs and priorities of users.

Research Structure

The research project being carried out by VIKSAT in the Sabarmati basin represents a preliminary attempt to:

- investigate the water scarcity and pollution problems in the basin and the emerging issues;
- analyse the impact the various supply and demand based water management interventions could have on water availability, demand and water quality within the basin today and in the future; and
- identify the institutional arrangements for implementing the water management interventions by reviewing existing institutions in the basin and proposing alternative arrangements.

Components and Methods

The research presented here has two main components: (1) evaluation of physical options for water management in the Sabarmati basin using the Water Evaluation and Planning (WEAP) system; and (2) documentation of existing institutions in the basin of relevance for water management.

All water management options have embedded assumptions.

The physical aspects of water management have been analysed by describing existing water scarcity and pollution problems and creating water balance scenarios for the years 2020 and 2050. These scenarios were designed to investigate combinations of water management interventions and contrast these with a base case developed by projecting current socioeconomic and demographic trends. Research to develop the water balance scenarios included study definition (in terms of boundaries, time horizon and hydrology), development of current accounts for water demand (agriculture, industry, and urban

domestic) and water supplies (surface and groundwater). A wide range of assumptions (related to demographic and socioeconomic trends, policy changes, water allocation, water and energy pricing and environmental policies; water resource systems and water use technologies) also were used to develop scenarios.

The institutional aspects of water management were evaluated by documenting existing institutions (government, NGO, private and community) within the Sabarmati basin and evaluating their ability to take effective management actions based on the professional resource base. The study investigated a range of rural institutions including village dairy cooperatives, tree-growers cooperatives, and large agricultural and dairy cooperatives. Government and research institutions were also studied. These include the Water and Land Management Institute Anand, Institute of Rural Management Anand, Gujarat Water Resources Development Corporation (GWRDC), Gujarat Water Supply and Sewerage Board (GWSSB), Gujarat Jal Seva Training Institute (GJTI) and Gujarat Ecology Commission (GEC).

Figure 1:
Gujarat and the Sabarmati basin.



Assumptions and Hypotheses

Evaluating the viability of different options for addressing water scarcity in the Sabarmati basin through generation of water management scenarios required making assumptions regarding future conditions that will affect the demand and supply of water. The study was designed to test a limited number of hypotheses regarding the potential utility of specific management actions. Assumptions and hypotheses related to this are given in the next section.

The institutional portion of the study was not designed to test specific hypotheses at this stage. Many questions of institutional design can only be tested through long term experiments based on actual management initiatives. As a result, the current study was designed to identify and evaluate existing institutions. This will then provide a basis for hypothesis testing in subsequent phases of research.

Water Management Hypotheses

- Local recharge and small scale water harvesting practices can make a substantial difference to water scarcity and *in situ* pollution problems, such as fluoride concentration and salinity, if carried out systematically throughout the Sabarmati basin;
- Demand side management can make a substantial contribution to addressing water scarcity, but not as large a contribution as imports of water through the Sardar Sarovar project do;
- Conjunctive management of surface and groundwater coupled with use of water imported through the Sardar Sarovar project would make the largest single contribution to addressing water scarcity in the basin.

Assumptions used in Water Management Scenarios

- Water demand will increase corresponding to the population increase. Absence of water management interventions will lead to higher demand leading to increased intersectoral competition.

- Agriculture, industry and other economic activities in the Sabarmati basin will continue to expand at historical rates;
- Cropping patterns will undergo changes as a function of water availability and economic returns; and
- Animal husbandry patterns will remain the same as at present.

Types and Sources of Data

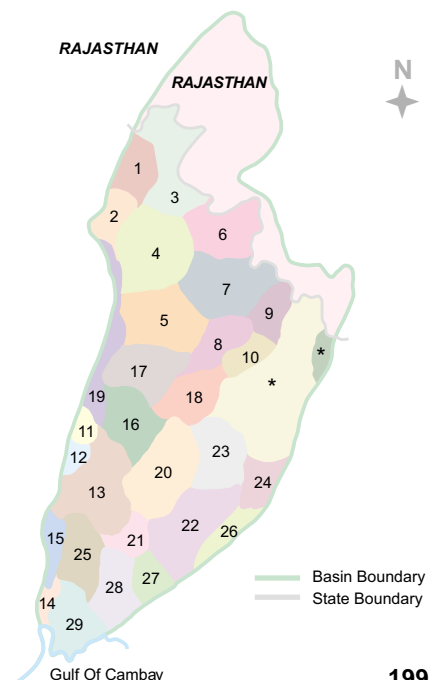
The data for carrying out the research was generated from both primary and a variety of secondary sources. For WEAP modelling, the types of data collected included hydrologic and climatic data (such as rainfall, stream flows, evaporation and evapo-transpiration rates),¹ data on groundwater recharge and extraction by taluka, releases from reservoirs and irrigation and municipal water supplies; groundwater withdrawal for municipal demand; data on crops and cropping

Assumptions in management scenarios relate to demographic trends, socioeconomic trends, pricing policy, resource systems, and technological choices.

Figure 2:
Schematic map of talukas in the Sabarmati basin.

1. Danta	2. Kheralu
3. Khedbrahma	4. Idar
5. Himmatnagar	6. Vijaynagar
7. Bhiloda	8. Modasa
9. Meghraj	10. Malpur
11. Gandhinagar	12. Ahmedabad
13. Sanand	14. Viramgam
15. Dholka	16. Dehgam
17. Prantij	18. Bayad
19. Vijapur	20. Kapadwanj
21. Mehmabad	22. Nadiad
23. Balashinor	24. Thasra
25. Matar	26. Anand
27. Borsad	28. Petlad
29. Cambay	

*Information not available



pattern by taluka from the Directorate of Agriculture; water requirements and water use rates for different crops from published reports; data on irrigation practices from field surveys; data on industrial water use; socioeconomic data (human and livestock); population (rural and urban); and population growth rates from Census reports.

In addition, for the wider study, information on investment in industries and the number and types of institutions in rural and urban areas, was collected from socioeconomic studies. Their organizational and institutional profiles were collected from primary institutional surveys and Census reports.

The Sabarmati flows through major urban settlements.

Water Scarcity and Pollution Problems in the Sabarmati Basin

Physical characteristics

Surface Water Hydrology

The Sabarmati is the main river of the Sabarmati basin and is also the largest of the four main rivers traversing the alluvial plains of Gujarat. The river originates at an elevation of 762 metres in the Aravalli Hills about 48 kilometres inside the state of Rajasthan. The six major tributaries of the Sabarmati are the Sei, Wakal, Harnav, Hathmati, Watrak and Bhogavo. The drainage areas and lengths of these sub-basins are shown in Table 1. The sub-basins are shown in Figure 3.

It traverses a further 371 kilometres of Gujarat before discharging into the Gulf of Cambay in the

Figure 3:
Drainage of the Sabarmati and its tributaries.

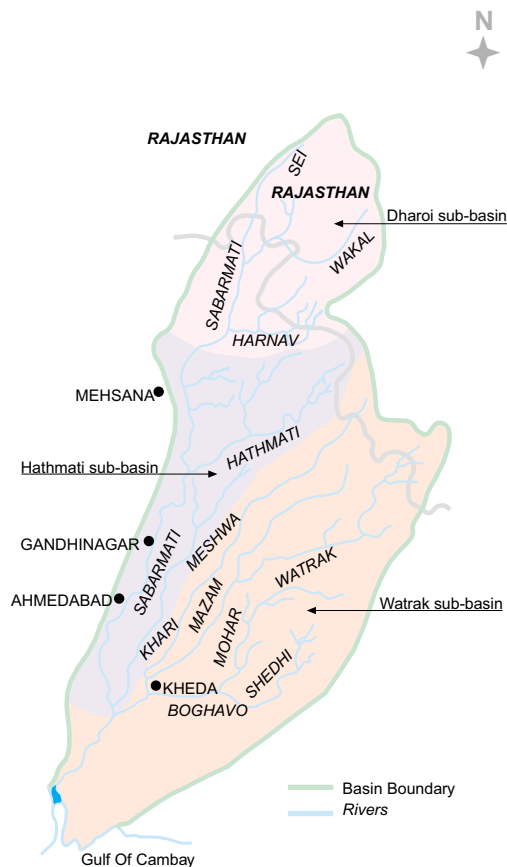


TABLE 1: Physical Characteristics of Sabarmati Tributaries		
Tributary Name	Drainage Area (Km ²)	Tributary Length (Km)
Wakal	1,625	88
Sei	946	95
Harnav	972	75
Hathmati	1,523	105
Watrak	8,638	248
Bhogavo	5,178	100

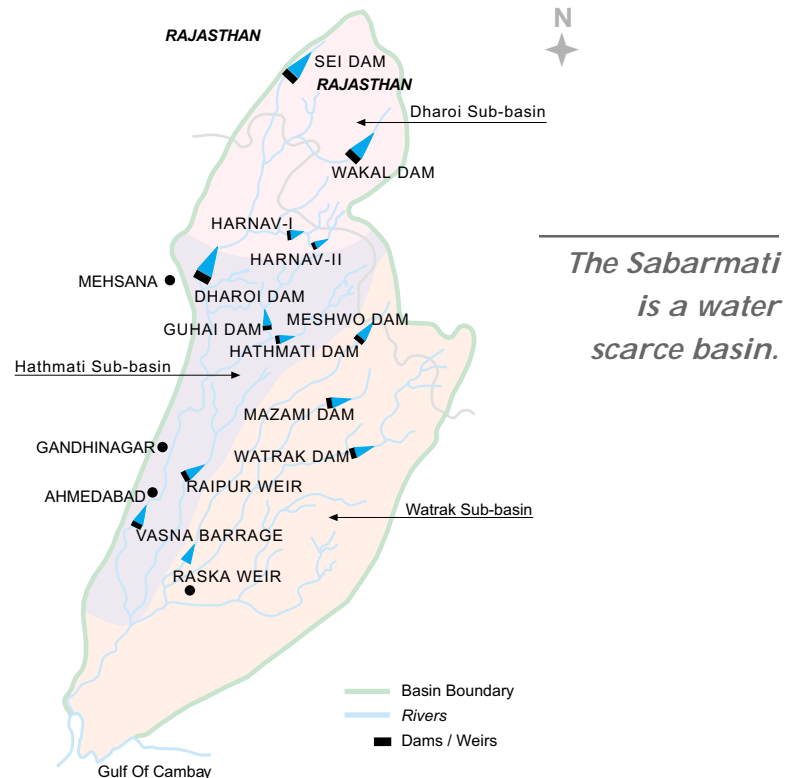
Arabian Sea. About three-quarters of the way down its course, the Sabarmati passes Gandhinagar and Ahmedabad. Of the total catchment area of 21,674 km², 17,550 km² is in Gujarat and the remaining 4,124 km² in Rajasthan. The drainage area within Gujarat covers parts of Sabarkantha, Mehsana, Banaskantha, Ahmedabad and Kheda districts (Table 2).

The Sei and Watal originate in the Aravalli Hills, while the others originate in the alluvial plains below. While the Sei basin is the smallest tributary with a basin spread of 946 km², the Watal is the largest with 9,337 km². Most of these tributaries are essentially storm channels drying up during low rainfall periods. The basin is divided into three sub-basins on the basis of watershed sub-systems. The catchment of the main river up to the Dharoi Dam² is the Dharoi sub-basin covering an area of 2,640 km². The Hathmati sub-basin, named after the major tributary Hathmati, encompasses 5,573 km² between Dharoi dam and the confluence of the Khari River. The third is the Watal sub-basin.

There are also several major and medium irrigation projects in the Sabarmati basin. These are shown in Figure 4.

The total surface water availability in the basin is estimated to be 1826 MCM of which 1,539 MCM is from the Gujarat part of the basin (GOG, 1996). An indication of the scarcity of surface water in the basin can be had from the total surface water availability within the basin which works out to 0.0855 MCM per km², whereas the average surface water availability for all catchments in the state is 0.13 MCM per km² (GOG, 1991).

Figure 4:
Major and medium irrigation projects in the Sabarmati basin



The Dharoi Dam has a total catchment of 5,540 km² with 2,639 km² falling within Gujarat state. The Dharoi Reservoir scheme supplies drinking water to the cities of Ahmedabad and

TABLE 2:
Proportion of Districts Falling within the Sabarmati Basin

District	Geographical Area (Km ²)	Area within the Basin (Km ²)	% Area within the Basin
Sabarkantha	7,390	7,250	98.11
Kheda	7,194	5,439	75.60
Ahmedabad	8,707	2,378	27.31
Mehsana	9,027	975	10.80
Gandhinagar	651	648	99.85
Banaskantha	12,073	860	6.77

Gandhinagar, at a plan allocation of 150 and 11 mgd respectively. It also supplies irrigation water to Mehsana and Sabarkantha districts at a plan allocation of 45,548 ha and 11,130 ha respectively. The Vasna Barrage, which has a total irrigated command area of 25,101 ha, and is located 4 km downstream of Ahmedabad, allows diversion of water for irrigation to paddy fields in Ahmedabad district through the Fatehwadi canal system. The canal turns productive when the discharge in the river exceeds 50,000 cusec.

The Sabarmati basin has both confined and unconfined aquifers.

Geology and Hydrogeology of the Sabarmati Basin

As previously mentioned, the Sabarmati River originates in southern Rajasthan and traverses in a southerly direction through most of Gujarat to join the Arabian Sea in the Gulf of Cambay. The river's source is in the metamorphic rocks of the

Ajabgarh series of the Delhi system consisting mainly of calc schist, calc gneiss and limestones, which have a regional north east-south west strike direction dipping towards north west as well as south east. The Sabarmati River basin is underlain mainly by the rocks belonging to the Pre-Cambrian age in its northern and eastern parts and recent alluvial deposits in the western and southern parts. The alluvial deposits underlie approximately two-thirds of the basin and are themselves underlain by rocks of Pre-Cambrian age. The maximum thickness of the sediments in the alluvial zone is 2,600 metres. The stratigraphy is given on the next page.

The confined aquifers occurring in the north eastern parts of the basin have good yield characteristics. The transmissivity³ of these confined aquifers is as high as 2,500 m²/day. The yield declines considerably toward the western parts of the basin where the transmissivity values are around 200 m²/day.

Figure 5:
Hydrogeology of the Sabarmati basin.



Unconfined aquifers in the north eastern parts of the basin are comprised mainly of igneous and metamorphic hard rocks with low yields indicated by transmissivity values ranging from 20-100 m²/day. This is also the case with Deccan Traps (basalts) occurring in the eastern parts of the basin under Sabarkantha district, and with igneous and metamorphic rocks in the north-northwestern part of the basin under parts of Kheralu taluka of Mehsana district and Danta taluka of Banaskantha district. Unconfined aquifers in the sedimentary Himmatnagar Sandstone formations (mainly occurring around Himmatnagar town in Sabarkantha district) have medium yield characteristics with transmissivity values of around 250 m²/day.

The rest of the basin, including parts of Kheda, Ahmedabad and Gandhinagar district, a part of Kheralu taluka in Mehsana district, parts of Himmatnagar, Idar, Pantij and Dehgam in Sabarkantha district is underlain by alluvial formations. These consist of alternating sand and clay zones, where thickness increases from the northeast to the southwest. The alluvial formations have good yield characteristics. Water in them occurs under unconfined, semi-confined and confined conditions. Figure 5 shows the hydrogeology of the Sabarmati River basin.

Socioeconomic Factors Affecting Water Use

Demography of the Basin

According to the 1991 census, the total population of the basin was 9.28 million with an average density of 310 per km². This population density is higher than that in the Gangetic plain. The population density for the Yamuna basin in Uttar Pradesh ranges from 165 people per km² to 265 per km². The densely populated districts of the Sabarmati basin include Ahmedabad, Gandhinagar, Kheda and Mehsana where density ranges from 410 to 1,660 per km². Forty-eight per cent (4.46 million people) of the basin population lives in major urban areas. This is much higher than the 34.5% state average. Moreover, there is a great degree of unevenness in the geographic distribution of this urban population as it is concentrated in a few cities. Ahmedabad, situated on the banks of the Sabarmati River has a total population of 3.31 million, comprising 74.2% of the total urban population and 35.7% of the total population in the basin. Table 3 shows the rural and urban population of the basin by district.

As can be seen from the Tables 3 and 4 the decadal growth rate for the basin was lower during 1981-91 as compared to 1971-81.

TABLE 3 :
Demography of the Sabarmati River Basin

District	Population Rural	Population Urban	Total	Density Person/km ²
Ahmedabad	547,896	3,405,384	3,953,280	1,660/320**
Banaskantha	120,803	10,673	131,476	150
Gandhinagar	240,661	166,450	407,111	630
Kheda	2,021,683	617,777	2,639,460	490
Mehsana	325,380	74,217	399,597	410
Sabarkantha	1,568,495	185,109	1,753,604	240

**320 excluding population and area of Ahmedabad city
Source : Census, Government of India, 1991.

TABLE 4 :
Decadal Growth of Population in Districts within the Sabarmati Basin

District	Percentage Growth		
	1971-1981 Base 1971	1981-1991 Base 1971	1991-1997 Base 1981
Ahmedabad	33.17	31.83	23.90
Banaskantha	43.96	41.89	29.09
Gandhinagar	44.08	59.76	41.48
Kheda	22.99	17.37	14.12
Mehsana	18.69	16.14	13.60
Sabarkantha	26.49	21.79	17.23

Source : Census, Government of India, 1991.

TABLE 5 :
Agricultural Land Use and Cropping Intensity

District	Cultivable Area/ Geographical Area (%)	Net Sown Area/ Cultivable Area (%)	Irrigated Area/ Net Sown Area (%)	Cropping Intensity (%)
Ahmedabad	78.00	87.70	17.30	114
Banaskantha	49.50	86.70	27.50	119
Gandhinagar	74.00	84.70	72.60	116
Kheda	82.40	91.80	37.40	119
Mehsana	66.60	86.90	21.90	132
Sabarkantha	69.80	87.90	26.60	112

Source : GOG, 1996.

The rural economy is based on rainfed agriculture but industry also has a long history in the basin.

Agricultural Development

Despite rapid industrial growth, the rural economy of the basin is predominantly based on rainfed agriculture, although greater access to irrigation as a result of groundwater development has led to development of water intensive irrigated agriculture in many areas (Shunmugam and Ballabh, 1998). Crop production is concentrated in the *kharif* (monsoon) and *rabi* (winter) seasons.

The intensity of cropping varies widely across districts. The total cultivated area expressed as a percentage of the total geographical area in each district varies from 89.5% for Kheda district to 49.5% in Banaskantha district (Table 5). The net sown area expressed as a percentage of the total cultivable area ranges between 85% and 92%. The cropping intensity, expressed in terms of the percentage of gross cropped area to net sown area, varies from 112% in Sabarkantha district to 132% in the case of Gandhinagar district. The net irrigated area, expressed as a percentage of the net sown area, varies from as low as 17.2% in Ahmedabad district to as high as 72.6% in Gandhinagar district.

Cropping patterns vary widely across the region. Table 6 below shows the cropping pattern in 1994-95 for five typical talukas in the basin (these talukas are representative of their parent districts in terms of soils, climate and water availability). This table shows that the cropping pattern is roughly balanced between food crops and non-food crops in Kheralu taluka in the north eastern part of Mehsana and in Gandhinagar districts. In the case of Bhiloda taluka of Sabarkantha district, Kapadvanj taluka of Kheda, and Dholka taluka of Ahmedabad district, on the other hand, food crops occupy the largest portion of the total cropped area in all seasons.

Industrial Development in the Sabarmati Basin

The types of industries in the basin and their geographical distribution have a major impact on water availability, allocation, use and water quality management. In Gujarat, the Sabarmati basin has been one of the three⁴ focal points of industry and trade for many centuries. As the region is conducive to cotton growing, some of the earliest important industries in the basin had to do with textiles and dyes, both of which required good

TABLE 6 :
Cropping Pattern in Five Talukas in the Sabarmati Basin

District	Name of Taluka	% Area under Food Crops	% Area under Oilseed	% Area under Fodder Crops	% Area under Non-Food Crops*
Mehsana	Kheralu	51.3	25.6	18.1	48.7
G'nagar	Gandhinagar	55.7	23.7	16.3	44.3
Sabarkantha	Bhiloda	86.3	8.5	4.1	13.7
Kheda	Kapadvanj	69.4	17.2	4.3	30.7
Ahmedabad	Dholka	76.2	2.2	16.4	23.8

*The non-food crops also include fibres apart from oilseeds and fodder.

water sources. During the British period, these and other industries expanded. Since independence, the trend continued with heavy investment in the area, resulting in a generally robust industrial economy. In fact, many of the industries that have grown in the basin over time are the heavily water consumptive ones such as textile production and processing, chemicals, and starch and corn products. At present, the textile industry still dominates, accounting for about 75% of the large-scale and 50% of the medium scale units. The next most common industry is the chemical industry accounting for 10-12% of large-scale and 15-18% of medium scale units.

Apart from these industries, other industries that are important in the area are dairy and alcohol. In addition, a number of industrial areas/ estates have been developed by the Gujarat Industrial Development Corporation (GIDC) during the last two decades. These are dominated by small and medium sized units involved in some of the industries mentioned above, plus engineering, electronics and the production of consumer goods.

The scale of the industrial economy can be gauged from the fact that there are around 103 large industries in the basin with a cumulative investment of Rs 2,200 crore.⁵ (Table 7). In addition, there are 68 large industrial projects currently being implemented with a total financial outlay of Rs 1,662 crore (GOG, 1996 p.35). Since economic liberalization, there has been a continuous heavy investment in the industrial sector throughout Gujarat. A *Times of India* article on June 14, 1997 stated that a very large investment of Rs 118,765 crore is underway in the industrial sector in the state. Of these,

82.5% are highly water demanding industries such as petrochemicals and chemicals, drugs and pharmaceuticals, textiles, glass and ceramics, and cement. All these industries are present in the Sabarmati basin. Furthermore, industrial development is a rural as well as urban phenomenon. It is, for example, proceeding rapidly in rural parts of many districts, including Kutch, Baroda, Ahmedabad, Mehsana, Bhavnagar, Junagadh and Kheda, all of which have projects totaling more than Rs 1,000 crore (TOI, 14 June, 1997).

The Sabarmati has been a focal point of industry and trade for many centuries.



Polluted water into irrigation canal

TABLE 7 :
Number of Projects and Investment in Industry by District in the Sabarmati Basin

District	No. of Projects	Per Cent Projects	Investment in Crore	Per Cent Total Investment
Ahmedabad	28	27.18	817.69	37.88
Banaskantha	2	1.94	49.92	2.32
Gandhinagar	15	14.56	324.94	15.05
Kheda	9	8.74	47.66	2.21
Mehsana	41	39.87	703.13	32.57
Sabarkantha	8	7.77	215.23	9.97
Total	106		2,208.57	

Source : GOG, 1997.

Availability of water has not been a limiting factor for industrial expansion. The ability of the industry to expand has, in fact, been heavily influenced by the easy availability of groundwater from deep alluvial aquifers underlying most of the basin. Although overall levels of extraction are unsustainable, most users face few limitations on their ability to pump water for use in their industrial activities.

Groundwater in eight out of twenty-nine talukas in the Sabarmati basin is "over-exploited".

From a water consumption perspective, it is important to note the concentration of industries in a few areas. Table 6 shows the number of industrial units and size of investment by district in the Sabarmati basin. It can be seen that out of the total 106 large industrial units, 84 with a total investment of Rs 1845.6 crores (83.5% in terms of investment) are concentrated in the three districts of Ahmedabad, Mehsana and Gandhinagar, which constitute only 20% of the basin in terms the geographical area. A CPCB (Central Pollution Control Board) report says that Ahmedabad alone has 80 large and nine medium scale units. There are also thousands of small scale units within this three district area. Overall, it can be stated that the demand for water is much greater in these three districts than elsewhere.

In addition to water demand, effective mechanisms for disposal of contaminated water and industrial effluents have not been developed

despite rapid growth of industries in the basin. The effluents from new and established industries have a significant impact on water quality. Untreated or partially treated effluents are disposed of into the Sabarmati River and sometimes onto surrounding land areas. They have become major sources of contamination for the river and (because the river and aquifer are hydraulically connected) for the aquifer as a whole. Pollution leads to a sharp reduction in the effective water availability for all uses.

As can be seen from Table 8, the total industrial water requirement in the basin is 1 per cent of the total water required for the agriculture sector.

Emerging Problems

Groundwater Depletion and Water Scarcity

Demand for water is increasing throughout the region due to industrialization, population growth and urbanization. This has led to the excessive withdrawal of groundwater (that is, over-development), causing problems of depletion and scarcity throughout the region.

In contrast to this, the surface water resource is underutilized. Out of the total water resource of 1826 MCM, 1539 MCM is contributed by the Gujarat part of Sabarmati basin of which 1320.57 MCM has been brought under utilization. With the use of carry over⁶ of 275.91 MCM, the untapped water resource is 494 MCM⁷ (GOG 1996).

In addition, the government policy of subsidizing power and well drilling has increased access to the resource, while reducing incentives

TABLE 8 :
Comparative Water Requirements in Different Sub-basins

Sub-basin	Domestic MCM/year	Livestock MCM/year	Industrial MCM/year	Irrigation MCM/year	Total MCM/year
Dharoi	8.76	0.88	2.00	163.79	175.43
Hathmati	209.90	21.00	26.00	1,268.55	1,525.45
Watrak	79.69	8.00	1.75	2,055.85	2,145.29

Source : Government of Gujarat, 1996.

for conservation. In some ways, policy incentives for groundwater development combined with the spread of mechanized pumping technology have created an illusion of plenty by allowing people to use groundwater resources accumulated, in some cases over thousands of years. The disastrous effects of this mining are compounded by rapid economic expansion.

Over-development of groundwater is evident in the government statistics. Out of the 29 talukas in the basin, eight are already in the “over-exploited,” (draft more than 100% of recharge) category, three in the “dark” (draft more than 85% of recharge), and five in the “grey” (draft between 65% and 85% of recharge) category. In sum, more than 55% of the talukas in the basin are already in the warning or over-developed categories. This is illustrated in Table 9 showing groundwater development levels in each district.

Two clear patterns of groundwater depletion and scarcity emerge in the basin depending on the prevailing hydrogeology. One occurs in the alluvial areas, while the other is in the hard rock zones. In the alluvial areas of northern Gujarat, which comprises a large part of the Sabarmati basin, the water storage capacity of the underlying strata is generally very good. Nonetheless, over-development has led to the water table falling at alarming rates – in some cases by as much as 3 metres per annum. Thousands of shallow wells are drying up and yield reductions in tubewells are reported across the whole central zone of the Sabarmati basin, particularly in Mehsana and Ahmedabad districts (GOG, 1992).

Generally, hard rock zones are characterized by poor long term water storage conditions due to

aquifer characteristics. As a result, in hard rock regions, groundwater availability is often limited more by storage capacities than by infiltration rates or the potential volume of water available for recharge (Phadtare, 1998). This is reflected in the water levels which tend to decline rapidly as pumping/extraction takes place. One often hears farmers complaining that their wells run dry rapidly soon after the monsoon and remain dry for substantial portions of the year. This type of seasonal scarcity has a major impact on irrigation and crop production (Puri and Vermani, 1997), even though no long term water level declines may be occurring. Under the spell of a good monsoon, water levels may recover to historical levels. Nevertheless, high levels of pumping may result in rapid seasonal declines. Although data is lacking to document this, observations by farmers and experts suggest that as well numbers increase, the rate of seasonal water level decline increases during the following monsoon.

The above patterns of depletion are observable in the urban areas of the basin too. Often the depletion may be acute, but is masked by the

In some areas water levels are falling by as much as three metres per year.

TABLE 9 :
District-wise Summary of Recharge and Draft

District	Total Ground-water Recharge (MCM/year)	Utilizable Ground-water Recharge (MCM/year)	Gross Draft (MCM/year)	Net Draft (MCM/year)	Level of Groundwater Development (%)	Category
Banaskantha	1,027.9	873.7	1,120.2	784.1	89.7	Dark
Mehsana	554.1	470.9	1,302.6	911.8	193.6	Dark
Sabarkantha	878.2	746.5	757.2	529.9	70.9	Grey
Gandhinagar	99.8	84.8	100.9	70.6	83.2	Grey
Ahmedabad	900.9	765.8	951.9	666.4	87.0	Dark
Kheda	1,090.1	926.6	705.9	494.1	53.3	White

Source : GOG, 1992.

Pollution is emerging as a major concern and because aquifers and the rivers are hydraulically connected groundwater can easily be contaminated.

enormous economic resources the urban areas have to augment their supplies. The situation in Ahmedabad, for instance, is especially well documented. As in the rural areas underlain by alluvium, increased demand has resulted in a rapidly declining groundwater table and lowered yields in tubewells. As early as 1974, estimates placed the annual extraction from aquifers underlying Ahmedabad at 200 MCM/yr—2.5 times the estimated annual recharge of 80 MCM (Pathak, 1985, p.12). Unlike the rural areas, the Ahmedabad Municipal Corporation (AMC) and private well owners generally have a greater ability to augment the amount of water available for immediate use. In Ahmedabad, this is done partly by increased pumping of groundwater, which currently makes up some 55% of the total quantity supplied to users by the AMC (Puri and Vermani, 1997). Between 1951/52 (when tubewell development started) and 1996/97, groundwater extraction from the AMC's tubewells for the municipal water supply increased enormously from 6.4 MCM to 226 MCM (Puri and Vermani, 1997).

Despite this enormous increase in groundwater extraction, it has long been realized that increased pumping alone will not be able to meet the ever-increasing demands of the urban areas such as Ahmedabad. Already, as discussed in the following section, a large portion of the remaining 45% of AMC's supplies are obtained through reallocation of rural water resources to the urban areas. Interestingly, despite the enormous increase in water supplied by the AMC, the per capita supply provided by the AMC has declined over the years from 197.04 lpcd in 1971-72 to 125.01 lpcd in 1996/97 (Source: Ahmedabad Municipal Corporation, personal communication, 1997). This was a major factor that led to a leap in the installation of private wells. Though no official documentation or records of such private installations are available, the trend is clearly observable in Ahmedabad.

Pollution and Quality Decline of the Resource

Pollution of the Sabarmati River downstream of Ahmedabad is extensive. It is both a problem in itself and exacerbates water scarcity. Treated and untreated effluents are disposed of into the Sabarmati River both above and downstream of Ahmedabad. This polluted river water finds use in the agricultural fields through the Fatehwadi canal system. According to the Central Pollution Control Board:

“...in the Gandhinagar-Ahmedabad reach, the Sabarmati becomes essentially a trunk sewer. Not only the treated/partially-treated/untreated effluents from the sewage collecting systems of the CRPF (Central Reserve Police Force) colony, Gandhinagar, and the city of Ahmedabad join the



Milk buffaloes drinking from polluted stream: Rajasthan
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river, but the entire sewage, sullage and industrial wastewaters from the fast growing suburbs and shanty-towns flow into the river through the numerous open drains really meant only to carry storm run-off, but now acting as open sewers for all types of wastewaters” (CPCB, 1989, p. 43).

To elaborate further, the wastewater inflows constitute a significant part of the final run-off in the river adding to the decline in water quality. Domestic sewage and sullage, industrial effluents and wastewaters from miscellaneous uses (including cattle watering) makes up 30% , 10% and 9 per cent respectively of the total wastewaters. This contributes organic and bacterial load, while the agricultural return water brings sodium and other dissolved inorganic constituents and probably some residual nitrates and pesticide residues from the chemicals applied to crops (GOG, 1996).

Such types of pollution of surface water bodies have major implications for the quality of the groundwater resource. The drinking water supply sources based on underground reserves in Ahmedabad, for example, are highly vulnerable to pollution as the surface and groundwater bodies are interconnected. Pollution of groundwater could render large portions of the entire groundwater resource unusable for domestic purposes and irrigation causing major reductions in the effective overall availability of high quality water in the basin.

Over-extraction also appears to have a negative impact on water quality in many areas throughout the Sabarmati basin. TDS levels in Ahmedabad, for instance, are frequently beyond permissible limits, and a widespread incidence of high fluoride levels in groundwater has recently been reported

from many pumping stations of the AMC. According to newspaper sources, water from AMC tubewells has fluoride levels of 6 parts per million (ppm) as opposed to the desirable limit of 1.0 ppm (Times of India, June 11, 1997). A survey of private tubewells indicated a TDS content as high as 2000 ppm as opposed to the desirable limit of 500 ppm (Times of India, June 19, 1997) in groundwater.

It may be noted in this context that high levels of pumping often cause migration of low quality water from adjacent or interbedded saline aquifers to freshwater aquifers. This may also underlie fluoride problems – although mechanisms for fluoride mobilization are not as well understood. Groundwater quality in rural areas of the basin has declined over the years as well. Out of the 921 villages affected in the basin, 532 (58%) villages are fluoride affected, 216 (23%) are salinity affected and 173 (19%) had excessive nitrate content (GOG 1996).

In view of the above, systematic data needs to be collected on the pollution of surface water and groundwater bodies from the perspective of source, type, magnitude and areal spread. This will form one of the focus areas for future research by VIKSAT.

Competing Uses of Water

Scarcity combined with declines in quality has led to increased competition for water, especially between the urban or industrial users and the rural users. The state of an ever-increasing demand juxtaposed with inadequate increase in per capita supplies has already been discussed in connection with the situation in Ahmedabad. This city's

Pollution and over-extraction have affected water quality throughout the basin.

TABLE 10 :
Area irrigated by Dharoi Reservoir

Year	Area Irrigated by the RBMC (Ha) ⁸	Area Irrigated By the LBMC (Ha) ⁹
1976	0	0
1977	0	0
1978	0	628.65
1979	293.58	581.20
1980	1,096.70	1,012.51
1981	3,586.48	4,255.70
1982	2,254.90	9,187.94
1983	15,360.00	12,130.90
1984	30,046.10	8,966.30
1985	34,001.07	2,772.80
1986	12,592.90	0.00
1987	0.00	3,641.40
1988	6,680.90	11,206.20
1989	27,822.30	5,439.30
1990	16,780.70	10,260.60
1991	40,956.50	10,284.50
1992	43,816.64	12,931.10
1993	51,684.51	9,944.40
1994	45,254.40	7,267.00
1995	49,033.70	1,906.10
1996	3,657.10	

Source: Dharoi Project Works, Irrigation Department, Government of Gujarat.

Conflicts over equitable allocation of available supplies are major in the Sabarmati basin.

competition for the scarce resource with the rural areas comes into focus more clearly when we look at the conspicuous example of the changing nature of water allocation from the Dharoi Reservoir. This reservoir was built to meet the irrigation needs of the downstream command, but this goal was never to be fully achieved. This is due partly to some years of drought (such as the 1987), but also because it now supplements the remaining 45% of the AMC's supply (the portion not supplied by groundwater development). The historical trends in area irrigated by the Dharoi Reservoir are given in Table 10.

The planned allocation for release of water for the Right Bank and the Left Bank command is 45,548 ha and 11,130 ha respectively. The above table shows that out of 21 years of operation, the planned allocation of water for irrigation was released during three years only (1993, 1994, and 1995) in the RBMC (Right Bank Main Canal) and during two years (1989 and 1993) in the LBMC (the Left Bank Main Canal). In contrast, the amount of water released for the Ahmedabad and Gandhinagar Municipalities from the Dharoi Reservoir has been steadily increasing. In 1971/72, the quantity released to these municipalities was 148.145 MCM. By 1996/97, the quantity released was 225.56 MCM (Puri and Vermani, 1997). From 1976-77 to 1996-97, water allocation for urban uses varied from year to year from a minimum of 7 per cent to 100 % of the water stored in the reservoir. In the drought years of 1986-87 and 1987-88, almost all the water stored in the reservoir was allocated to Gandhinagar and Ahmedabad (Shunmugam and Ballabh, 1998). The adverse effects of reallocation of water intended for irrigation has been further compounded by decreases in storage availability in the Dharoi Reservoir. Sedimentation studies conducted on the Dharoi Reservoir indicated a total reduction in the capacity by 13.97 MCM (which is approximately 2 per cent of the designed live storage capacity of 775.89 MCM of the reservoir) over a four year period from 1990 to 1994.¹⁰ In sum, it can be concluded that neither the groundwater nor surface water sources currently supplying water in the basin are being managed sustainably.

The above is just one illustration of the many types of competition that exists in the Sabarmati

basin. Conflicts around equity is another set of issues that exists in the basin. This dimension is studied in depth by Janakarajan at the Madras Institute for Development Studies, whose findings are presented in this publication. The equity dimension in the Sabarmati basin will be investigated in the next phase by VIKSAT as part of its continuing research.

Institutional Issues

Existing institutional responses to address water scarcity and pollution problems in the basin are limited. Current approaches to the physical situation are highly sectoral in nature. They do not take into account the linkages between water users or water use sectors and are focused more on augmenting the available supplies. A few alternative systems exist, such as those which reuse and recycle wastewater that could increase effective availability of water, in spite of the increased physical and social viability of such systems, especially in the urban areas.

The issues which the government has so far attempted through legal and regulatory approaches are groundwater overdraft and industrial pollution. Where groundwater overdraft is concerned, attempts to regulate extraction have been made through placing limitations on access to institutional financing (subsidies through government controlled banks) for new wells and through well spacing regulations. Neither approach has been particularly effective. Wells are privately owned and often located in remote rural areas, both of which make enforcement difficult. Furthermore, existing legal and regulatory measures do not reflect the complex physical

factors affecting the availability of water or the socioeconomic dynamics controlling the access to it by users. Hydrologically meaningful and socially or economically viable regulatory approaches are yet to be developed.

With regard to pollution by industries, pollution control norms and laws are in place. So far, effective state-level interventions to control pollution of the Sabarmati River, for example, have been judicial through court orders. These have led to the closure of hundreds of industries in and around Ahmedabad. From the point of view of industries, the cost of installation of treatment plants is often prohibitive. The large number of polluting small industrial units normally can ill afford such plants. In any case, the existing laws and acts are inadequate and less than comprehensive as far as the environmental performance of the production units is concerned. They are at best “end of the pipe” solutions. Largely disregarded are the possible options of pollution control that could be adopted in the earlier stages of the process of production or even the larger societal issues that encourage pollution producing industries.

Summary of Emerging Issues

The pattern that emerges in the Sabarmati basin is a familiar, global one: Increased demand, arguably fueled by increased access to available resources, but certainly fueled by the triad of industrialization, population growth and urbanization, that lead to increased exploitation. Deliveries to users have grown in absolute terms but have not kept pace with growing demands.

Existing legal and regulatory measures do not reflect the complex factors that affect availability of water and access to it by users.

This has led to over-development, a decline in quality of the resource and widespread problems of scarcity. Scarcity, in turn, has led to increased competition resulting in decreased access to water for the disadvantaged segments of the society.

The portentions of the current trend present a bleak picture. There is little scope for further augmentation of supplies either by increased pumping or other extraction methods even to maintain the current levels of per capita supply. The *status quo* is unsustainable.

The remainder of this paper focuses on existing institutions that could be participants in a reoriented approach to water management, and on the WEAP modelling VIKSAT has done in an attempt to understand the current situation. The potential impact on the balance between demand and supply of water under different management alternatives is also evaluated in a preliminary manner.

Study of Existing Institutions in the Sabarmati Basin¹¹

Existing institutions that are active on water issues in the Sabarmati basin and those who could play a major role in future management initiatives are described here. The goal of the study is to look at both the conventional state and governmental organizations that have traditionally played a significant role in water management and at the “less conventional” organizations, such as rural cooperatives. The latter group has not played much of a role as yet but has a large rural membership base that is directly affected by water problems. They could, as a result, emerge as active players.

Government and Research Institutions

Water and Land Management Institute (WALMI), Anand

The Water and Land Management Institute (WALMI) is an autonomous body under the Gujarat Irrigation Management Society (GIMS) set up in 1980-81 with the objective of addressing issues related to land and water in a holistic manner. The focus has been on bridging the information gap between irrigation potential and utilization and also between actual productivity and potential productivity of irrigated land. The institute emphasis is on training and the provision of technical guidance to farmers and field officers of the various government departments dealing with water and land related issues. It also provides consulting services and is engaged in action research. There are two programme units, namely training and technical, headed by joint directors, with the following activities: 1) imparting training to the in-service personnel of government departments; 2) carrying out action research with farmer participation to contribute to the knowledge base on water management issues; and 3) disseminating information through various publications. The thematic training programmes, targeted at farmers and government officials, cover a range of topics and issues such as groundwater recharging, farm level management of irrigation, and the reclamation of saline, alkaline or water logged areas, to farmer participation in irrigation water management.

The Institute has a staff of about 60 professionals with wide ranging expertise in the

The government has traditionally played a major role in water management.

fields of agronomy, civil engineering, agricultural sciences, soil sciences and social sciences. Most of the professionals are doctorates in their respective disciplines. Staff are often deputed to national and international training programmes, seminars and workshops. Around 70 per cent of the professional staff are young (below 40 years), which helps bring innovative thoughts and ideas into the programme.

Though the Institute has an autonomous status, it does not appear to be fully free from bureaucratic aspects that reduce its effectiveness. Often, members of the professional staff at the Institute are on short term deputation from the irrigation department, making it difficult to carry out activities in a sustained way. The bureaucratic norms and procedures adversely affect the work culture and the morale of the professional staff, which in turn affects the quality of the work. In addition, the Institute has recently started facing funding constraints resulting in delays in project completion.

It is partly due to similar bureaucratic constraints that there is little direct interaction between the professional staff at the Institute and the communities on which they do their research. Though WALMI has undertaken action research projects involving farmer participation, its involvement in project implementation is by and large very limited. The transfer of technology forms an essential component, but is addressed by the local staff of the irrigation department. This process prevents the farmers from getting involved with the programmes initiated by WALMI and restricts the experience the professional staff could gain by working more closely with the farmers.

Institute of Rural Management, Anand

The Institute of Rural Management, Anand (IRMA) is an autonomous institute, set up in 1979 as a society under the Societies Act. It was established primarily to further education and training in rural management and to provide research and consulting services to cooperatives and other agencies engaged in the socioeconomic development of rural communities, especially the rural poor. Today, IRMA's activities are governed by the following objectives:

- to provide relevant education and training to young men and women for managing income generating and developing activities on behalf of rural producers;
- to offer training courses for policy makers, directors, general managers and those in charge of specific managerial functions in rural enterprises and projects;
- to conduct research on operational problems in the rural sector in order to help improve the management of rural enterprises and projects; and,
- to undertake basic research into the process of rural management to augment the existing body of knowledge on the subject.

As a management institution, it concerns itself primarily with bringing about change through enhancing the effectiveness of organizations. IRMA is also expected to be an intellectual resource base for the member controlled rural cooperative movement that functions in most of Gujarat. Apart from providing professional training programmes in rural management, IRMA undertakes research and consultancy in a wide variety of areas in the

Academic institutions are beginning to focus on water problems.

rural sector. These are intended to build on the existing body of knowledge of issues in these areas, and ultimately contribute to changes in the related policies and programmes.

Recognizing the critical role of natural resources in the rural livelihood systems, IRMA takes a keen and active interest in research, training and consultancy in the areas of common property resource (CPR) management. Unlike the conventional approach of looking at technical efficiency, IRMA's research has always concentrated on exploring options for better management of CPRs, the idea being that better management ensures easier access to the benefits of the CPRs for the poor, thereby serving as an instrument of poverty alleviation (IRMA, 1995).

In the context of CPR management, focused research is carried out on understanding issues with reference to groundwater and surface irrigation systems. In groundwater, IRMA's research has focused on public tubewell irrigation as a means of enhancing access of the rural poor to groundwater. Research has also looked at the ways of redesigning tubewell programmes, as well as understanding water markets and their implications for equity and sustainability of groundwater use. IRMA studies on water markets have highlighted the role of electricity pricing and supply on the economics of modern water extraction mechanisms and on the structure and conduct of localized groundwater markets.

Ahmedabad Municipal Corporation

Ahmedabad Municipal Corporation was established in 1858 as a municipality by the British government. In 1950, AMC covered a total area of

90 km². Today it covers an area of 190.84 km² catering to a population of 2.9 million. AMC employs 25,000 workers on its payroll, while another 5,000 are employed indirectly in schools, hospitals and transport services supported by the corporation. The structure of AMC is made up of two bodies one consists of elected representatives, the other is administrative.

All the departments are headed by deputy municipal commissioners (Dy. MC) who are responsible for a range of services. Under the Dy. MC's, there are different professionals appointed on the basis of work competency. The professionals are generally engineers, MBAs, diploma holders in engineering, teachers, librarians, clerks and typists. From 1990, a new line of thinking for introducing innovations has emerged within the AMC. This is because AMC had been criticized for lack of competency to deal with issues emerging due to rapid industrialization and urbanization in and around the city of Ahmedabad. Subsequently, the Administrative Reform Cell was formed within the AMC to identify ways of improved functioning of each of the wings and make concrete suggestions for ensuring a higher level of efficiency in its service delivery systems.

The AMC jurisdiction is divided into 43 wards and 5 zones represented by 129 elected councilors having different political affiliations. A standing committee has executive powers and is comprised of 12 councilors, the Municipal Commissioner and Dy. MCs (Figure 6). The committee meets once a week to review the work. The elected representatives enjoy a lot of power in the matter of project selection and implementation as they are also backed by their own political parties. The Municipal

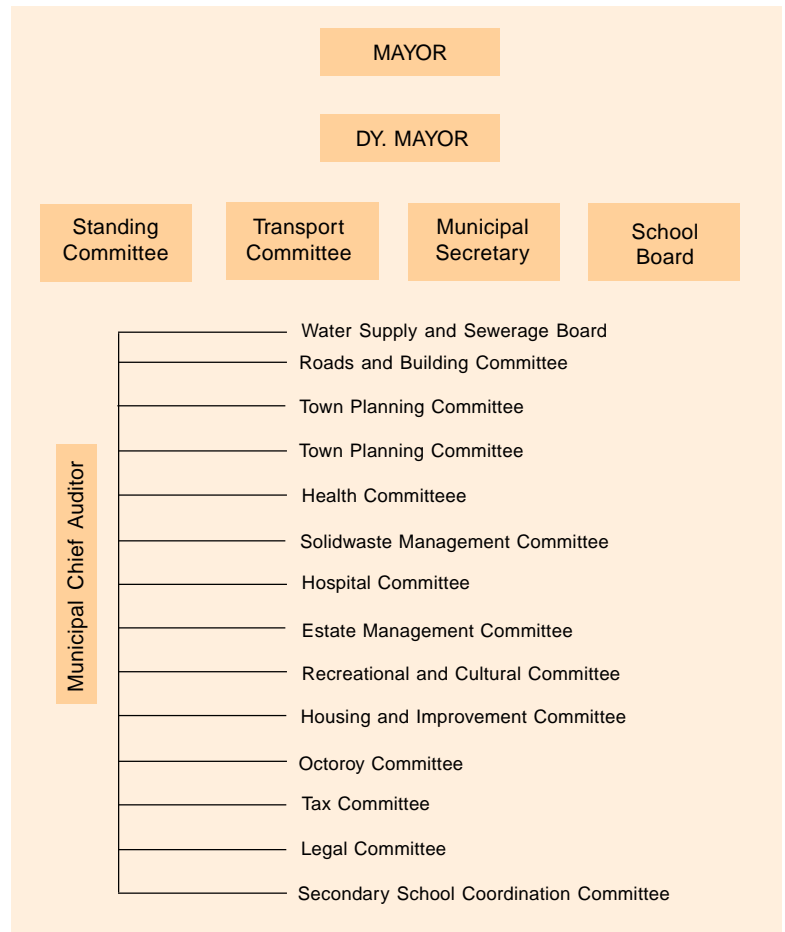
The Ahmedabad Municipal Corporations is the major entity responsible for water supply in the city.

Commissioner has to obtain the standing committee's approval for projects where outlay exceeds Rs 500.00.¹² The standing committee also supervises appointments of the Class I officers in the corporation. The municipal board meets once a month with all the 129 elected members and the representatives of the administrative wings.

In recent years, AMC has embarked upon special human resource development initiatives to improve the efficiency of its employees. The initiatives began with the formation of the Administrative Reform Cell to look into the loopholes within the present administrative structure, which is as bureaucratic as any other government institution. A reputed private consultancy firm, A. F. Ferguson, based in Bombay, has been assigned the task of reviewing the present structure and suggesting alternatives. The firm was expected to submit its report in September 1998. As an outcome of the review, some major changes in the structure of AMC were expected. In the meantime, since 1998, staff of AMC have been deputed for one-month training in batches of 50 to the Institute of Local Self Government in Ahmedabad. This institute is an autonomous body imparting training and skills in the area of local and decentralized governance. The training programmes are a part of the larger attitudinal changes of its employees and the corporation bears all the expenses for the same. Accordingly, the higher officials are also sent on training and to workshops according to their area of specialization and interest.

AMC displays immense potential for playing a key role in urban water use management as it possesses the authority and expertise to deal with

Figure 6:
Structure of the Ahmedabad Municipal Corporation



the problems. It has the decentralized structure with representation from the general public that can be capitalized on for any intervention.

Gujarat Water Resources Development Corporation (GWRDC)

Gujarat Water Resources Development Corporation (GWRDC) branched out as a separate department from the Public Works Department (PWD), Government of Gujarat, in 1976 in

The Gujarat Water Resources Development Corporation was established to assist exploration and development of groundwater.

The focus of the Gujarat Water Resources Development Corporation has now shifted from development to management.

recognition of the increasing need for development of groundwater resources. It was set up primarily to drill tubewells to increase access of resource poor farmers to groundwater for irrigation. These activities are carried out by different wings of the corporation, that is, the Geology Wing, Mechanical Wing and Civil Wing. These wings cater to different aspects of groundwater development. For example, the Geology Wing, which comprises geologists, hydrologists, geophysicists and chemists, carries out groundwater investigation. Similarly, the Mechanical and Civil Wing, which comprises mechanical and civil engineers has professional competence for coordinating various mechanical and civil works such as well drilling and the laying out of distribution lines.

However, with over-development of groundwater occurring in certain parts of the state, the strategy of the corporation has begun to change from development support to efficient management through farmer participation. The dismal physical and financial performance of the state owned tubewells, the increasing financial burden on the GWRDC and the growing recognition of the management capabilities of farmers have largely been responsible for such a shift in policy and programmes of the corporation. As a result, around 300 out of the 3,000 odd tubewells owned by the corporation have been turned over to the farmers' organizations for management (Kumar, 1995).

GWRDC has a very large professional staff for carrying out groundwater development. The corporation regularly sends its staff for training to upgrade their skills. The recent World Bank aided Hydrology Project being undertaken by the corporation has a strong training component. For all training purposes, the corporation is

coordinating with WALMI in Anand. Usually, once a year, the technical staff attends training sessions. The field staff is periodically exposed to more intensive training courses ranging from 10 to 30 days.

The corporation has expertise in the area of water resource investigation and management. It is engaged in the collection of hydrological and geo-hydrological data for the entire state, and is now planning to take up recharge activities in the areas where groundwater has been depleted in alarming proportions. Already, projects have been initiated to artificially recharge groundwater in the water scarce areas.¹³

The corporation is also aware of the fact that such efforts should be supplemented with proper regulation to control further development of the resource. It has recognized the increasing need to involve the communities in the process of regulation and management of the precious resource. Now, even for drilling wells, the corporation seeks the support of the villagers. In the near future, the corporation envisages having more such project initiatives taken up for the sustainability of the resource.

Gujarat Water Supply and Sewerage Board (GWSSB)

The board was set up with the objective of supplying safe drinking water to urban and rural areas and creating infrastructure for hygienic sewerage facilities to the people. It was started in 1979 as a board, and prior to this, the organization was known as the Public Health Department. The board is divided into three zones, namely, the South Gujarat, Ahmedabad and North Gujarat

zones. The later includes Surendranagar and Kachchh and Saurashtra districts. Each zone is headed by the chief engineer under which there are three sectors – financial, administration and technical. The technical sector is comprised of various departments like material, mechanical, enquiry and quality control, monitoring, training and research and development.

The board appoints graduate engineers as trainees who take up senior positions after promotion. In addition, the board has recently started appointing people with a background of sociology and social work because of the change in the thinking from pure technical to more social. This has happened due to a gradual realization that drinking water problems cannot be addressed through engineering solutions alone but require understanding of the socioeconomic dimensions as well.

To operationalize its mandate, the board has classified villages according to the status of water supply and availability. These classifications are:

- (1) No-source village : Village with no source of water supply;
- (2) Partly completed (PC)-I : Village having water supply of 10 lpcd (litre per capita per day);
- (3) PC- II : Village having water supply of 10-20 lpcd;
- (4) PC-III : Village having water supply of 20-30 lpcd;
- (5) PC-IV : Village having water supply of 30-40 lpcd.

These classifications are based on the Minimum Need Programme developed by the Government of India in which the minimum water need for rural areas is referred to as 40 lpcd. For the urban areas, it is 70 lpcd.

Water supplied by the board is from two main sources, surface and groundwater. Groundwater is extracted through tubewells and hand pumps, depending upon the availability of the water source and the geohydrology of the area. Management of water systems developed by the board depends on scale. In the first, smallest, category, one village is chosen and the maintenance of the water harvesting structures are handed over to the village *panchayat*. At larger scales (clusters of 10 villages or larger groups of 25-100 villages), water is supplied through pipelines and the maintenance is done by the board. Even within the smallest category hand pumps in villages are provided and maintained by the board itself.

The board faces major problems because demand generally exceeds supply. Most of the time, the supply is based on the average rainfall of a specific area. However, rainfall is dependent on the water cycle of the particular area and hence it is difficult to maintain regular supplies. Furthermore, large-scale deforestation has occurred which disrupts the water cycle in many parts of the state and affects the distribution of water. This is compounded by rapid drops in groundwater levels and competition from industries and agriculture.

Despite the above general pattern, water related problems differ from region to region. For example, southern Gujarat has a problem of water logging, whereas northern Gujarat faces the problem of groundwater depletion. Large tracts of

Water problems differ from region to region, complicating the Gujarat Water Supply and Sewerage Board's mission of sustainable drinking water supply.

inland Kachchh are affected by inherent salinity in groundwater systems, whereas salinity due to sea water intrusion occurs in both Kachchh and Saurashtra. The board has to cope with all these problems in its attempts to supply drinking water.

In view of these problems, there is a major shift in the groundwater extraction policy of the government. A major decision to source drinking water supplies from surface water and avoid using groundwater, wherever possible, has been taken. A comprehensive plan has been initiated for Mehsana district by Tata Consultancy under which water would be supplied to villages through canals from the Dharoi Dam. A defluoridation plant is set up as a pilot project in Chanasma taluka which falls outside the river basin in Mehsana district. The plant covers 62 fluoride affected villages.

There is a welcome change in the thinking of the board. The board has decided to involve communities in the management of water. A social wing has been created within the organization to involve people in the execution of activities related to water supply. The board facilitates the formation of *pani samiti* (water committees) under the supervision of *gram panchayat* (elected village council) for the same. The members include the health worker, a *gram panchayat* member, teachers and an official from GWSSB. The social wing of the board works with the *taluka panchayat*, the Taluka Development Officer (TDO), the *village panchayat* and the officials at the board for coordination and management of the water supply plans. The social wing also extends training and other support needed for better implementation of the programme.

Gujarat Jalseva Training Institute (GJTI)

Accepting human resources development as a sound economic investment, the World Bank appraisal mission in the early 1980's suggested that the Gujarat Water Supply and Sewerage Board (GWSSB) develop a comprehensive training scheme and associated infrastructure. The goal was to create an institute capable of meeting training needs related to the project and the sector beyond the project period. Accordingly, Gujarat Jalseva Training Institute (GJTI) was established by GWSSB in October, 1988 with the World Bank's financial support. The aim was to enhance and upgrade the professional skills and the behavioural attitude of the GWSSB staff to meet the challenging needs in the field of drinking water supply and sanitation. The institute not only caters to the training needs of the GWSSB, but also to the local bodies and NGOs.

GJTI has an extensive training complex. The institute building houses five lecture halls, a seminar hall, a conference room, a library, a remote sensing laboratory a mobile testing laboratory, a mechanical workshop, a computer system with high-tech hardware and leading software including Geographical Information System. GJTI runs more than 50 training and awareness programmes in a year.

GJTI is headed by a director of the rank of chief engineer assisted by two joint directors, eight senior training officers, six training officers and six assistant training officers. The regular staff of GJTI is 62 with 22 casual workers. GJTI has five separate

Because of groundwater quality problems, the Gujarat Water Supply and Sewerage Board has decided to supply drinking water from surface sources wherever possible.

wings - civil, mechanical, hydrological, laboratory and administrative. All the wings include in-house as well as field training cells. Many of the faculty members are well qualified and trained under a trainer's training programme.

The institute's training plan includes: training for water sector staff from the grass roots to the top level; field training for junior staff; seminars/workshops for senior officers; awareness and community participation camps for the general public; specialized need-based training and trainers training programme for specialized groups and non government organizations (NGOs).

Gujarat Ecology Commission(GEC)

GEC aims to integrate environmental and developmental concerns to facilitate fulfillment of basic needs and improve living standards. Formed in 1988, it works as a state level nodal agency for ecological restoration, organizing people's action to prevent ecological degradation, planning for sustainable development and establishing appropriate institutions. Replacing the traditional sectoral approach, GEC strives to develop a holistic overview of the region through a comprehensive, multi-disciplinary database, compiled from various sources. With the help of computers and GIS, the data is presented as a series of maps and analysed by a team of experts to obtain a broad view of the trends in different parameters, their critical interrelationship and the influences of the adjoining regions. People are viewed as partners in order to evolve a system of sustainable use of resources without undermining the productive potentials of the systems.

At the policy level, the GEC works to bring about a dialogue and get policy makers and environmental organizations to understand that a common vision and cooperation in ecological restoration is the only way to ensure sustainable human welfare. At the grass roots level, NGOs are being motivated and mobilized to sow the seeds for an environment movement. The GEC is in a process of developing an action centered network involving different government agencies, scientists from different disciplines, academic institutions, NGOs, individuals, business and industries and communication experts to enhance the scale and pace of ecological restoration. Further, a comprehensive, Environment Information System (EIS) is being developed to serve as a databank and provide ecologic data to all actual users (NGOs, cooperatives, government departments and media). Multi-disciplinary studies have been commissioned to prepare a state level environment scenario, which would form the basis of a productive plan. The commission has prepared a taluka level profile based on soil and water parameters. The current ecological status of Kachchh has also been documented.

GEC has been involved in networking with small NGOs in order to have a larger outreach. The commission assists NGOs to enable them to achieve ecology related objectives by sharing ecological information and organizing exposure visits/training programmes and motivation camps, identifying suitable projects and funding sources, and developing district level platforms for experts, NGOs and government officials. GEC expected to create a network of about 1,000 NGOs in all the 19 districts of Gujarat by the end of 1996.

*Dialogue
between policy
makers and
environmental
organizations
builds trust.
This has been a
major focus of
the Gujarat
Ecology
Commission.*

Rural Economic Institutions

Although a wide range of cultural, economic and educational institutions exists in rural areas, economic institutions are dominant.¹⁴ These are closely linked with the economic activities in the region, such as agriculture, animal husbandry and dairying, which in turn are tied closely to the natural resource base. Institutions of this type that operate in the Sabarmati basin include dairy cooperatives, agriculture produce and marketing cooperatives and district milk producers' cooperative unions. Many of the villages in the region have one or more of these institutions in operation.

Dairy cooperatives have improved livelihoods throughout much of Gujarat. They are now becoming active on water issues.

Table 11 below shows the number of rural cooperative institutions, their membership size and the paid up capital in five districts that fall within the basin. These cooperative institutions are primary¹⁵ agricultural credit cooperative societies, primary consumer stores, primary marketing societies, central and state marketing societies, primary processing societies, other primary societies, other societies at the state level and fishermen' primary cooperative societies. The table indicates that they are important in terms of their number, social base, broad geographical distribution and financial capabilities.

TABLE 11 :
Profile of Rural Cooperative Institutions

District	Number	Membership	Paid Up Capital (Rs)
Banaskantha	1,893	277,600	8,2673,000
Gandhinagar	875	125,146	22,985,000
Sabarkantha	2,204	716,400	210,286,000
Mehsana	3,337	844,500	211,337,000
Kheda	3,055	1,278,200	276,134,000
Total	11,364	3,241,846	803,415,000

Mehsana Dudh Sagar Dairy

Throughout Gujarat, including in the Sabarmati basin area, district level dairy cooperative unions were set up under Operation Flood.¹⁶ The Mehsana Dudh Sagar Dairy (Mehsana District Milk Producers Cooperative Union), located in Mehsana district headquarters, is a particularly interesting cooperative union due to its involvement with some of the common property issues, especially the ones related to water resources. This cooperative union operates partly in the Sabarmati basin, and has a membership of around 350,000 from 1,050 village level dairy cooperatives affiliated with it. The village level dairy cooperatives collect and supply milk to the Dudh Sagar Dairy, which has a large capacity plant to process the milk into a variety of milk products and market them. Through the formation of milk cooperatives in almost every village in Mehsana, the dairy has contributed to improving livelihood opportunities in the rural areas of the district and to the district's overall economic development and prosperity.

Shri Motibhai Chaudhary,¹⁷ the chairman of the Dudh Sagar Dairy, has been concerned about groundwater depletion and the serious toll of the resultant water scarcity problems especially on the aspirations of the farmers in the region. In response, he has set up a foundation to address the scarcity problems locally by promoting local water management initiatives.¹⁸ The foundation has already identified several locations for construction of water harvesting and groundwater recharge structures in many villages in Mehsana district and submitted a project proposal to the Government of Gujarat worth 20 million rupees.

The foundation also raises its own funds through farmers' contributions through the district dairy cooperative. It is an indication of the foundation's strength that it has been able to bring in some 11 million rupees in one day by collecting one day's contribution of milk production from each cooperative member.

Village Dairy Cooperatives

With the formation of regional and village level dairy cooperatives, dairying has become a major economic activity in the rural areas. These cooperatives have now become an integral part of most rural communities and are both economically strong and socially vibrant. In order to understand the situation better at the village level, VIKSAT has undertaken studies of the villages of Umri in Kheralu taluka of Mehsana district and of Nana Kotasana, also in Kheralu taluka.

Umri has a total of 800 households with people from about 14 castes and communities living together without evident conflict. Out of the 800 households, 500 are members of the village dairy cooperative. All the major castes and communities are well represented. The cooperative collects around 1,500 litres of milk every day, which is worth approximately Rs 18,000. This implies that the average monthly income from dairying for cooperative members is approximately Rs 1,080. Over time, the cooperative has been able to develop its own infrastructure for collection, quality control testing, storage and sale of milk. Recently, a cooperative was formed in the village to address groundwater depletion and land degradation problems. This new cooperative already has a membership of around 100, that is one-eighth of the total households in the village.

Nana Kotasana, another village located in the northern extreme of the Kheralu taluka has a population of around 1,500 people with a total of 171 households, which is comprised of 225 nuclear families. All except 10 families own land for cultivation. The unregistered dairy cooperative working in the village has 65 members and has been in operation since 1994. The average milk production is 400 litres per day, worth around Rs 120,000 per month (Rs 1,440,000 per year). This implies that the average income for a family from dairying is around Rs 24,000 per annum or Rs 2,000 per month.

Agriculture Cooperatives

As is the case with dairy cooperatives, agriculture and tree growers cooperatives are common throughout rural Gujarat. In Mehsana district, for example, agriculture cooperatives have been in operation since the early '70s. These cooperatives have a large number of farmers as members from every village. They supply seed and fertilizers to the member farmers through their outlets spread across the district. Such agricultural cooperatives have been instrumental in modernizing agriculture throughout the region by introducing hybrid varieties of traditional crops (such as wheat and millets) and also some of the oilseed cash crops (such as castor and mustard).

Tree Growers' Cooperative Societies

The last in the series of institutions operating in the region are the Tree Growers Cooperative Societies (TGCS), which are less conventional. Though these TGCSs appear to be insignificant in terms of number and geographical distribution,

The cooperative movement has created opportunities for heterogeneous communities to work together without conflict.

they are important in that they have begun to deal with natural resource management issues. They are registered under the Cooperatives Act, and the byelaws of Tree Growers' Cooperative Societies (of the Government of Gujarat) are applicable to them. One of the prerequisites for the formation and registration of these TGCSs is the availability of common land (wasteland, degraded forest land or pasture land) for forestry related activities.

Tree grower's cooperatives are increasingly common but their activities are more sporadic and dispersed and their returns less immediate than is the case with dairy cooperatives.

Gadvada, a small region of 32 villages in the northern part of Kheralu taluka, is one area where TGCSs are becoming active. The region faces natural resource related problems such as soil erosion, land degradation and water scarcity. All villages in the region have a reasonably large amount of village common land, which is degraded. At present, ten cooperatives are operational in the area, promoted by VIKSAT to address the problems of land degradation and groundwater depletion. They are involved in forest protection, wasteland re-vegetation, soil water conservation and water harvesting activities. The first of such cooperatives was formed in a village called Kubada in 1986. The members of these cooperatives are small and marginal farmers.

There is a clear distinction between dairy cooperatives and TGCSs. In the case of the dairy cooperatives, the selling of milk is such a daily economic activity that people have strong incentives to sustain it, while in the case of TGCSs, the activities are more sporadic and dispersed and the returns less immediate. Typical activities undertaken by TGCSs include the planting and protection of trees, construction of water retention and harvesting structures and the cutting of

grasses, all of which involve relatively low levels of investment.

The age profile of members in the various cooperatives is more or less balanced between the young (between 20-40) and the old (above 40 years of age). Young people, particularly men, often migrate to cities such as Ahmedabad and Surat, and to towns such as Satlasana, Mehsana and Kheralu for wage labour.¹⁹ They maintain constant contact with their villages by visiting once every two to three months. However, after the age of 40, they often settle in their native villages to pursue their traditional occupations.

In general, the cooperatives have good representation from all the communities/ castes. The level of education attained by cooperative members is generally low, which is a reflection of the educational profile of the village itself. However, the fact that many rural inhabitants have exposure to the outside world, thereby gaining a wide range of experience (ideas, technologies, language and culture), helps them gain confidence to tackle their local problems. Of late, the educated youth in the villages are found taking great interest in the cooperatives. This indicates that the direction is being set for a vibrant and sustainable cooperative institutions at the micro level. The fact that these cooperatives have not emerged from any outside interventions (as in the case of primary agriculture societies), but are a result of the need to address the resource degradation problems at the local level, is considered a very healthy sign. Institutions having the above characteristics are bound to become viable and sustainable for any cooperative action.

Analysis of Existing Institutional Capacity for Water Management

At present, there is no one institution or a set of well-linked institutions able to carry out or manage the full range of activities necessary for a comprehensive and successful water management programme. Each set of institutions has its strengths and weaknesses.

The government and quasi-governmental institutions and other organizations concerned with water in Gujarat are designed and established on the principles of engineering and technology needed for water development and are capable of dealing with technical issues related to development focused functions. More specifically, most government institutions in Gujarat were designed to carry out water resource exploration, surveys, drilling, aquifer and surface water assessment functions. They were also designed as implementation organizations to undertake construction of water supply and irrigation projects often involving interbasin transfers or deep well drilling. None of the scientific and technical institutions have had much involvement in the scientific and technical issues related to water resource management as opposed to development. They have, for example, little experience in monitoring or assessing water use or operating combined surface, conveyance and groundwater systems conjunctively. This is not surprising since few regions in the world have considerable practical experience in these key management areas. As a result there is a large gap in the skills essential for management.

In addition to limited experience with management, most government scientific and technical organizations lack social perspectives and are not aware of micro-level issues varying from area to area. Though there is a growing acknowledgment that water management is a social activity, the capacity to deal with the social dimensions of water management issues within these institutions is more or less lacking. Most government institutions also lack skills to analyse the social and economic issues and the social engineering skills to deal with user groups or communities, all of which are prerequisites for implementing many local management solutions.

The research and training institutions probably serve as a strong link between the technical institutions, the government institutions and the institutions or people at the local level. They are strong in analysing physical, social and economic issues related to water management and have the ability to conceptualize new social and technical approaches and act as powerful catalysts for policy and programme change. They can assist the government or non-government technical institutions in developing basin level water management perspectives. These research/training institutions can also train and orient professionals from government technical agencies in tackling water management problems, which have many dimensions beyond engineering.

The quasi-government institutions, such as municipal corporations and municipalities, have substantial financial and technical resources to carry out technical projects related to water resource development, water supply, sanitation,

In Gujarat organizations concerned with water focus on the technical and engineering aspects of resource development but have little expertise in management.

water recycling, and water harvesting and recharging. These institutions need statutory powers to enforce legal and regulatory measures for water conservation and management in order to achieve long term water management objectives, and could benefit from strengthened links with the research and training institutions.

Cooperatives represent an existing institutional framework that could contribute to regional water management.

The numerous rural village institutions, such as the village level dairy and agriculture cooperatives in the basin, have a strong social base. Many individuals associated with them have a thorough understanding of the natural resource condition, factors affecting resource use, resource management issues and the factors which are critical to evolving strategies for managing natural resources. However, their area of expertise or understanding is often limited to one village or a group of villages in their microclimate.

Many individuals involved with larger cooperative institutions, on the other hand, often have a similar grasp of the local issues and, with the geographical distribution of the cooperatives, may be more knowledgeable about conditions and needs in areas that are much larger than an individual village. These individuals and/or institutions are involved in rural development and

natural resource development activities in and around the basin and have strong resource mobilization capabilities and social mobilization skills. The institutions are, however, designed to support farmers with immediate economic activities – such as the transport, processing and marketing of milk – not for long term natural resource management functions. They lack both experience with the broad set of issues central to water management and sound technical or engineering capabilities. They also have no legal, statutory or financial powers related to water management. Such institutions do, however, have the capability to mobilize the existing rural village institutions – dairy cooperatives, agricultural produce cooperatives, forest cooperatives and water cooperatives. They are also well aware of the manner in which water problems threaten the rural areas in which they work.

Overall, the large cooperatives represent an existing institutional structure that could contribute to attempts to address regional water management needs. Their capacity, however, needs to be strengthened. For this, stronger links between these institutions and the government, technical and research/training institutions need to be forged.

Defining the Option Boundaries for Local Water Management

Introduction

With groundwater overdraft in rural and urban areas, declining surface water availability due to pollution and increasing population and water dependent economic activity, the gap

between water supply and demand is widening throughout the Sabarmati basin. In this section, alternative water management strategies to address water scarcity and pollution problems in the Sabarmati River basin are investigated – in a very preliminary manner – using Tellus Institute's

Water Evaluation and Planning (WEAP) system. This is done by creating water balance scenarios for the years 2020 and 2050 that can be used to compare proposed water management interventions to a base case scenario in which little management is attempted, while demand continues to grow at historical rates.

WEAP Configuration

The WEAP configuration for the Sabarmati basin is given in Figure 7. The WEAP model for the Sabarmati basin has the following components:

Demand Sites

The demand sites identified for the Sabarmati basin are: Ahmedabad urban demand; Ahmedabad industrial demand; Gandhinagar urban demand; rural agricultural demand; rural domestic

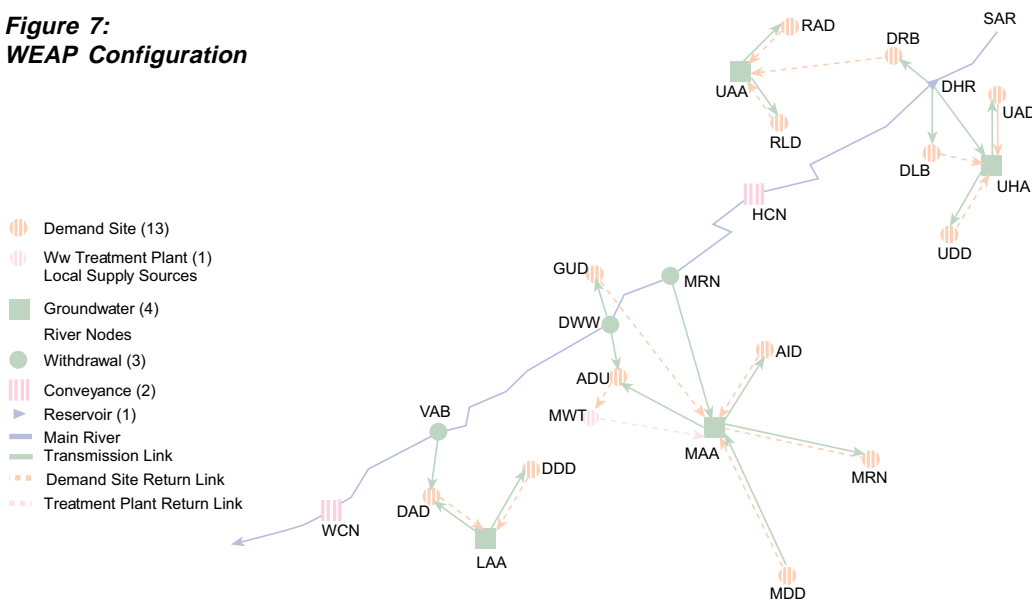
demand; upper zone agricultural demand; upper zone domestic demand; middle zone agricultural demand; middle zone domestic demand; Dholka agricultural demand; Dholka domestic demand; and Dharoi right and left bank demand.

Supply Sources

The water supply sources in the basin are categorized into local supply sources and the Sabarmati River. Among the local sources identified are the upper alluvial aquifer, upper hard rock aquifer, middle alluvial aquifer and lower alluvial aquifer. Those supply sources identified in the Sabarmati River are the Dharoi reservoir (which is treated as a reservoir node), mid recharge node (treated as a conjunctive use node), Dudheshwar water works (treated as a withdrawal node), and the Vasna barrage, which is also a withdrawal node.

Computer models can be used to simulate different management scenarios that serve as a basis for dialogue between stakeholders.

Figure 7:
WEAP Configuration



Understanding assumptions is key to effective analysis.

Network Links

The network links identified in the model are the transmission links from all the supply sources to all the demand sites. They include: transmission from Dhudheshwar water works to Ahmedabad urban and Gandhinagar urban demands; transmission from the four groundwater based local supply sources to the corresponding eight demand sites (agricultural and domestic for each zone); transmission from Vasna barrage to Dholka agricultural demand; transmission link from Dharoi reservoir to the left and right bank canal command areas located in Zone II and Zone I respectively.

Confluence Nodes

Two confluence nodes are identified along the main trunk of the river. They are Hathmati and Watrak confluences.

Demand Site Return Links

All the demand sites have demand site return links identified in order to incorporate the return flows after use to the supply sources such as river and aquifer.

Wastewater Treatment Plant

The Effluent Treatment Plant for domestic waste from Ahmedabad urban water use is treated as a Wastewater Treatment Plant in WEAP and is connected to the Ahmedabad Urban Demand Site by a demand site return link and the effluent from the WWTP is taken to the middle zone alluvial aquifer using a treatment plant return link.

Current Water Demand in the Basin

The current water demand in the basin is divided into agricultural demand, rural domestic demand, urban demand and industrial demand. The agricultural demand is further divided into six sub-sectors. The agricultural demand in each zone is divided into area under various different irrigated crops in each zone, which is again subdivided into percentage area under different irrigation devices such as small border irrigation, furrow irrigation, drip irrigation and sprinkler irrigation. Finally, the actual water use rate per unit area figures (which includes the farm level efficiencies) estimated through field studies were used as the water use rate for each irrigation device for every crop.

Similar subdivisions are made in the rural domestic demand sector within each zone. These are divided into end uses such as human uses and livestock uses in terms of number of users for each end use. The end use “human uses” is further subdivided into devices such as drinking and cooking, and other uses. The “livestock use” is further subdivided into devices such as cattle drinking and cattle bathing. Each end use is allocated a specific water use rate.

The urban demand in Ahmedabad is divided into subsectors, namely: west AMC area, east AMC area, western periphery, eastern periphery and Fort Wall area on the basis of the differential water demand and use rates existing in these areas in terms of population of each zone (adopted from a study done by Centre for Environmental Planning and Technology, Ahmedabad). These subsectors

are further subdivided into end uses namely: drinking and cooking, bathing, washing and cleaning, toilet and gardening (which is applicable only to western and west AMC areas). The end uses are again subdivided on the basis of water use devices (traditional and low flow shower heads for bathing, traditional and flushing for toilets and traditional and washing machines for washing respectively) expressed as percentages, with each one of them attributed with water use rates specific to the device. Gandhinagar urban demand is categorized in a similar manner, except that the sector is divided into subsectors reflecting construction styles (bungalows and flats) instead of zones.

Where industry is concerned, only one demand site is identified in Ahmedabad. This is divided into 3 subsectors on the basis of the industrial zones in and around the city, that is, Odhav industrial zone, Naroda industrial zone and Vatva industrial zone. The current industrial water use (volumetric) in each zone is taken as the water use rate in each zone.

Current Water Supplies

The parameters used to determine the current supplies from the local sources (groundwater) were: the monthly pumping capacities of the aquifers (with one modification anticipated in the future year, which applies to the subsequent years);²⁰ the maximum accessible storage; the initial accessible storage and the annual natural recharge.

The Sabarmati supplies include: the headflows into the Dharoi reservoir, which was given as

monthly inflows into the reservoir in the base year; the storage characteristics of the reservoir; the net monthly evaporation rates; the initial storage volume; dead storage; the total storage volume; definition of reservoir operation rules (top of conservation level, top of buffer pool and the buffer zone coefficient) and the future modifications in the reservoir storage characteristics.²¹

Network Losses

The network parameters are used to determine the actual supply requirement for each demand site and reflect monthly variation of the demand across the years, the losses at the demand site and the conveyance losses in water distribution. The network data used in the model are: monthly demand variation coefficients (to apportion the yearly demand into monthly demand values) and the percentage losses at the demand site and the reuse rates; the transmission losses from supply sources to demand sites, and the capacity of the source to transmit; percentage losses in transmission from withdrawal nodes (Dharoi reservoir node and the mid recharge node) to aquifer, which are treated as conjunctive use links; capacities of wastewater treatment plants (capacity and the annual load factor and the decay and removal rates in percentages).

Base Case of Water Supply and Demand

The base case of water demand is generated using the following: projected future growth rates²² in cropped area; percentage cropped area under different water use devices in different time horizons; urban population growth rates, and the

Demand varies according to region, use and technology.

Preliminary results indicate that recharge based on local sources could reduce the gap between supply and demand by less than one per cent.

growth in water use devices in different sub-sectors; industrial growth rates; and the rural population growth rates (for rural domestic demands). In the case of agriculture, separate growth rates are used for food and cash crops, while for area under different irrigation devices (which refers to systems of irrigation, that is, long borders, flooding, small borders, drip, micro-sprinklers, etc.) of different crops, an interpolation method was used. In the case of urban population, the growth rates are estimated on the basis of the historical data of the demographic trends. In all the cases, historical data are the basis for future projections.

Base case projections of demand at the point of end use, supply requirements (demand plus transmission and other losses), and supply availability are presented below:

The figures of supply requirements incorporate the losses during transmission from the supply sources to the demand sites, and at the demand

sites; and hence, are much higher than the demand figures.

A comparison of Tables 12, 13 and 14 indicates that the gap between the supply requirements and actual supplies widens over a period of time. The gap becomes 1,017 MCM in the year 2020 and 1,875 MCM in the year 2050.

Evaluation of Water Management Options

Scenario 1: Local Recharge Options

In this scenario, we have analysed the impact of local interventions to increase available supplies by using recharge structures in the upper catchment area and the middle alluvial aquifer. Preliminary results indicate that it would be possible to create, through this type of intervention, an overall increase in supplies from both groundwater and surface water sources, of

TABLE 12:
Current and Estimated Future Demand in the Sabarmati Basin (MCM)

Demand Site	1996	2020	2035	2050
Ahd Urb Demand	208.9	389.1	576.4	858.0
Gand Urban Dmd	13.1	23.6	34.18	49.50
Ahd Indu Demand	11.0	26.1	32.50	41.9
Rural RAD	176.1	202.2	219.99	238.4
Dhol Agr. Deman	189.4	476.6	502.9	534.9
Upzone Agr Demd	621.6	706.9	764.7	822.9
Middle Zone RAD	1,592.0	1,850.0	2,038.2	2,246.1
Rural Domestic	2.39	3.85	5.2	7.0
Upzone Domestic	12.7	20.4	27.4	6.9
Midzone Domestic	18.5	29.8	40.1	3.9
Dholka Domestic	32.8	52.7	70.9	95.4
Dharoi Rt Bank	87.2	86.5	85.3	83.5
Left Bank Canal	22.5	22.3	22.0	21.7
Total	2,988.1	3,889.8	4,419.7	5,090.0

about 8.09 MCM and 10.14 MCM by 2020 and 2050 respectively. This is insignificantly in comparison to the gap of 1017 MCM projected for 2020 and 1875 MCM projected to occur in 2050. In sum, preliminary results indicate that local recharge could reduce the gap between the amount of water available and that required by less than 1 per cent.

Scenario 2: Efficient Water Use Technologies and Reduced Conveyance Losses

In this scenario, the potential impact of changes in water use technologies in different sectors is analysed. The scenario investigates the impact of use efficiency improvements (such as adoption of improved irrigation technologies in agriculture and packages of technologies such as low flow showerheads in households and in industries) on overall demand. It is assumed that 50% of the area under every crop (except paddy) will come under one of the efficient irrigation systems (drip/micro tubes, sprinkler, mini sprinkler, small border depending on its suitability for each crop) by the year 2050. In addition, appropriate percentages are assumed for adoption of efficient water use technologies in different sub-sectors (drinking and cooking, bathing, washing and toilet, and gardening) of urban domestic sector. This variation is different for different areas of Ahmedabad city. It also incorporates potential savings through reduced losses in conveyance systems (reduced network losses) in urban water supplies, irrigation canal systems, and field delivery system in groundwater irrigated areas. In this, it is assumed that by the year 2006, conveyance losses in distribution network catering

TABLE 13 :
Current and Estimated Future Demand in the Sabarmati Basin (MCM)

Demand Site	1996	2020	2035	2050
Ahd Urb Demand	240.3	342.4	507.3	755.0
Gand Urban Dmd	15.00	15.6	22.56	32.7
Ahd Indu Demand	13.8	14.7	18.28	23.6
RB RAD	176.1	202.2	219.99	238.4
Dhol Agr Demand	189.4	476.6	502.85	534.8
Upzone Agr Demd	621.6	706.9	764.70	822.9
Middle Zone RAD	1,592.0	1,850.0	2,038.21	2,246.2
Rural Domestic	2.4	3.9	5.18	7.00
Upzone Domestic	12.7	20.4	27.42	36.9
Midzone Domestic	18.5	29.8	40.06	53.9
Dholka Domestic	32.8	52.7	70.89	95.4
Dharoi Rt Bank	87.2	86.5	85.34	83.5
Left Bank Canal	22.5	22.3	21.97	21.7
Total	3,024.2	3,823.7	4,324.7	4,951.9

TABLE 14 :
Current and Estimated Future Supply the Sabarmati Basin (MCM)

Source Name	1996	2020	2035	2050
Local Sources				
Upper Alluvial Aquifer	209.9	88.7	88.5	89.8
Upper Hard Rock Aquifer	697.9	751.5	785.1	618.9
Mid Alluvial Aquifer	2,250.4	1,355.2	1,423.0	1,561.7
Low Alluvial Aquifer	220.1	294.1	307.2	313.1
Sabarmati				
Dharoi Reservoir	149.7	57.6	12.6	30.9
Mid Recharge Node	0.00	0.00	0.00	0.00
Dhudh Water Work	18.7	11.0	1.7	171.2
Vasna Barrage	60.6	248.8	160.1	290.6
Total	3,607.3	2,806.9	2,818.1	3,076.2

to urban domestic and industrial uses will be reduced by 33 per cent and 50 per cent respectively. Also, the water reuse rate in urban and industrial uses will reach 50 per cent by the year 2006. Preliminary results from this scenario are given in Table 15.

TABLE 15 :
Change in Gap between Demand and Supply due to Efficient Water Use and Conveyance Techniques in 2020 and 2050 AD

Year	Demand Reduction (MCM)	Reduction in Supply Requirement (MCM)	Increase in Supplies (MCM)	Reduction in Gap between Supplies and Demand (MCM)
2020	370.05	486.62	-227.55	259.93
2050	701.77	944.60	-31.31	913.29

Efficient water use combined with supply augmentation could eliminate overdraft and increase groundwater storage.

The combined effect of this scenario is reduction in the demand, leading to reduced return flows from various demand sites to their corresponding aquifer (local sources of supplies) indicated by the negative increase in supplies.

Scenario 3: Conjunctive Management Option

In this scenario, the overall impact of recharging the mid-alluvial aquifer using water imported from the Sardar Sarovar Narmada main canal on the overall supply availability – with no change in water use and conveyance efficiency – is evaluated. It was assumed that surplus run-off water could be diverted from the Sardar Sarovar reservoir to the Narmada Main Canal during the monsoon and used for recharge. The recharge rate is assumed to be 50 m³ per second, and 2006 is the starting year. This water is applied through a large number of local storage ponds. The results show that the increase in the overall supplies in the years 2020

TABLE 16 :
Change in Gap between Demand and Supply due to Conjunctive Management in 2020 and 2050 AD

Year	Demand Reduction (MCM)	Reduction in Supply Requirement (MCM)	Increase in Supplies (MCM)	Reduction in Gap between Supplies and Demand (MCM)
2020	0	0	157.14	157.14
2050	0	0	156.25	156.25

and 2050 will be 157.14 MCM and 156.25 MCM respectively (Table 16). The increase in storage in the mid level aquifer is 376 MCM by the year 2020 and 423 MCM by 2050. The significant increase in the supplies in the mid alluvial aquifer is not reflected in the overall increase in supplies in the basin due to the fact that :

- in this scenario, demand and supply requirements remain unaltered as compared to the base case; and
- the local recharge envisaged due to the availability of surplus Sardar Sarovar water is applied to recharging the mid alluvial aquifer.

This leads, on one hand, to drawing more water from various supply sources, including the mid alluvial aquifer (since there is no change in water use efficiency and conveyance efficiency as compared to the base case). On the other hand, supplies are increasing in the mid alluvial aquifer. The combined affect of these two effects is seen as the greater increase in supplies in the mid alluvial aquifer as compared to the increase in the overall supplies.

Scenario 4: Efficient Water Use and Supply Augmentation

In this scenario, efficient water use technologies are introduced in all the sectors of water use, and supply is augmented (as in Scenario 1). Here, the conveyance losses are the same as in the base case. So, it differs from the combined scenario of 1 and 2. The overall impact on demand, supply requirement and overall supplies from this combined approach is evaluated and the results are presented in Table 17.

This table indicates that the overall supply from various sources declines irrespective of the local recharge activities initiated in the upper aquifer area using the excess run-off in the catchment. This is due to the fact that the supply requirements have declined substantially due to the demand side interventions. As a result, less water is supplied from various sources to demand sites. The local recharge activities and demand side interventions, however, have a major impact on groundwater storage – which increases by 726.67 MCM and 25.75 MCM in the year 2020 and 2050 respectively in this scenario.

Comparison of Options

A comparison of the above scenarios is presented in Table 18. As mentioned in the introduction to this section, the above scenarios are preliminary and far from comprehensive. Of the scenarios evaluated, the largest overall impact on water scarcity could be achieved through demand management coupled with efficient water conveyance systems. The second best option is local

TABLE 17 :
Change in Gap between Demand and Supply due to Efficient Water Use and Local Recharge Activities in 2020 and 2050 AD

Year	Demand Reduction	Reduction in Supply Requirement (MCM)	Increase in Supplies (MCM)	Reduction in Gap between Supplies and Demand (MCM)
2020	370.05	359.75	-112.28	247.47
2050	701.77	678.35	-47.62	630.73

recharge combined with efficient water use practices. We did not run a scenario that combined all three of these local options (that is, demand management, efficient conveyance systems and local recharge). This combination would probably have the largest net impact without resorting to water imports.

It is noteworthy that the supply side interventions using water from within the basin (as in local recharge Scenario 1) do not make any significant impact on reducing the gap between demand and supplies. This is important because, aside from water import through the Sardar Sarovar Project, most governmental and

Addressing water scarcity will require changes at the level of individual users, hydrologic systems and regions.

TABLE 18 :
Comparison of Water Management Options

Type of Management Interventions	Reduction in Gap between Supplies and Demand in 2020/2050 (MCM)	Demand in 2020/2050 (MCM)	Supply in 2020/2050 (MCM)	Increase in Groundwater Storage 2020/2050 (MCM)
Local Recharge Activities	8.09/ 10.14	3,889.84/5,090.05	2,814.97/3,086.37	215.51/ 11.53
Efficient Use and Reduced Transmission Losses	259.93/913.29	3,519.79/4,388.28	2,579.33/3,044.92	799.13/726.32
Conjunctive Management Utilizing Water from Narmada	157.14/156.25	3,889.84/5,090.05	2,964.02/3,232.48	-34.51/-10.97
Local Recharge and Efficient Use Practices	240.47/630.73	3,519.79/4,388.28	2,694.60/3,028.61	726.67/25.75

local initiatives to address water scarcity focus on small scale recharge projects. From a technical perspective, these recharge initiatives are probably irrelevant except, perhaps, at a very local scale.

A second major point to note from the analysis is that demand side management and reductions in transmission losses (Scenario 2) probably have more efficacy in addressing water scarcity problems by themselves than water imports. Water imports through the Sardar Sarovar projects have, however, been the primary focus of governmental efforts to address water scarcity. The most sustainable solution, perhaps, could be found by combining demand side management, reductions in transmission losses and conjunctive management utilizing imported water. This should be investigated through detailed scenarios.

Overall, the above scenarios suggest that the most effective avenues for addressing water scarcity will require changes in water use at:

- *the level of individual users* (that is, adoption of efficient water use technologies and practices);
- *the level of systems* (that is, improved conveyance systems); and,
- *the level of regions* (that is, aquifers for conjunctive management).

This will require institutional arrangements capable of addressing management needs at these three levels. The institutional context must encourage individuals to adopt improved water use technologies and use water efficiently. It must also encourage system improvements by organizations such as farmer user groups (including well companies), the irrigation department and municipal corporations. Finally, some overarching organization must be present that could implement regional scale activities such as conjunctive management. The next section focuses on these issues.

New institutional arrangements for water management are needed.

Identifying Institutional Arrangements for Water Management

This section explores potential institutional arrangements for water management in the Sabarmati basin. Since regional approaches to management have never been attempted in India, models do not exist. As a result, the approach we propose weaves together the strengths of existing local institutions with lessons from other countries.

Underlying Premise

Our approach to devising appropriate institutional arrangements for basin level water

management implementation reflects two core needs that essential to achieve the objectives. These objective are:

- 1) the need to maintain the sustainability of water use and perform inter-sectoral water allocation tasks; and,
- 2) the need to meet the water management goals of different localities based on location specific issues and local management needs.

The first need for regional approaches necessitates institutions that have financial and technical resources necessary to perform the analytical and scientific tasks required for developing basin level water management perspectives. These institutions also need to be capable of representing the array of politically powerful user groups that are regionally important (that is, farmers in the rural areas, the rural local governments, urban population, municipal corporations, industries in the urban and rural areas, the Irrigation Department and the Gujarat State Water Supply and Sewerage Board). The second set of needs requires local institutions that are oriented towards the issues in their respective localities and have a thorough understanding of the range of factors affecting the success of management within those local areas.

In the above context, proposed institutional arrangements for basin water management will need to involve a mix of government/quasi-governmental technical and scientific institutions, research/training institutions and non-governmental organizations and rural cooperative institutions (both apex and village) with vertical and horizontal linkages between different types of institutions operating with varying scales of operation. The capabilities of existing institutions and the scale at which they are operating largely define their potential role in water management and their position in the proposed institutional approach.

Institutions and Linkages

The institutional arrangement proposed here is a mix of governmental, urban and rural water

management institutions each operating at different scales. Three to four levels of institutional hierarchy are considered essential:

1) Basin level – To develop a broad perspective on water management needs throughout the basin and to ensure interaction between different parts of the basin, which are reflected in more localized management approaches.

2) Regional and Watershed – Sub-regions within the basin have different contexts and management needs. Many water management problems are essentially regional in nature and cannot be addressed either by localized action or through management at the basin level alone.

3) Local/Village – These institutions are the “natural” primary social unit in the basin for many water management activities, particularly those involving changes in water use by individuals, need local level support.

4) Urban – Urban water management needs are different from those in rural areas. This makes separate urban water management institutions (possibly sub-units of existing municipal corporations) necessary. These would be the urban equivalents of the local village institutions proposed for rural areas.

At the highest level, we propose an overarching basin level Sabarmati Basin Water Management Society (SBWMS). The SBWMS is envisioned primarily as a technical planning forum that brings together and coordinates the activities of government departments and research institutions. This institution is intended to identify broad water

Vertical and horizontal linkages between different types of organizations that operate at varying scales are important.

Water allocation is always a politically sensitive issue.

management options for the basin from a systemic perspective and determine the scale at which each one would need to be implemented in order to ensure a balance between demand and supply within the basin. The institution would also identify water allocation issues and either allocate water to meet key needs or propose alternative mechanisms for reallocating supplies. As water allocation is always a politically sensitive issue, this institution might not be responsible for actual reallocation but could identify options – and the tradeoffs inherent in each – for debate by stakeholders and political decision makers.

SBWMS is proposed primarily as a technical organization; hence, it would not be capable of representing views of users. As a result, a Stakeholders' Forum (SF) is proposed for the basin. All user groups in the basin would be members of this forum. The SF is intended as the primary institution in which users will have a major say on water management issues at the basin level. The issues, needs and priorities identified in the SF are intended to guide SBWMS in its efforts to identify management options that are socially, technically and economically viable as well as politically acceptable.

In addition to the basin level SBWMS and SF, Regional Water Management Institutions (RWMI) operating at the district or the taluka level are proposed. These would operate under the SBWMS and SF and provide them with the necessary technical information for regional planning. The primary mandate of the Regional Water Management Institution would be to assist in the identification of locally viable water management interventions, organize existing village level institutions and facilitate formation of new village/

watershed institutions. They would also be the primary institution responsible for implementing water management activities at the regional level and coordinating water management activities.

Finally, local water management organizations are proposed within each village (or village cluster) that would be responsible for local planning, implementation and support to individual water users.

The following paragraphs discuss the structure and constitution of the institutions proposed for basin water management, their role in implementing various management interventions and their vertical and horizontal linkages.

Sabarmati River Basin Water Management Society

As noted above, the mandate of the proposed Sabarmati Basin Water Management Society would be to ensure a balance between supply and demand within the basin and to allocate available basin water amongst different sectors of use. This could be done based on an integrated analysis of basin water management needs and their physical, social and economic viability of different approaches to meeting those needs. In addition, to identify potential water management interventions for the basin, the SBWMS would also suggest the scale at which each intervention should be implemented in different regions. This would provide guidance to regional and grass root level institutions in their attempts to develop location specific plans.

Evolving management strategies for a large basin calls for expertise in water harvesting/

groundwater recharge and water conservation technologies in different sectors of water use, such as agriculture, urban domestic use and industry. This has to be supported by reliable information on the physical characteristics of the resource, such as the hydrology, geology and geo-hydrology, the current level of groundwater exploitation, pollution levels and the social and economic factors affecting the resource use in the region.

To meet these requirements, the Sabarmati Basin Water Management Society should function as an independent technical agency. The mandate of existing governmental organizations focuses primarily on the development of water resources and relatively narrow sectoral functions (such as irrigation or drinking water supply). This mandate has become obsolete in the present context of resource over-development. Furthermore in many case, many existing government organizations are facing major problems of institutional sustainability due to financial limitations.

In the above context, it is proposed to constitute the SBWMS by the pooling of techno-managerial staff from government departments, such as the Irrigation Department, Department of Narmada and Water Resources (DONWR), Gujarat Jal Seva Training Institute (GJTI), GWRDC, WALMI and the western regional office of the Central Ground Water Board (CGWB) based in Ahmedabad. The SBWMS would also require the services of social scientists, agronomists and economists, who can be hired from research institutions such as the Institute of Rural Management Anand and VIKSAT. Pooling technical staff from these governmental organizations into the SBWMS would ensure development of an integrated perspective on basin water management needs. It would also help

reduce duplication between agencies, thereby reducing recurring costs.

The SBWMS would ultimately need legal/statutory powers to enact regulations required for effective implementation of the water management solutions proposed for the basin. As a result, one of its first tasks in conjunction with the SF would be to review existing legal and legislative structures and to propose alternatives.

Stakeholders' Forum

It is important to have a forum which can adequately represent the interests of various stakeholders within the basin and also influence the management decisions being taken by the basin level water management committee. Water management needs and priorities often differ between stakeholders, which frequently conflict. As a result, achieving larger water management goals for the basin would require compromises by stakeholders. Furthermore, consensus is essential in order to identify management options that would be politically possible to implement. For this reason, participation of the stakeholders communities in water management decision-making would be critical to meeting the needs and priorities of the different stakeholders in the basin. Therefore, institutional avenues would be required to evolve stakeholders' participation in planning and implementing basin plans.

As envisioned here, the Stakeholders' Forum will have representation from a wide variety of primary stakeholders including:

- farmers using surface water in the basin;
- farmers living in Dharoi command;

The scale at which interventions need to occur is an important aspect in institutional analysis.

Achieving larger water management goals will require compromises among stakeholders.

- farmers pumping groundwater from the basin for irrigation;
- farmers in Fatehwadi irrigation command;
- industries in and around Ahmedabad city;²³ and,
- the AMC and other municipalities, and the town *panchayats*.

In addition to primary stakeholders, representation from secondary stakeholder research institutions such as the Physical Research Laboratories²⁴ (PRL) and Non-governmental organizations working on water and natural resource related issues in different districts in the basin (especially those working in Banaskantha, Ahmedabad, Mehsana, Sabarkantha and Kheda)²⁵ will also be important.

Regional and Watershed Institutions

As noted above, there are a number of regional (district-level) cooperative institutions, such as the Mehsana Duddh Sagar Dairy, in 4 of the districts²⁶ falling within the basin. These institutions have substantial human and material resources, strong organizational and financial management capabilities and social mobilization skills. They have the potential to serve as strong instruments for implementing large-scale water management projects and assist in developing management strategies covering an entire region. In addition, they can support more localized water management initiatives and serve as a link between villages and the SBWMS by:

1) identifying villages that have scope for introducing management interventions like harvesting, recharge, and water conservation technologies in irrigation);

2) organizing village communities to form village level institutions (where they are non-existent) and watershed committees for implementing them; and,

3) managing implementation funds.

As some of the physical activities necessary to augment groundwater supplies are to be carried out at the watershed level, the activities taken up in different villages within the same watershed need to be coordinated so that they become effective. Since regional institutions rarely follow natural units such as watersheds, a “watershed committee” may need to be formed at the watershed level. Such an organization would have representation of village level institutions from all the villages falling in the watershed.

The case of the Joint Forest Management (JFM) programme has amply demonstrated the role of federations in the “scaling up” of JFM. These federations not only serve as a forum for discussing and solving larger issues facing the implementation of forest management plans and bring more and more villages in the joint management efforts, but also help resolve inter and intra-village conflicts emerging during the process.

The specific roles of such institutions envisaged are:

- **Setting up of village level institutions:** It would be the responsibility of the watershed association to ensure that village level institutions exist in all the villages falling in the watershed.

- **Coordination of various village level physical activities:** Since all the physical interventions have

to be carried out on a watershed basis, they have to be implemented in all the villages concerned (wherever the physical situation permits). Effective coordination is required to ensure that the activities are taken up simultaneously.

■ **Resolving conflicts between villages:** Conflicts are common in natural resources use and management. It is possible that one village would not cooperate with the village institution of the neighbouring village in implementing the management plans due to conflicting interests. In such situations, the watershed committee can intervene in the matter and help them resolve the conflict and smooth out the implementation process.

It is important to note that in the case of a small micro watershed falling completely within the administrative boundaries, of a particular village, there would not be any need to create or form a separate watershed committee, as the village level institution itself would be able to tackle all the issues related to implementation of the groundwater management plan within the watershed.

Village Level Institutions

In the structure proposed here, village level institutions would be responsible for identifying and carrying out the physical activities concerned with water management activities in local areas. The role of a village level institution would be as follows:

- evolving local water management solutions appropriate for the locality, which would include identification of possible physical

interventions, like building of recharge systems and plantation/afforestation activities, suggesting locations for the same, and identifying potential users of end use conservation schemes;

- framing rules and regulations necessary to help affect management decisions, which fall within the broad water management framework, and enforcing them; and,
- implementation of physical activities to be carried out at the village level, and resource allocation according to the use priorities.

As previously discussed, many of the villages in the Sabarmati basin already have local institutions engaged in economic activities, such as dairying, marketing of agricultural produce, and forestry and water management activities. These institutions have the organizational capabilities required to plan and carry out local water management activities, provided they receive technical and financial support from external institutions.

Urban Water Management Institutions

The urban administration has the responsibility of providing water supplies for domestic, commercial and industrial purposes in municipal areas. The AMC is one such administration within the Sabarmati basin. It has considerable financial, technical and intellectual resources to plan and implement water development and management projects within the municipal area. In addition to these existing capacities, the AMC possesses statutory powers to enforce regulations (such as those related to drilling of tubewells by private housing societies and industries, and protection of drinking water sources from pollution). The AMC

The role of village level institutions could include:

- *the evolution of local management systems,*
- *framing rules and regulations, and*
- *implementing management activities.*

The Ahmedabad Municipal Corporation should play a more proactive role in urban water management.

could also enforce measures, such as installation of roof water harvesting structures in existing and new housing stock. Violation of AMC regulations may entail cancellation of building licences, imposition of penalties or severing of water supply connections. Funds collected through penalties and water charges could be used to invest in such programmes a wastewater recycling and water harvesting by the municipal authorities. The AMC has already formulated a major project to recycle the urban domestic waste using sand aquifer treatment²⁷ downstream of the Vasna barrage in the Sabarmati riverbed.

In addition to regulation, the AMC should metre water supplies to all the housing stock in the municipal area. It is recognized, however, that the infrastructure and administrative resources required for this could be large. Metering would enable the AMC to levy water charges or taxes on a volumetric basis. This could be used as a

powerful instrument to create the incentive for urban water users to shift to efficient water conservation technologies, thus leading to a change in water use practices.

Overall, the AMC has a relatively broad array of enforcement and financing mechanisms available to it. These provide a strong basis for developing and enforcing urban water management regulations. Its strong financial position should enable the corporation to develop innovative mechanisms for developing new water supplies for the urban area. It could, for example, offer subsidies to farmers in the basin (who use both the surface water and groundwater) and to private housing societies and industries in the municipal area to invest in water conservation technologies. The “saved” water could then be used to meet the needs of populations living within the area. The corporation could, in effect, buy the water saved through such conservation practices.

Alternative Water Rights Structures

Beyond the set of organizations proposed above for implementing water management in the Sabarmati basin, water rights issues may ultimately need to be addressed. Many of the water management actions needed for implementation will conflict with existing legal and customary rights and use patterns. Water allocation, for example, conflicts with the established rights of land owners to drill wells and use groundwater as they wish. The absence of a well defined property rights structure in groundwater provides little incentive for the users to use the water efficiently. The current institutional vacuum created due to the absence of clear water rights has also resulted in inequitable access to the resource. Under the

current regulations, water rights are limited to only those who own land in which the right to drill wells is part of land ownership. Issues such as access equity and efficiency have to be built into the management goals of any common pool resource. For these reasons, water rights reform issues will probably need to be addressed before the management institutions proposed above can become fully effective. Rights reform will need to reflect both the practical needs of managing the resource base *and* equity issues.

In any water management strategy, benefits and costs are unlikely to be equitably distributed between portions of the community. It is, for

example, very likely that only a section of the community will receive benefits in terms of improved water levels in the wells, increase in soil moisture and land fertility. In the local initiatives for managing groundwater resources, the influence of recharge efforts is likely to be limited to small areas surrounding the recharge system and only those farmers whose wells fall in the influence area of the recharge system will receive direct tangible benefits. In arid and semi-arid regions (which is the prevailing condition in most parts of the Sabarmati basin), the irrigated area is much less than the cropped area. Any increase in supply availability can be used to bringing more area under irrigated agriculture. There are also many other users within the basin such as industries and municipalities who would grab any new water supply created. This can undermine the efforts of the local management institutions. In short, unless communities can establish rights over the resource they protect, and unless the demand of water is properly controlled by the adoption of efficient use practices, sustainable solutions to emerging problems are not likely to evolve, and maintaining the balance between demand and supply is likely to become a difficult task. Finally, establishment of tradable rights and water markets has been suggested by many researchers as a sustainable mechanism for addressing water allocation and associated access equity and efficiency issues.

Given the above issues, establishment of tradable water rights for groundwater could be one of the viable solutions. Such rights could be vested either with the State or with the aquifer management committees. These committees could sell the rights to legally registered village level cooperative institutions. The members of the cooperatives could then buy the rights to use

groundwater. The members would include both landholders and the landless. Landholders who do not own wells and the landless could also become members. To ensure equity, every member of the cooperative would have a fixed entitlement on the basis of the family size. This would be available free of cost or at a nominal rate. Entitlements, once allocated, would be tradeable among cooperative members. This would create incentives for the farmer members to adopt efficient water use technologies such as drips and sprinklers in their fields. Water sales by the landless and small landowners to other users would also become an avenue for an additional source of income. If the farmer member uses more than his/her “entitlement” without purchasing supplements from members who wish to sell all or a portion of their entitlement, the farmer could be charged a higher rate than that charged for fixed entitlements by the village cooperative. Overall, the goal would be to develop localized water markets that benefit all members of the local community.

In the case of large groundwater basins, many stakeholders for the shared resource (such as industries, the farming community, urban water users and municipalities) will exist. In such situations, the extent to which the markets operate can be as large as the size of the basin, depending on the geographical spread of the potential water users. Establishment of water markets and rights will create incentives for the users to invest in efficient water use practices to bring down the use levels or save from the fixed entitlements. As a result, apart from increasing the use efficiency, such markets (if operated within a rights framework) could also act as an effective tool for addressing inter-sectoral water allocation issues.

The current institutional vacuum created due to the absence of clear water rights has resulted in inequitable access to water resources.

Establishment of water markets and rights will create incentives for users to make efficient use of their water entitlement.

Industries or municipalities might, for example, be willing to provide financial assistance to farmers to invest in efficient irrigation technologies. The farmers could, in turn, sell the additional water saved to the same industries. The rationale behind this idea is that agriculture continues to account for the lion's share of the total water use in any region and that a small percentage saving in water use will result in a large increase in effective

availability of water for other uses. Such a system will also enable water transfers between basins. Furthermore, developing water markets (in areas where they are non-existent) would help the well owners to sell the water saved from his/her usual entitlement to a potential buyer. Overall, extensive and well-developed water markets could help address issues of access equity and efficiency in water use.

Conclusions

Preliminary results presented in this paper offer two conclusions:

1) Addressing water management needs in the Sabarmati River basin requires approaches that focus on demand side management. Although these results need to be confirmed, preliminary modelling efforts using WEAP indicate that local recharge and imported water supplies will be inadequate to significantly reduce the water scarcity problem in the next century. Local recharge, in particular, can only contribute in a very minor way to addressing the scarcity problem. Improvements in the system and end-use efficiency are essential. Demand side management approaches combined with conjunctive management of locally available and imported surface and groundwater supplies could be used as a basis for arriving at sustainable solutions.

2) The variety of local institutions already exists that could contribute to water management in the region. At present, however, these institutions are not linked or woven into a framework capable of supporting the evolution or implementation of integrated water management approaches. An institutional framework for this purpose consisting of state,

regional and village level organizations has been proposed. This framework needs, however, to be developed in further detail and, if possible, tested through pilot implementation projects.

The next phase of research needs to address demand side management, local supply and conjunctive management options in much greater detail from the perspective of technical and economic feasibility combined with social acceptability. Detailed modelling is required to confirm current conclusions and to identify those sets of actions that could really contribute either individually or in coordination with other management options to addressing regional water scarcity problems. Once physical management options are clarified in greater detail, institutional questions will need to be revisited to determine the kind of structures that might enable their implementation.

In addition to analytical activities, research is required on social responses to the findings presented above. Demand side management concepts need, for example, to be explored with local communities and existing institutions in order to identify potentially viable strategies.

Notes

- ¹ Collected from the Water Resources Investigation Circle, Narmada and Water Resources Department, Government of Gujarat.
- ² Dharoi Dam was constructed in 1976 and is located 165 km upstream of Ahmedabad city.
- ³ Transmissivity, or the coefficient of transmissibility, is defined as the rate of flow of water through a vertical strip of a water bearing formation (aquifer) of unit width and entire depth of the aquifer, under unit hydraulic gradient (that is, h/L , where h is the difference in the pressure head at two points situated L units apart).
- ⁴ The Naroda-Vatwa belt, Gandhinagar-Kadi belt and the Vadodara-Ankleswar belt are known as Golden Corridors of India in industry and trade circles. The Naroda-Vatwa corridor falls fully in the Sabarmati basin.
- ⁵ 1 Crore is 10 million.
- ⁶ Carry over denotes the volume carried over to next year in the average monsoon year.
- ⁷ $1539 - (1320-275.91) = 494$ MCM.
- ⁸ RBMC - Right Bank Main Canal.
- ⁹ LBMC - Left Bank Main Canal.
- ¹⁰ Source: Projects Division, Dharoi Reservoir, Kheralu, Mehsana district.
- ¹¹ In addition to the institutions covered in this section, there could be other GOs and NGOs who could play a significant role in water management. Their roles needs to be explored in detail.
- ¹² Rs 500,000
- ¹³ The Vijapur project in Mehsana District is focusing on artificial recharge of groundwater whereas the project at Ukai Canal area is on community lift irrigation. The professional staff of GWRDC who were earlier engaged in groundwater investigation and well drilling are now involved in designing and implementing recharge systems.
- ¹⁴ By economic institutions, we refer to those institutions which are engaged in economic activities.
- ¹⁵ The state of Gujarat has a long history of cooperative movements that are further institutionalized by the state authorities. Therefore a super structure of cooperative societies with an apex bank at the state level, the district central cooperative bank at the district level and the cooperative societies at the village level is built up with the support from the government for strengthening the rural economy. The societies at the village level are categorized as primary societies. The same nomenclature is used for all village level societies.
- ¹⁶ A success story on the dairy scene in India during the sixties was the farmer-owned Amul cooperative in Anand (Kheda district, Gujarat) with its integrated approach to production, procurement, processing and marketing of milk along cooperative lines. Operation Flood I was launched to create 18 "Anands" with an investment of 1,160 million, generated from gifted commodities received from the World Food Programme. Operation Flood I led to a resurgence in the dairy industry during the seventies. A much larger dairy development programme was initiated as Operation Flood II in 1979 with a soft loan of US\$ 150 million provided by the World Bank.
- ¹⁷ Shri Motibhai Chaudhary is a well known Gandhian who has done commendable work to improve the livelihoods of the rural poor in Mehsana through the dairy cooperative movement.
- ¹⁸ The Motibhai Chaudhary Foundation also focuses on animal husbandry, another key issue in the region.
- ¹⁹ Migration for jobs in the diamond cutting industry is especially common.

- ²⁰ The monthly pumping capacities of the local supplies (groundwater) in WEAP modelling were reduced in the year 2006 for the areas where the category of groundwater exploitation is grey/dark and was increased in the area where it is white. This modification is made assuming that some legislative measures will be enforced by the year 2006 to control groundwater extraction in grey/dark areas. In the same time, farmers will be encouraged to use groundwater more in the areas which fall in the white category.
- ²¹ The capacity of Dharoi reservoir is gradually declining due to sedimentation. It is anticipated that by the year 2026, desilting operations would have taken place to restore the original designed capacity of the reservoir.
- ²² A constant growth rate is adopted in this report, compounded annually.
- ²³ According to the report of the Industries Commissionerate, Government of Gujarat, out of a total of 7,287 factories in the 6 districts which fall partly in the basin, 4,946 (68%) are concentrated in Ahmedabad alone and out of the 72,167 Small Scale Industries (SSI) in the 6 districts, 44,570 (61%) are in Ahmedabad.
- ²⁴ The PRL has done a substantial amount of scientific research studies on the Sabarmati basin, including water balance studies, artificial recharge experiments and augmentation of water supplies in Ahmedabad by tapping deep aquifers in Ahmedabad.
- ²⁵ Some of the major NGOs having action programmes in the region are SEWA, VIKSAT, UTTHAN, DSC.
- ²⁶ Mehsana, Banaskantha, Sabarkantha and Kheda have apex cooperative unions, which have a large number of village dairy cooperatives working under them.
- ²⁷ This system has been developed by scientists from the Physical Research Laboratories in Ahmedabad, a premier research institution doing fundamental research on a variety of basic scientific issues. The process involves allowing the sewage water to pass through the riverbed sand and join the shallow/ phreatic riverbed aquifer. In the process, the BOD and the COD of the sewage is reduced to minimal levels.

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C H A P T E R

6

**Dug Well Recharging
in Saurashtra, Gujarat**

A Local Response to Water Scarcity

M. Dinesh Kumar, Shashikant Chopde and Anjal Prakash

Introduction

Over-exploitation of groundwater resources in Saurashtra is causing faster seasonal depletion of the resource in inland areas and saline intrusion in fresh water aquifers of coastal areas resulting in scarcity of water for irrigation, drinking and domestic uses and industries. Low annual rainfalls with high inter-annual variability and frequent droughts compound this. The problems are more acute in the summer months when the wells go dry.

Acute shortage of water has led to seasonal and permanent migration of members of vulnerable communities.

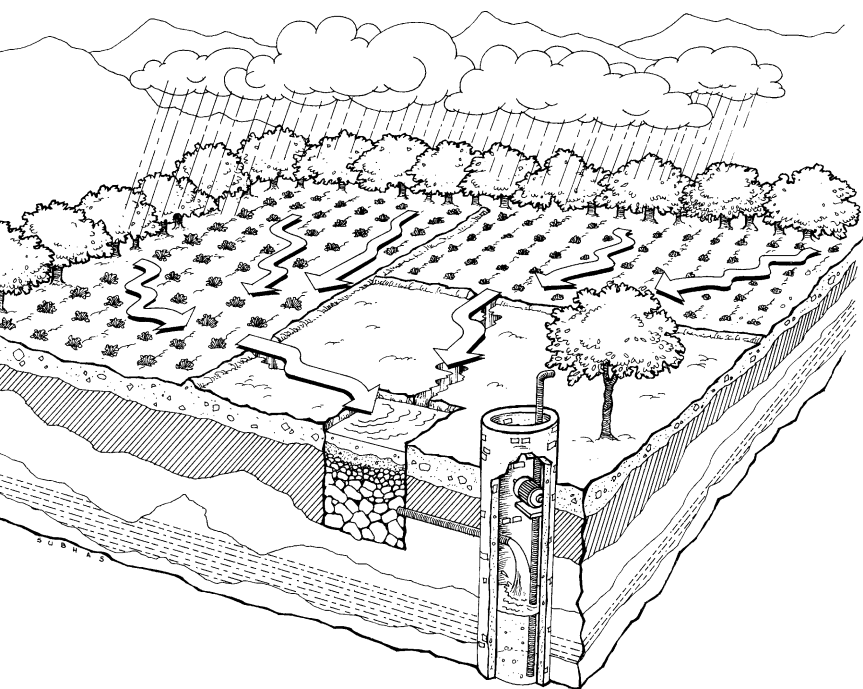


Diagram of dug well recharge structure with improved water filter.

On the whole, government responses to address the scarcity problems, such as creation of new drinking water sources and artificial recharge of groundwater in the coastal areas have had a limited impact. These responses also lack a holistic approach to water management. Further, they fail to capture the complex physical, social, cultural and economic conditions prevailing in the areas of intervention, which strongly influence the effectiveness of any water management intervention. As a result, they fail to make any significant impact on the overall water availability situation.

Acute shortage of water for agriculture and drinking has resulted in large-scale migration – both seasonal and perennial – of both agricultural and other vulnerable communities from rural areas to urban areas in search of labour. The problem, if not addressed, poses a serious threat to the sustainability of agriculture, the communities dependent on it and the overall economy of the region.

In response to the water scarcity problems looming over the region, a movement has emerged in Saurashtra to recharge aquifers of the region. Farmers are using a simple technique called dug well recharging to divert and inject the run-off from fields and from natural and artificial drains into their farm wells. The movement, which was started by a few farmers in Upletta-Dhoraji in Rajkot district of Saurashtra, is now claimed to have spread over the entire Saurashtra region covering the rural and urban areas and involves recharge of about 300,000 wells.

The Well Recharge Movement in Saurashtra

According to Shamjibahi Antala¹, the president of Saurashtra Lok Manch Trust (SLMT) which is a non-governmental organization working for rural development: “It was 1988, when the farmers of Dhoraji-Upletta, the small townships of Saurashtra, started to fill their wells with flood waters passing through nearby their farms. Having been affected by three consecutive years of drought, these people have been inspired to collect rainwater and to their surprise they found that the flood water filled in the wells bring the water table up and they could take the *kharif* crop. This simple and handy solution touched the leaders of Saurashtra Lok Manch Trust who in turn studied this system and prepared literature to provide information to the farmers on the well recharging technique”.²

The movement was also picked up on by many religious and spiritual institutions, religious heads, saints, scholars, voluntary organizations and rural communities. Some of the key institutions, organizations and individuals associated with the movement are:

- **Aga Khan Rural Support Programme India (AKRSP (I)):** a non-government and non-profit organization working on rural development in communities in the districts of Junagadh, Bharuch and Surendranagar in Gujarat through participatory natural resource development and management activities, and
 - **Vruksh Prem Seva Trust based in Upletta, Rajkot.**
- The approach of dug well recharging is based on two simple facts. First, substantial amounts of rainwater, which falls on the ground runs off into the sea or evaporates. Much of this could be collected near the place it falls. Secondly, the collected water can be stored in the depleted aquifers by directly injecting it into nearby open dug wells. This technical approach is creative and simple because it minimizes the distance between the point of collection and the use of water, unlike in the case of large water resource systems which involve long distance conveyance systems causing huge seepage losses and reduced efficiency.
- The movement claims to have recharged about 300,000 wells in Saurashtra in the last 5 years. According to Shamjibhai Antala, at least one hundred billion gallons of rainwater were injected into the wells in June-July 1995. However, no scientific estimates are available on the difference in water level rise between recharged areas and areas where recharge activities have not taken place.
- **The Swadhyaya Movement:** a spiritual movement led by Shri Pandurang Shastri Atawale working for social and cultural changes in society
 - **Lok Bharati Sanosara:** a voluntary organization working for social development mainly through rural education and grass roots action
 - **Indian Farmers Fertilizers Cooperative (IFFCO)**

Dug well recharge involves directing rainwater and run-off into existing open wells.

Water Management Implications of Dug Well Recharging

There are rainwater harvesting projects undertaken in India which had the goal of storing water underground, but the dug well recharging movement deserves special attention as a water management approach. Implementation of the recharge technology is decentralized and hence, can serve as the basis for a community based approach to solving water scarcity problems. In addition, the technology is simple and

financially viable, which makes it attractive even for poor farmers to implement. Furthermore, the technology has been implemented in an area that covers up to 40% of the state of Gujarat that makes the potential hydrologic and environmental impacts large. Finally, two-thirds of India is underlain by hard rock, which in turn makes the potential for replicability of the technique high in other water scarce areas.

Groundwater level declines in hard rock areas are often a seasonal phenomenon. Levels rise during the monsoon but drop rapidly as pumping starts.

Physical Science of Well Recharging

Physical Situation

Understanding the physical process of dug well recharging requires an understanding of the geology, geo-hydrology and hydrology of the region. Hydrologically, Saurashtra is drained by a large number of rivers and streams that flow southwest into the ocean. These rivers have only monsoon flows. Though the rainfall is low to medium, the rainfall mostly occurs in high intensities for short durations. This, coupled with the presence of heavy, medium and deep black soils having poor infiltration capacities and low thickness, which are underlain by hard rock formations result in high run-off and flash floods. A large number of medium and minor surface reservoirs have been created to harness surface run-off from the catchments in the region for irrigation, drinking and domestic uses, and industries. The total surface water availability from these reservoirs is estimated to be 5,458 MCM.

Geologically, Saurashtra is underlain by the hard rock basalt of the Deccan Trap,

except in the coastal strip, where cavernous limestone is found. Geo-hydrologically, the aquifers are shallow and confined with no primary porosity. There is only secondary porosity due to the presence of fractures and weathered zones. The secondary porosity also reduces with increasing depth and consolidation. The yield characteristics of the aquifers (that is, specific yield and transmissivity) are generally poor and also vary significantly across space and depth.

There are estimated to be some 700,000 shallow and deep dug wells in the entire region. These are used both for irrigation and drinking purposes. Dug cum borewells and deep borewells are also found in limited numbers.

Seasonal depletion of groundwater is a widespread phenomenon in Saurashtra. The water level rises high during the monsoon, but due to the poor storage capacity of the aquifer, the water level starts receding rapidly as pumping starts. Thousands of wells go dry by the onset of summer.

Technical Aspects of Dug Well Recharging

The well recharging technique, which essentially involves diverting run-off into the wells, has some variations depending upon the point of collection of water and the type of well used for injecting water underground. During fieldwork, two types of collection methods were found: collection of field run-off with diversion directly into dug wells and diversion of water into the wells from natural and artificial drains. In the case of direct diversion to the well, it is necessary to have the land sloping toward the well to eliminate the need for conveyance systems.

In most of the cases studied, run-off water is diverted directly into the well without any primary treatment. In some cases, however, water passes through one or more filters before being introduced into the well. It may pass through filters made of gravel, sand and soil, through a sedimentation tank or through a graded filter to remove organic matter and fine particles.

In the village Panch Pipalia in Dhoraji it was found that out of the 60 farmers who were reported to have done well recharging, nearly 50 were diverting water from canals and putting it underground. These farmers are not employing any filtration technique because the water from the canal is clean. During discussions, two of these farmers pointed out that the water being used is that from the flood run-off in the canal during the rainy season and not the water released into the canal. It also came out clearly during the discussions that these farmers did not need to make any investment for carrying out these activities.

The Saurashtra Lok Manch Trust has developed techniques to recharge aquifers using hand pumps and borewells as well.³ The motivating factor for this was that dry hand pumps are a common phenomenon in both urban areas and rural villages in Saurashtra, and in the rural areas, frequent failure of borewells drilled for irrigation is widespread. Many farmers are using their failed borewells for rejuvenating the aquifers and thereby improving the yield of the running open wells, which are close to these borewells. During the fieldwork in one village named Kathrotta, it was also found that some farmers are using failed borewells for recharging.⁴

In the case of hand pumps and borewells located adjacent to houses, roof tops are the collection surfaces. Rainwater collected from the roof-top is diverted directly to the hand pump or borewell through a pipeline without filtration.

Estimates of Recharge Potential Through Dug Wells

No systematic hydrologic studies have been undertaken by any agency to estimate the hydrologic impact of well recharging either for the region as a whole or for individual wells that are recharged. The figures available are preliminary estimates made by Antala and a few others who promote the dug well recharge movement.

Antala bases his estimates on field observations of the number of times the well is filled (the "fillings") and on the storage capacity of local wells. A dug well in Saurashtra has a storage capacity of nearly 400 m³ and in a normal rainfall year the well gets at least 4-5 fillings. In that case, the total water stored by a single well in the course

In many cases run-off water is diverted directly into the well without primary treatment. Pollution risks are great.

of a year is approximately 1,600 m³. Taking it further, SLMT claims that a total of 480 MCM of water is recharged through some 300,000 wells in the region.

Rainwater from roof tops can also be used to directly recharge aquifers.

These estimates seem to have a weak scientific basis as they do not take into account the run-off rates and the limited catchment area of the recharge wells. They, in turn, assume that all the water stored in the well during the monsoon is due to the recharge installation. A close look at the hydrologic parameters, such as magnitude of rainfall, rainfall intensities and soil infiltration rates, reveals that the recharge figures are likely to be overestimated. We have made back of envelop calculation and projections based on the fieldwork carried out in villages where farmers have taken up recharge activities. The heavy and medium black soils have high initial infiltration rates that become almost insignificant after 4-5 hours. The cumulative infiltration during the initial 4-5 hours is around 0.30 metres, which means the first few rainfall events (if the total magnitude is less than



Sediment trap for dug well recharge: Gujarat

or equal to 300 mm) is most unlikely to cause any run-off. Subsequent wet spells, if they occur immediately after the first ones, can generate significant run-off. In the case of a long gap between these wet spells, the infiltration capacity of soil can increase substantially due to shrinking and cracking at the surface, which in turn will further reduce the run-off rates.



Holding pond for recharge water: Gujarat

The total amount of rainwater falling in the Saurashtra region in a normal year is estimated to be 33,920 MCM of water with 510 mm of water falling over a total area of 64,000 km². If one considers an optimistic figure of 300 mm as the total (most of which will be lost in evaporation and filling the soil moisture deficit), the available run-off is only 13,440 MCM. Taking the figures of the Government of Gujarat, the net groundwater recharge taking place in Saurashtra is estimated

to be 4,289 MCM.⁵ The storage created through all the surface systems put together comes to around 5,458 MCM.⁶ This leaves 3,692 MCM of water unaccounted for. Now, on the basis of the assumption that 700,000 wells can be recharged every year at a rate of 1,600 m³ per well, a total of 1,120 MCM of water will be recharged underground. This means that the rainwater to be captured for the purpose is around 30% of the run-off left out.

Of the above 1,120 MCM only a portion could be collected due to variations in local topography. For example, potential catchment areas may not slope toward wells or water may fall on areas where it will run-off into streams instead. It should be noted that if the estimated water were captured, it would be at the cost of reduction in storage in the reservoirs and of monsoon flows in the local rivers.

Another estimate of the recharge potential of dug wells comes from discussions with farmers who use the method. They have indicated that in an average year, the farmers could see a water column of depth ranging from 20-25 feet (about 6 to 8 metres) in their wells after each major rainfall event that vanishes in 12 to 24 hours after the rains. This means that 350 m³ of water could be recharged (if one considers 5 major rainfall events for a well with a diameter of 10-12 feet). This is less than one-tenth of the 1,120 MCM estimated above.

To summarize, back of the envelope calculations based on the hydrological and meteorological characteristics of Saurashtra and the primary data collected from the farmers

indicate that the recharge estimates provided by the promoters of dug well recharging need to be used with caution.

Potential Impact on Water Quality

The dug well recharging movement poses serious questions about water quality, health, hygiene and environment. First of all, the water being recharged is mostly run-off from fields and the natural and artificial drains passing by the side of farmers' fields. The field run-off might contain agricultural residues apart from organic matter. The infiltration tanks, if properly designed, can remove the organic matter and bring down the Biological Oxygen Demand (BOD), but cannot remove the agriculture residues. Therefore, the Chemical Oxygen Demand (COD) of the water is potentially high. Mr. Ashwin Shah also put forth similar arguments. If the water from the well is used for drinking and other human uses, it could pose health hazards. Again, in none of the situations that the authors have come across, were farmers using well designed filters and sedimentation tanks. Secondly, drains and streams in rural areas flush out garbage and sewage from villages and the organic wastes from agricultural fields during the rainy season. Blocking these channels and diversion of water from them can cause unhygienic conditions in and around the village due to the dumping of waste.

The counter view of those active in the movement is that the large reservoirs of Saurashtra have the same sources of water as the recharged wells, but that there have not been health problems related to the use of water from these sources. This,

Activists supporting dug well recharge need to aware of and evaluate the pollution such activities could cause.

of course, misses the point that highly centralized systems such as the large reservoirs have expensive treatment plants that are not viable in decentralized, small-scale systems such as the recharge wells.

Economics of Recharging: Myth and Reality

Estimates of the economic benefits generated through recharge are based on anecdotal information.

Water being recharged is mainly used for irrigation by the farmers in Saurashtra. Most of the wells are farm wells into which field run-off can be diverted. The extensive work done in Saurashtra has helped collect enough evidence to establish this fact. The farmers mention that the water is not potable as it contains mud and silt. Overall, farmers do not perceive significant changes in water availability in wells that have been recharged; additional water available is only enough to give one or two supplementary irrigations. Most of the farmers interviewed during the fieldwork said that they could give one supplementary irrigation to their *kharif* groundnut in low rainfall years. In high rainfall years they could increase the area under irrigation for winter crops in comparison to similar rainfall years before recharge activities were initiated. Supplementary irrigation is, however, critical to obtaining high yields from groundnut. The farmers opined that in bad rainfall years, without supplementary irrigation, crop yields fall to 20% of the average yield. The last support irrigation not only helps prevent crop failure but also increases the yield substantially.

A large amount of anecdotal evidence regarding the economic benefits of recharge is, however, circulating through the media and other informal

forums. There are, for example, assertions based on the back of the envelope calculations made by Vayak and Khanpara quoted in Shah (1998). They estimated that 10,000 wells were recharged in Kutch and Saurashtra during 1993-94 and that this cost the farmers Rs 500,000 but raised net output by Rs 80 crore (Shah, 1998). The economics of well recharge advanced by Vayak and Khanpara were based on the following estimates: Saurashtra receives an average rainfall of 508 mm and a recharged well can irrigate 8 additional acres during *rabi*. Recharging a well costs Rs 800 at a maximum and an irrigated *rabi* crop gives a net income of Rs 10,000 per acre. Again, these figures are estimates.

The basic flaw in the above economic analysis is overestimation of the irrigation potential created through recharging wells. To irrigate an additional 8 acres of *rabi* crop (let us say winter onion, which requires 700 mm depth of watering) would require at least 22,680 m³ of water. If one assumes an average run-off of 50 mm (10% of the average rainfall of 500 mm) to be available for recharging the wells, the free catchment required for each well will be 110 acres or 0.453 km². This is impractical, as the average landholding of the farmers is around 10 acres. The weakness of the argument can be more clearly understood from the claim made by Shri Shamjibhai Antala during his interview with the authors that around 700,000 wells in Saurashtra can be recharged with incremental hydrologic and economic benefits. If, the entire geographical area of Saurashtra could be used as a catchment for recharging the 700,000 wells in the region, gross catchment for an individual recharge well would be only 22 acres. Furthermore the actual catchment area would be

much smaller if one considers the source area of the major, medium and minor surface irrigation schemes (where the water has already been harnessed), and the land which topographically cannot be drained into dug wells.

In order to have a more accurate estimate of the amount of recharge and the returns, VIKSAT carried out a survey of 15 farmers in Kathrotta village⁷ in Rajkot district of Saurashtra who have taken up dug well recharging. Results of analysis of the primary data collected from these farmers are presented in Table 1.

The results given in Table 1 indicate that the number of crops and total area under different crops have increased. But the average area under each crop for the individual farmer has reduced substantially for all the *rabi* crops. Overall, the watering intensity during *rabi* has increased. While the hours of watering per *bigha*⁸ were 34.55 during *rabi* before recharge activities were initiated, it is estimated to be 49.50 after recharge.

The total hours of irrigation possible to provide through each well has also increased after recharges. While the average hours of irrigation per well (based on data of 13 wells) was estimated at 297 hours before recharges, it was estimated at 377 hours after recharge, an increase of 80 hours. This is equivalent to increasing the area under irrigation by nearly 2 *bighas* (0.80 acres) assuming an average of 40 hours of irrigation per *bigha* — for a *rabi* crop (a reasonably accurate number based on our field surveys). A closer analysis shows that the difference is due to the increase in hours of watering during *khariif*. After recharge activities, the average total hours of

TABLE 1:
Impact of Recharging on Crops and Cropping Pattern

Name of Crop	No. of Farmers Having Grown the Crop					
	Before Recharge			After Recharge		
	No	Total	Average	No	Total	Average
Wheat	3	27.50	9.17	8	26.50	3.30
Onion	6	57.50	9.60	8	62.60	7.80
Castor	3	32.00	10.67	5	45.00	9.00
Coriander	2	27.00	13.50	6	21.00	3.50
Cumin	2	*	*	4	*	*
Groundnut	9	15.80	1.70	8	28.00	3.50
Cotton	3	4.50	1.50	4	8.75	2.20

*Area figures not available.

watering declined by 10 hours in *rabi*, while it increased by 90 hours in *khariif*. The increase in water availability increases farmers' ability to give support irrigation to groundnut and increase the productivity.

If one assumes that the farmer grows a high valued crop like onion which gives a net return of Rs 10,000 per acre of irrigated crop, the additional return will be Rs 8,000 per recharge well. Now, if one makes a reasonably accurate assumption that 50,000 wells in Saurashtra are recharged, the total annual economic return would be 400 million rupees.

The Social Dynamics Behind the Movement

The mass movement for well recharging which has emerged in response to major increases in water scarcity problems. It was catalysed first by the Saurashtra Lok Manch Trust, *swadhyaya pariwar* (spiritual institution). Subsequently, in the aftermath of the three year drought from 1995 to 1997, some Hindu sects, numerous NGOs and

The recharge movement emerged as a response to increasing water scarcity.

other mass based social organizations have played major roles in encouraging the movement.

Swadhyaya pariwar is a closely-knit community. The more devoted and committed among the *swadhyayees* spend a good deal of time and effort in communicating new ideas across the *swadhyayee* community. *Swadhyaya pariwar* has developed an indigenous communication capacity that propagates information regarding new technologies widely and rapidly. Audio and video recordings of Athavale's talks are played before voluntary gatherings of *swadhyayees*. These act as a powerful medium for spreading new ideas and messages. There are several reasons why the recharge initiatives grew into a mass movement. Tushaar Shah⁹ discusses some of these in his recent paper on the issue (Shah, 1998), which we also think are important: First, the core *swadhyayees* showed readiness to give a serious try to the ideas of the movement founder who catalysed the first generation of recharge activities. Secondly, the idea of dug well recharging was marketed in the packages of instrumental devotion (that is, it was included along with the printed religious packets handed out by the organisation) and no stage in the earlier years did the *swadhyayees* ask the farmers to recharge their wells for economic reasons. Instead, they untiringly cited Athavale's teachings that, "if you quench the thirst of Mother Earth, she will quench yours".

The Saurashtra Lok Manch Trust, which is a mass based social organization organized rallies in rural areas to address the masses and propagate concepts regarding the urgent need for in-situ water harvesting.¹⁰ The entire focus of their work was to place water scarcity issues on the social and economic agenda, to create water literacy

among the ordinary people and educate them regarding various techniques for aquifer recharge through dug wells. The arguments advanced by the SLMT centered around three basic issues: 1) Saurashtra has unique hydrological features where low aquifer storage characteristics and high rainfall intensities result in little groundwater storage; 2) the inherent drought proneness of the region and common occurrence of seasonal as well as longer-term water scarcity problems; and, 3) well recharging as an in-situ way of harvesting rainfall, the source of all water and thus supplementing other water sources.

Additional factors, however, contributed to the growth of well recharging as a broad farmers' movement not restricted to *swadhyayees* or followers of other religious sects. The investment for well recharging is small and often negligible; the benefits of recharging are perceptible in terms of rise in water levels in wells and increased well yield; and the economic returns are much faster. Above all the technology is easy for ordinary people to understand, replicate and implement.

Some of these factors also explain why the movement did not pick up in other parts of Gujarat, such as north Gujarat where water scarcity problems are equally critical. One of the reasons, which is also important from the point of view of inspiring the people,¹¹ is that the rate of run-off in the alluvial areas of north Gujarat, where soils are sandy, is low compared to Saurashtra which has clayey soils. As a result, the amount of water that can be captured from run-off in north Gujarat is small. In addition, landholdings in north Gujarat are rather small, which again reduces the quantum of water available for recharging.

Social movements can have a major impact by improving water literacy.

Institutional Response to the Recharge Movement

In spite of the fact that the villagers have responded positively and transformed recharge initiatives into a people's movement, the movement has not received enough attention from the policy makers. First, no information is available on the actual scale of recharge undertaken as no systematic studies have been done. Needless to say, even less information is available on the physical (hydrologic) impact of recharging. Well recharging is extensive and it could alter the overall water balance even in large basins. As a result, information on the number of wells which could beneficially be recharged without causing significant changes in water available for surface schemes is important. This is also important because many financial institutions have started showing interest in dug well recharge proposals as a source of water supply for irrigation and want to consider them as bankable projects.

The movement to recharge dug wells has attracted attention from other states in India. Officials of the groundwater departments from states such as Rajasthan, Madhya Pradesh and Tamil Nadu have visited Saurashtra over the last few years to understand the recharge movement and to explore the possibility of replicating the technology in their respective states. Orissa has gone one step ahead in this direction. There the government has already started implementing water conservation and rainwater harvesting techniques in some of the water scarce and economically backward districts in the state.¹²

If dug well recharge initiatives are not technically and environmentally sound damage to

the aquifers of Saurashtra needs to be avoided. The movement is a creative response to regional problems and should be provided with guidance to make it technically, environmentally and economically sound. In addition, if necessary, financial assistance should be provided to improve its success.

Future Areas of Work

Dug well recharge as a technique is promising. The technique is people friendly (low cost, technologically simple and easy to implement); it has the potential to contribute significantly to solving problems of individual farmers; it promotes decentralized water management; and the entire activity is happening without much institutional support. There is, however, a long way to go before it should be advocated as an environmentally sound and sustainable approach to water management. Studies will be required to understand:

- the hydrologic, water quality and economic impacts of dug well recharge for individual wells;
- the change in overall water balance of a basin due to dug well recharge; and,
- the environmental impacts of dug well recharge, such as potential pollution problems.

Research is also necessary to determine the optimal number of dug well recharge systems that a region/basin can support and to develop some quantitative criteria for recharge system design.

Beyond the technique itself, it is important to recognize that dug well recharge will not solve the

Uncertainties include:

- *economic benefits,*
- *overall water balance,*
- *environmental impacts, and*
- *water quality effects.*

Ultimately, the impact of the Saurashtra well recharge movement may depend on whether or not it can evolve into a wider social movement for water management rather than just supply enhancement.

water scarcity problems of arid regions. Where rainfall, the primary source of water, is both limited and highly variable. While the amount of new supply that can be created may be significant, our estimates indicate that it falls far short of potential water needs. Ideally, water harvesting initiatives of this type would form part of a larger package of management actions designed to increase water use efficiency and reduce

demand as well as to supplement supplies.

The well recharge movement in Saurashtra represents a very significant social initiative to address water scarcity problems. Ultimately, however, its larger impact may depend on whether or not it can evolve into a wider social movement for water management rather than just supply enhancement. This is perhaps the most significant question for future research and action.

Notes

- ¹ Shri Shamjibhai is a self-taught man and is among very few activists and experts who have looked at rain as the fundamental source of all water, rather than rivers, to evolve a technical solution to water problems.
- ² Personal communication Shri Shamjibhai Antala had with Ashwin Shah, a US based civil engineering consultant working on water related issues in Gujarat.
- ³ Personal communication, Shamjibhai Antala.
- ⁴ One farmer named Patel Virjibhai Nathabhai Vachchani has four borewells of which one is high yielding, the second one is low yielding and the remaining four dysfunctional. The recharge system designed and installed by him is worth studying. He has constructed a surface tank just on the lower side of his sloping field, which collects field run-off. The water is then pumped into the borewell, which is dysfunctional. This water, according to the farmers, improves the yield of the neighbouring pumping borewell. During the winter and summer, he pumps out the water from the low yielding well and stored in the same surface storage tank. This water is then taken to the field channel by gravity and mixed with the water from the high yielding well to irrigate the fields.
- ^{5 and 6} Personal Communication, Gujarat Water Resources Development Corporation.
- ⁷ Kathrotta is a village where recharge activities were carried out by the farmers very systematically with technical and financial input from Indian Farmers' Fertilizer Cooperative (IFFCO). Around 80 farmers in the village have taken up dug well recharging last year.
- ⁸ One *bigha* equals 0.4 acres.
- ⁹ Director Institutions and Governance programme, International Water Management Institute, Colombo.
- ¹⁰ The Saurashtra Lok Manch took out a rally in 1995 in Saurashtra during which volunteers used a large number of pamphlets describing the various simple techniques for well recharging. The mass media like newspapers popularized these events.
- ¹¹ While talking to some farmers from Mehsana in north Gujarat about the scope of dug well recharging in the area, the response came immediately from some of the experienced farmers saying, 'Where is the water to recharge?' The situation in Mehsana is far different from the situation in Saurashtra, as the soils are sandy and allow very little run-off".
- ¹² Mr Antala, who is spearheading the movement, was recently invited by the Government of Orissa to suggest solutions to water scarcity problems in the state. Based on the suggestions made by him, the district administration of Kalahandi and Ghanshyampura – two of the economically backward districts in the state – have already started implementing dug well recharging projects in the area with people's involvement.

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C H A P T E R

7

**Local Strategies for Water
Management and Conservation**

*A Study of the
Shekhawati Basin, Rajasthan*

M.S.Rathore and R. M. Mathur

Introduction

The state has now started to focus on groundwater “management” not “development”.

Groundwater is a primary source of water supply for irrigation and domestic use in rural and urban areas in Rajasthan. Over the past five decades agricultural growth in the state has been supported primarily through increasing the use of groundwater. This process has been greatly encouraged through a combination of direct and indirect subsidies. Credit policies subsidizing the development of new wells and energy pricing policies that subsidize diesel and electricity have reduced costs of extraction. Equally important, however, have been broader agricultural price support and procurement prices for crops and input subsidies for seed and fertilizer. The package of direct and indirect support has enabled farmers to expand production greatly and has encouraged greatly increased levels of groundwater extraction as an integral part of the process.

The main objective of the above policies has been to increase agricultural production and provide food security for the rapidly growing population. Expanding the use of groundwater *per se* was never the primary objective of these instruments. Expansion of agriculture and the spread of energized pumping technology have, however, fundamentally changed water use patterns and resulted in dramatic water level declines. Groundwater extraction now exceeds recharge in many low recharge areas. Competition between users and uses (agriculture, domestic, industrial, and commercial) is growing fast, which has had a further impact on overdraft conditions. It is clear that the present pattern of groundwater utilization is unsustainable. Rajasthan has passed the stage in which society can focus on groundwater “development” as a

catalyst for agricultural development and entered into the phase of groundwater “management” (Shah, 1997).

Attempts to address groundwater overdraft in Rajasthan have focused on integrated management, basin management and water balance approaches. Each of these has, in one way or another, failed to deal with the complex problem. The primary limitation lies in implementation mechanisms. Approaches focused on the economics of groundwater extraction (primarily limitations on credit access in overdeveloped areas) and legislative regulation (primarily restrictions on electricity connections and well spacing regulations) have been tested in different forms in a number of states in India. These policies have generally proved unenforceable and had little impact on groundwater overdraft problems.

During the last five years subsidies have been proposed and tested as instruments to directly influence water use. Farmers have been encouraged to use sprinklers to save water so that the area under irrigation could be increased and the demand for water reduced. Sprinkler technology is being widely adopted in parts of Rajasthan and the objective of increasing the area irrigated has been fulfilled. Net water savings have, however, not been realized and there may have been a negative impact on the level of groundwater exploitation because of the increased area under irrigation. Part of this is a result of contradictions in the policy objectives. Reductions in groundwater extraction would only be expected through improved irrigation technologies

if the cultivated area were to remain relatively constant. An additional factor may be the limited efficiency of many of the sprinklers. Studies in other areas have indicated that overhead sprinklers often lose 40-60 per cent of the water applied through evaporation (Moench, 1991a). Since virtually all sprinklers in Rajasthan are of the overhead type, there may be little actual savings. In any case, although adoption of sprinkler technology has been relatively widespread in Rajasthan, this has had little impact on the rate of groundwater depletion. Local responses to the increasing water scarcity associated with overdraft vary according to location and landholding patterns. Two common responses, however, are shifting to cropping patterns with low water demanding crops and the deepening of wells.

Objectives

In order to address groundwater overdraft problems, it is essential to understand use responses to varying water availability situations. The present research is part of a broader study undertaken to identify and communicate the water management needs that can be addressed through local management strategies. The study focuses on case study sites located in the Shekhawati Basin, an arid zone in northern Rajasthan. Objectives of this study are:

1. To document the range of water management challenges facing populations in the case study sites;
2. To document existing physical responses to management needs and identify other alternative physical responses from the perspective of both local and technical/official communities. (Some

This report is divided into five sections. The first focuses on the objectives of the study. This is followed by an overview of the status of water resources in Rajasthan and includes a description of the supply and utilization of water resources and the nature of emerging problems. The next section provides background information on the Shekhawati Basin and its northeastern sub-basins in which the case study was conducted. The fourth section documents the local level responses in management of water resources and presents the results of the field survey. The final section outlines suggestions to deal with the groundwater problems. The report is based on the results of the first phase of research and draws on a combination of secondary data and initial field surveys in the case study region. The present study covers only the northern half of the basin.

of these physical responses include new supply development, end-use conservation and reallocation).

3. To identify the scale at which different physical responses must be implemented in order to address the previously identified water management needs;
4. To document existing incentive structures created by government policies, water markets, water rights and customary practice that govern the ability of local communities to adopt or implement alternative physical solutions; and
5. To identify potential avenues for changing incentive structures and developing efficient, equitable and sustainable water resource management systems.

Local responses to increasing water scarcity vary according to location and landholding patterns.

Overview: Water Resources in Rajasthan

Rajasthan is a predominantly agricultural state located in northwestern India. More than seventy per cent of the population depends on agriculture, animal husbandry and related activities. Limited availability of water is recognized as the most important factor constraining growth and development. This is especially the case with regard to agricultural productivity, which is dependent on an assured and timely supply of water. As a result, investment in better utilization of available surface and groundwater resources has remained a priority in all development plans drawn up for the state since 1950.

Groundwater serves seventy per cent of the irrigated area in Rajasthan.

Figure 1:
Location map of Rajasthan.



RIVER BASINS				
1. SHEKHAWATI	2. RUPARALI	3. BANGANGA	4. GAMBHIR	
5. PARBATI	6. SABI	7. BANAS	8. CHAMBAL	
9. MAHI	10. SABARMATI	11. LUNI	12. WEST BANAS	
13. SUKLI	14. OTHER NALLAHS	15. OUTSIDE BASIN		

More than two-thirds of the state has arid to semi-arid climatic conditions. Very low and uncertain rainfall, many rainless months, a high probability of drought years, and very little surface water flow are the characteristics of these regions. The annual average rainfall in much of the arid zone is only 200 mm. More than 90 per cent of this rainfall occurs during a few major rainstorms in the four months of the monsoon season. In addition, the variability of precipitation over space and time is high.

For geographic, economic and technical reasons, most irrigation projects (except for the Rajasthan Canal) are located in the eastern half of Rajasthan. Most of the economically attractive sites for construction of major and medium irrigation projects have already been identified and developed to provide irrigation. According to the Department of Irrigation the total surface water potential within the state is estimated at 1.96 million hectare metres. Of this, 1.79 million hectare metres of water is received under various inter-state river basin agreements. Since 1951 the state has begun or completed 9 major, 60 medium and 1,582 minor irrigation projects. The total expenditure incurred until the beginning of the Ninth Five Year Plan on Major and Medium Projects amounts to Rs 29,749 million and on minor projects Rs 9,004 million. This investment has been used to create an irrigation potential of 1.92 million hectares through major and medium projects and 290,000 hectares through minor projects. The cost per hectare of additional irrigation potential in major and medium projects during the Eighth Plan was Rs 57.6 thousand and

it is increasing over time. In spite of huge investments in surface irrigation structures, canal systems irrigate only 30 per cent of the net irrigated area in the state, the remainder being irrigated by groundwater.

The assessed groundwater potential (gross recharge) is estimated as 13,157 MCM (Table 1). Of this, approximately 16% is utilized for drinking water purposes and about 84 per cent is utilized for irrigation. In terms of volume, industrial use is negligible. Thus, available groundwater potential for irrigation is estimated to be 10,975 MCM. At a state level the stage of groundwater development (the proportion of the gross recharge that is extracted) has increased from 31 per cent in 1980 to more than 64 per cent in 1996. In many locations the percentage is much higher and there are widespread and clear cases of groundwater over-exploitation. The extent of over-exploitation in the state is evident from the data reported in Tables 1 and 2 and Figure 3. The number of administrative blocks in which the state classifies groundwater as being under critical condition has increased from 12 in 1980 to 105 in 1996, and 33.8 per cent of the groundwater zones have become “dark zones” where exploitation is estimated to be more than 80 per cent of the recharge.

In Rajasthan, rapid population growth and the expansion of economic activities have led to increasing demand for water for a variety of uses. Most water use, however, is for irrigation, which accounts for nearly 90 per cent of the total water utilized in the state. Wells are the major source of irrigation contributing more than 60 per cent of the net irrigated area. In total there are around 1.2 million wells. Their use is strongly influenced

TABLE 1:
Change in Status of Groundwater in Rajasthan (1990-1995)

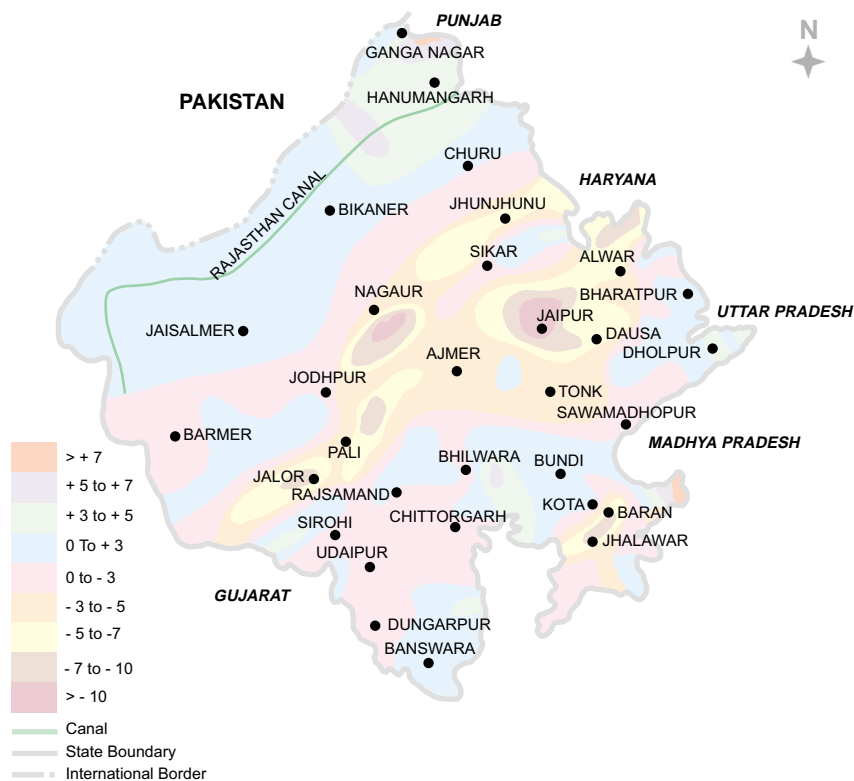
Item	1990	1995
Groundwater Potential Zones (area in km ²)	213,144	212,621
Gross Recharge (MCM)	12,708	13,157
Available Groundwater Resource for Irrigation (MCM)	10,801	11,028
Groundwater Draft (gross) (MCM)	9,368	9,916
(a) Domestic	526	697
(b) Irrigation	8,841	9,085
(c) Diverting of mines (kota)	-	134
Groundwater Balance		
(a) Gross	3,340	324
(b) Net	4,981	4,535
Stage of Groundwater Development (%)		
(a) Overall	74	75
(b) For irrigation	54	59
Category Potential Zones (Number, %)		
(a) White	484 (61.4%)	322 (54.2%)
(b) Grey	84 (10.6%)	71 (12.0%)
(c) Dark	221 (28.0%)	20 (33.8%)

Source: Groundwater Department, Government of Rajasthan, Jaipur.

Figure 2
Districts of Rajasthan.



Figure 3:
Change in pre-monsoon water levels between 1984 and 1997.



SOURCE: Ground Water Department, Jodhpur.

TABLE 2 :
Groundwater Potential in Rajasthan (1980-96)

Years	Available groundwater resources for irrigation (MCM)	Net irrigation draft (MCM)	Groundwater balance (MCM)	Stage of groundwater development (per cent)	Blocks under critical and semi-critical category (no.)
1980	10,947	3,323	7,624	31	12
1984	13,790	4,927	8,863	36	33
1988	10,967	5,465	5,502	50	65
1990	10,801	5,821	4,981	54	88
1992	9,849	4,714	5,135	48	92
1993	10,881	5,512	5,369	51	96
1995	10,975	6,494	4,481	59	109
1996 (P)	10,975	>7,000	<4,000	>64	105

P - Provisional

Source: Groundwater Department, Government of Rajasthan, Jaipur.

by annual rainfall. In wet years, groundwater is used as a major source of supplemental irrigation. In dry years, it is the primary source but use is limited because a large number of wells run dry. Overall, approximately 23% per cent of wells run dry or go out of use every year. In addition to irrigation, groundwater is the primary source of water supply for drinking and domestic uses in rural and urban areas of Rajasthan. It is the primary source of water for approximately 80 per cent of Rajasthan's drinking water needs and is also an important source for industrial and other economic uses.

Groundwater resources in Rajasthan are showing increasing signs of degradation, as can be seen in Figure 3, which depicts water level changes between 1984 and 1997. In many areas over the last decade water level declines have ranged from 3 to more than 10 metres, with the most affected part being in the centre of the state. Water level declines have also led to declines in water quality. Almost 30 per cent of the districts have attained the critical stage (extraction exceeds 80% of recharge) and an additional 50 per cent are in the semi-critical stage (extraction exceeds 60% of recharge) of groundwater development (Table 3).

The most common response to overdraft problems in Rajasthan, India and elsewhere, has been to seek new external sources of supply – more big surface water projects, for example. Experience shows that this solves only part of the problem and at a very high cost. In spite of huge investment in creating surface water harnessing structures and a major programme of Watershed Development and Management in Rajasthan, groundwater levels continue to decline rapidly.

Overall, new surface water harnessing structures are unlikely to have a major impact on the groundwater overdraft. Limited new water supplies are available for capture and the cost of doing so would be high. The potential impact of recharge is also limited by the unavailability of water, the high variability of rainfall over both time and space, and the large areas of land where recharged water is not usable for irrigation or drinking purposes because of the salinity of the soils. In any case, approaches that emphasize supply augmentation only address part of the problem and are not sustainable in the long run.

Surface and groundwater are part of the same hydraulic system, and demand and supply are two sides of the same coin. Therefore, the water resource management problems of Rajasthan have

to be addressed by adopting an integrated approach rather than a sectoral or purely supply focused approach. Given the limited availability of new supplies, demand side management is essential. Theoretically, this could be done through enforcement of a central control regime in which a regulatory agency allocates water optimally over time. Studies show, however, that central control offers virtually no gain over common property arrangements enforced by the community (Provencher and Burt, 1994). In addition, it is unclear how water use could actually be regulated on a practical basis by a central

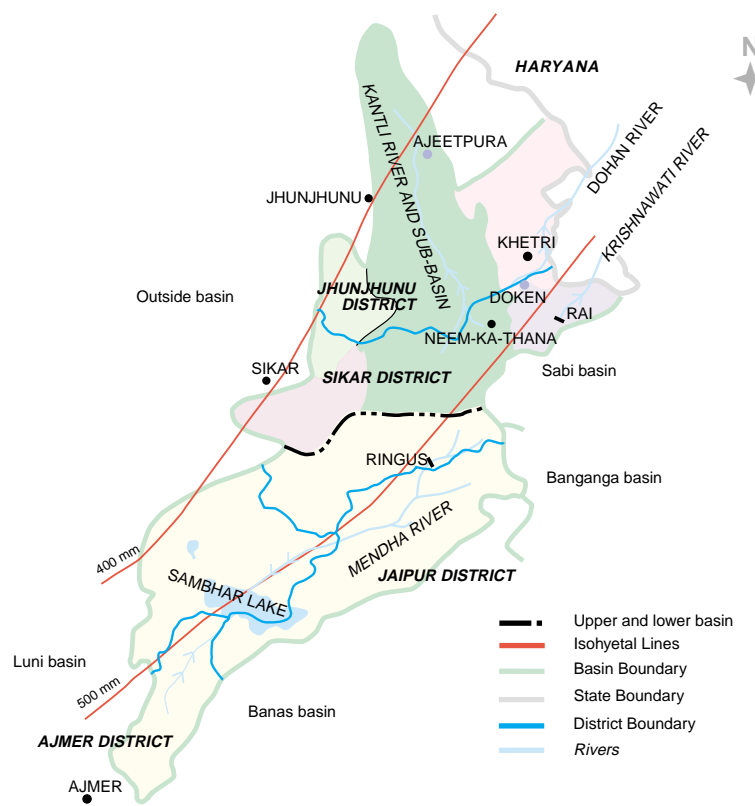
Given the limited availability of new water supplies, demand side management is essential.

TABLE 3:
Categorization of Rajasthan's Districts by Status of Groundwater (1984-99)

Safe	Semi Critical	Critical
	Ajmer	Alwar
Barmer	Bundi	Jaipur
Jaisalmer	Chittorgarh	Dausa
Bikaner	Churu	Baran
Ganganagar	Dholpur	
Hanumangarh	Dungarpur	Jodhpur
	Jhalawar	Nagaur
Banswara	Kota	Sikar
Bhilwara	Pali	Jhunjhunu
Rajsamand	Jalore	
	Tonk	
	Sawai Madhopur*	
	Sirohi*	
	Udaipur*	
	Bharatpur**	

Note: * - Sawai Madhopur, Sirohi and Udaipur district being hard rock area and below normal rainfall of 1996 they have increased to critical stage.
 ** - In safe category as per data, but because of saline area, it has been placed in semi-critical category.
 Source: Groundwater Department, Government of Rajasthan, Jaipur.

Figure 4:
Shekhawati River showing basin and political boundaries and hydrometeorological details.



A key policy issue is to define the level and scale of intervention for management.

agency in Rajasthan. An alternative option is to develop a broad based approach to demand side management of groundwater. This could encompass a very broad range of interventions intended to influence access to water and its use pattern. Measures could include introduction of a new groundwater law covering registration of wells, restricting water pumping capacity, minimum norms for spacing and depth of wells and appropriate pricing of water and of energy. The success of these policies largely depends on the response of the people, particularly the farmers.

Under existing law, which is based on English Common Law, and regionally accepted traditions, landowners have an “absolute right” to pump groundwater. They have the right to sink wells on their land and pump as much water as they can from it – provided water is available in the aquifer. The doctrine makes groundwater into a common pool resource in which all overlying landowners have a pumping privilege. Under this right of capture doctrine, groundwater mining is profitable even when it is unsustainable. As a result, irrigated acreage has spread and in most areas water levels have declined precipitously. Both users and the government are aware of this and efforts are on to translate government concern into

effective institutional change. Institutional change, particularly when it could affect individual pumping rights is, however, politically sensitive. As a result, substantial debate over what form groundwater management should take has started in recognition of the urgent need to slow the rate at which water is pumped. This debate intensifies in drought years when groundwater pumping depths often fall precipitously, spurring debate about the future of the resource.

In addition to legal issues, a key policy issue is to define the level and scale of interventions for different sets of management actions – for example, do they need to be implemented at a village, regional or state scale and can they be implemented by organizations at these levels. Because demand management depends on changes in water use by individual farmers, local management approaches may be the most appropriate for addressing certain sets of needs. The political sensitivity of regulatory approaches and legal or other institutional changes also points toward the need for the development of participatory, local approaches to management. What these local management options might be has not, however, ever been systematically investigated.

Research in the Northern Shekhawati Basin

Methodology

The Shekhawati Basin in northeastern Rajasthan is the focus of a long term study of which this paper is the first portion. The first phase of the study has involved collecting

information on the Shekhawati Basin as a whole and on choosing field study sites in the northeastern area of the basin, that is, the areas of the Kantli, Krishnawati and Dohan sub-basins (see Figures 4 and 5). Six villages were selected based on depth to groundwater. The villages of

Ajeetpura and Doken, located within the Kantli and Krishnawati sub-basins respectively, were chosen for the current field study. The remaining villages to be studied are also in the Kantli sub-basin.

This study was planned to represent an arid agro-climatic region. Of the 14 administratively defined “river basins” in the state, only the Shekhawati is classified as having arid conditions (the western portion of the state falls in the arid zone but is not officially classified as being part of a river basin). Figures 1, 4 and 5 show the locations of the river basins in Rajasthan, and features of the whole and then the upper Shekhawati Basin.

Low annual rainfall makes groundwater the major water source in this basin. With depth to water being a major factor determining access, differences in the depth to groundwater across the basin were taken as the basis of the selection of villages for the detailed study. In order to identify possible study sites, a hydrological map of the study area was super-imposed on the basin map to delineate areas with different depths to groundwater and categorized as: depth less than 10 m, 10-20 m, 20-30 m, 30-40 m and 40-50 m. One village from each one of these categories was randomly selected for detailed study. Results of only two village studies are reported below. The first of the randomly selected villages, Doken, in the Krishnawati sub-basin, lies in the “less than 10 m” belt. The second village, Ajeetpura, in the Kantli sub-basin, is in the 40-50 m belt, the deepest zone in the Shekhawati Basin. Figure 6 shows depth to groundwater in the Upper Shekhawati Basin and the location of the two study villages. Studies are ongoing in the other selected villages that are identified in Figure 4.

For selected villages a list of households was prepared. Sixty-five households from Doken and 45 from Ajeetpura were randomly selected for a detailed survey. A village and household questionnaire was prepared for a one-time survey. For analysis of data the sample households were post stratified on the basis of size of land owned and size of family. Aside from the individual household survey, group discussions and village meetings were organized to understand the perceptions of the people on the emerging water problems and their solutions.

Depth to groundwater determines access.

Figure 5:
Upper Shekhawati Basin showing sub-basins study villages and irrigation projects.

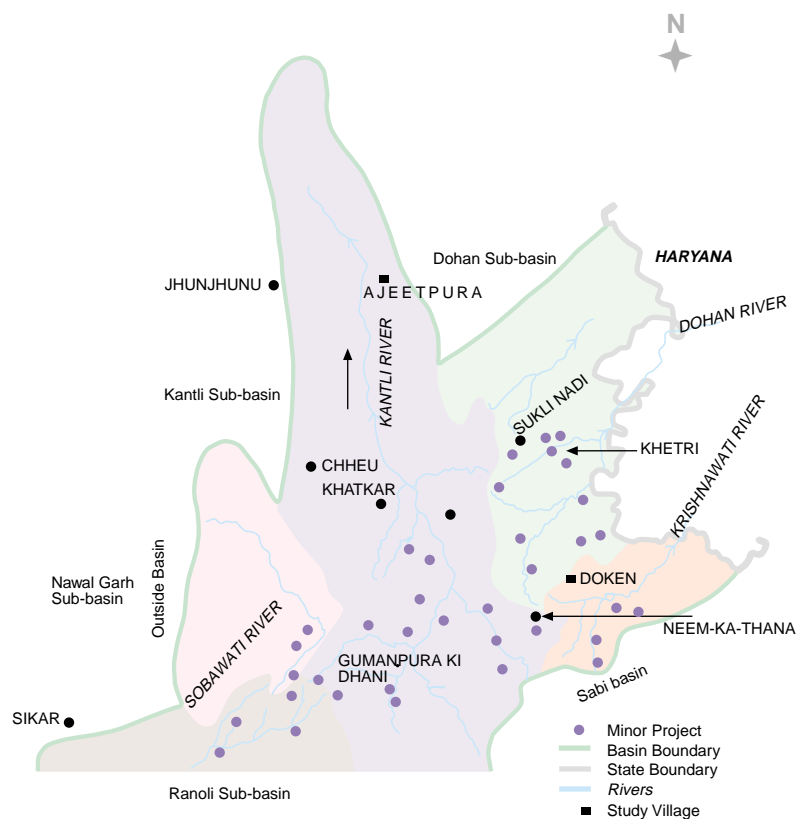
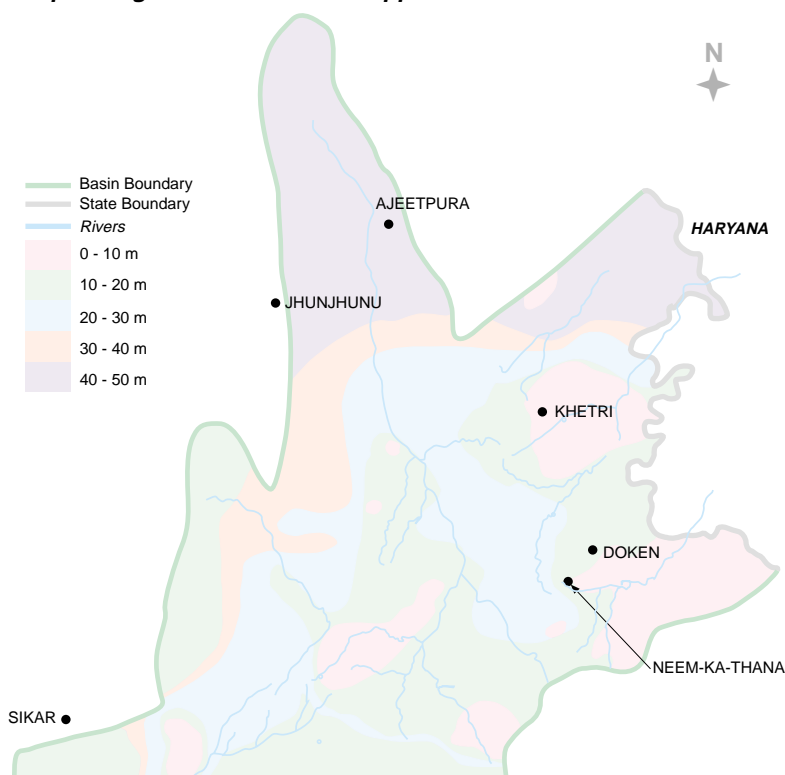


Figure 6:
Depth to groundwater in the upper Shekhawati Basin.



Source: Ground Water Development Government of Rajasthan, 1997.

Physical characteristics of the basin

Climate

The Shekhawati Basin falls within the East Rajasthan subdivision defined by the India Meteorological Department. The year may be divided into four seasons: The winter season lasts from mid November to the beginning of March, the summer season from March to June, the monsoon season from July to mid September and the post monsoon season from the latter half of September to mid November.

The summer season between March and June is marked by a continuous increase in temperature. June is the hottest month of the year with a mean daily maximum and minimum temperature of 40.6° C and 27.3° C respectively. January is the coldest month, with mean maximum temperature of 22.2° C and a minimum of 4.1° C.

Relative humidity during the southwest monsoon season is generally high. During the rest of the year, the air is normally dry. The relative humidity during summer afternoons can drop to 15 to 20 per cent. The mean annual humidity values are 58% in the morning and 35% in the evening.

The mean annual rainfall over the basin is 476 mm, of which about 92 per cent falls during the months of June to September. July and August are the wettest months. The coefficient of variation of the annual total rainfall is 11.9 per cent.

Geography

The Shekhawati Basin is an administratively defined unit consisting of several sub-basins that have been clustered by the Government of Rajasthan for administrative purposes. Only the upper portions of the Krishnawati and Dohan rivers are located within the Rajasthan portion of the Shekhawati Basin, as both rivers cross into Haryana State. The Shekhawati Basin extends over parts of Churu, Jhunjhunu, Sikar, Jaipur, Nagaur and Ajmer districts. It is divided into an upper and lower basin as shown in Figure 4. The total area of the basin is 11,522 km². The northern part, which includes the Kantli, Krishnawati and Dohan

In the Shekhawati Basin, ninety-two per cent of rainfall occurs in the monsoon.

rivers covers an area of 4,495 km². The Kantli is the biggest among these rivers originating from the centre of the Shekhawati Basin and draining towards the north where it vanishes in the Thar Desert. The southern portion is an inland drainage basin covering 7,027 km², whose main river is the Mendha, which flows to the southwest into the Sambhar Salt Lake. Orographically, a small, most eastern portion of the basin is marked by hilly terrain belonging to the Aravalli chain. The northeastern part of the area is fairly flat, but interspersed with moderately elevated hills. West of this area there are fairly flat valleys along the Kantli and Mendha rivers and the tributaries of the latter. The entire western and southern portion of the basin is an extensive alluvial plain sloping gently towards the inland drainage area of the Thar Desert.

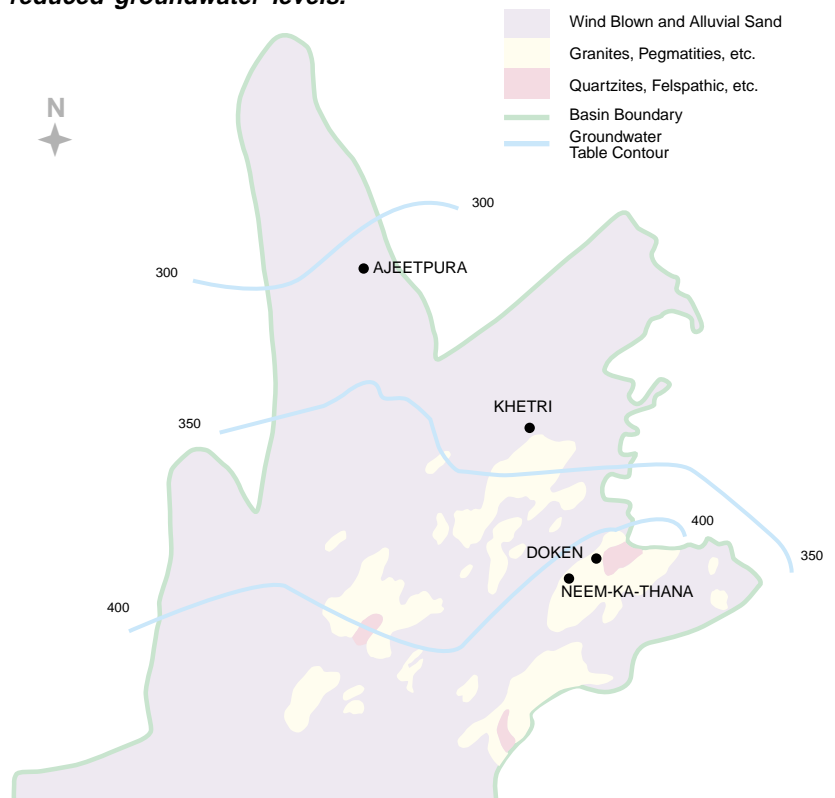
The Kantli River originates in the hills south and southwest of Guhala village in Sikar District (27°44': 75°32'), flows north through Sikar and Jhunjhunu districts and finally disappears in the sand dunes near Naurangpura village in Churu district (28°22'30": 75°27'30") after flowing a distance of about 134 km. The Dohan River, to the east of the Kantli, rises near Mandoli (27°46'30": 75°48') in the western slopes of the Dohan Protected Forest (PF) and flows to the northeast, eventually disappearing in the sand dunes of Haryana. The Krishnawati River, which is directly south of the Dohan and east of the Kantli, originates in the hills of Sikar district, flows northeast for about 42 km in Rajasthan and subsequently disappears in the sand dunes of Haryana near Dilpur village. The drainage pattern is essentially dendritic.

Geology and Landforms

The geological formations in the basin are mostly covered by a thick blanket of wind blown sands and sand dunes, leaving few outcrops in the area (Figure 7 shows the geology of the sub-basins this study is focused on). Isoclinal antiforms and synforms are, however, present in the rocky strata exposed in the hills. There are three distinct types of landforms in the basin: hills, dun valleys and sandy plains with sand dunes. The majority of the basin is comprised of a monotonous sandy plain broken only by sand dunes that are aligned east-northeast to west-southwest.

The landscape is composed mostly of monotonous sandy plains.

Figure 7:
Geological map of the upper Shekhawati Basin showing reduced groundwater levels.



The performance of similar aquifers differs significantly from one location to another.

Except for the Khetri hills, whose western slopes constitute the catchment of the Kantli River, all the hill ranges lie in the catchment of the Dohan and Krishnawati rivers. These are offshoots of the Aravalli range and occur as narrow, elongated and discontinuous hill ranges, broadly parallel to each other. Prominent hill features in the basin are the Khetri Protected Forest (PF) hills, reaching a maximum elevation of about 790 metres, the Ganwari PF hills, with their highest point at 846 m, and the Gadrata PF hills. These are all structural hills, with their axes running northeast-southwest to north-south, similar to the regional Aravalli strike in the area. There are also isolated remnant hills in the same alignment as the Aravallis, standing out here and there as monadnoks.

The dun valleys are narrow, strike and anticlinal or synclinal that separate the various hill ranges. They are erosional (and tectonic) in origin and filled, for the most part, with river alluvium. Pediment zones and scree deposits are also likely to occur here.

Hydrogeology

As previously noted, the drainage of the Shekhawati Basin can be separated into a northern and a southern zone. These zones appear to be defined by a dome shaped hump at the centre of the basin that also forms the water divide. The surface and sub-surface flows from the Kantli, Krishnawati and Dohan sub-basins are draining in three different directions. The boundaries between the three sub-basins are to all intents and purposes groundwater divides assumed to have been formed parallel to the surface water divides. As a result, the "Shekhawati Basin" is more a

combination of hydrological units that have been combined for administrative and analytical purposes by the government.

Two types of aquifers can be classified on the basis of the lithology of the basin: alluvium or unconsolidated sediments and the hard rock areas (areas of consolidated rocks). Their distribution in the northern sub-basins can be seen on Figure 7. More than 80% of the entire basin is covered by unconsolidated sediments in the form of wind-borne sands, sand dunes and fluvial deposits, that is pebbles, gravel, sand (of various grades), silt, clay, kankar and even hard pan and talus material. Groundwater in these areas occurs under water table to semi-confined to locally confined conditions. The hard rock areas, on the other hand, contain either quartzites or schists, granites and gneisses. The quartzites occur disconnectedly as outcrops or in topographic lows where the sediments are thin. They are hard and compact rocks, in which groundwater is very limited and are located in Neem Ka Thana in Sikar district and in Khetri in Jhunjhunu district. The schists, granites and gneisses occur as a part of the Delhi Super-group of rocks in Jhunjhunu district. Where the schists occur, they are poorly jointed, but, being soft, are often weathered down to a depth of 30 metres. The granites and gneisses are usually hard, massive and poorly jointed with a comparatively thin zone of weathering. Groundwater occurs mostly in the thin weathered zone under unconfined conditions, but the aquifers are generally poor, capable of exploitation only locally and selectively.

The performance of the same general type of aquifer may differ significantly from area to area depending, for example, on the thickness and

composition of alluvium or the degree of consolidation in the hard rocks, (that is, the presence, extent and type of fractures, joints, and degree of weathering). For example, in the Jaipur area the alluvium is about 60 metres thick. In the Sikar District it is about 30 to 80 metres thick, with the saturated sediment thickness varying from 10 to 50 metres, and in the Jhunjhunu area it is about 53 metres thick, with only a thin veneer in places where there are rock outcrops. The saturated aquifer thickness in the Jhunjhunu area ranges from 8 to 28 metres.

The available groundwater contour maps produced by the Rajasthan Groundwater Department show the depth to water table, flow directions and groundwater table gradient. They indicate that depths to the SWL within the basin range from 10 to 43 metres. However, shallower SWL depths, reaching almost ground surface (1 to 2 m), have been recorded in exploratory boreholes drilled to the semi-confined alluvial and Bilara limestone aquifers.

Surface Water Resources

There are 60 minor and one medium irrigation projects in the Shekhawati Basin with a catchment area of 97 and 910 km² respectively and a live storage of 8 and 46 million cubic metres respectively. These surface water supplies have been reserved exclusively for irrigation purposes, unlike some cases in which such surface water supplies are diverted to meet urban, industrial or domestic water requirements. On one hand, the minor water harvesting structures have helped to raise (or diminish the decline) of the water table in the adjoining areas/villages. On the other hand, however, they have had a negative impact on the

flow of the Krishnawati and Kantli rivers, resulting in declines in the water table at the tail end of the river. Figure 5 shows the sites of minor and medium irrigation projects in the upper Shekhawati Basin.

Groundwater Resources

Groundwater in the Shekhawati Basin in shallow water table aquifers is tapped by open dug and dug-cum-borewells located mostly in the alluvium but also present in the hard rock areas. The depths of wells vary from 35 to 50 metres in Sikar district to 55 metres or more in Jhunjhunu district. Groundwater in these wells is under water table conditions, except in the case of dug-cum-borewells, where the deeper aquifer under pressure may also have been tapped. The variation in average yields obtained from such wells varies widely, ranging anywhere from 50 to 600 cubic metres a day depending upon the type of aquifer.

In the case of deep semi-confined and confined aquifers groundwater is tapped by deep tubewells. Large numbers of such tubewells have been installed during the last 10 years, particularly in Sikar and Jhunjhunu districts. The transmissivity of the aquifer in these parts of the basin varies from 122 m²/day to 420 m²/day and the reported specific yield (storativity) value, that is, water table condition, ranges from 6 per cent to 39 per cent.

The groundwater quality within the basin is generally high, at times even excellent. Water of the highest quality is found in the Kantli sub-basin both based on electrical conductivity and potability criteria. However, due to over-extraction of groundwater in the extreme downstream portion of Kantli sub-basin salinity has increased.

While water harvesting structures have helped to raise the water table, they may reduce river flow.

Base flow is an important component in the basin water balance.

Unpublished studies conducted by Tahal Consultants based on information supplied by the Groundwater and Irrigation Departments indicate that groundwater outflow from the basin is significant. This is mainly due to the fairly high transmissivity of around 1,000 to 1,500 m²/day in the downstream stretches of the aquifers. Outflow from the Kantli sub-basin, the largest of the three sub-basins, is about 5 to 10 cubic metres a year. From the Krishnawati sub-basin, on the other hand, it is 10 to 20 cubic metres a year.

Prior to groundwater extraction the entire annual groundwater output, amounting to about 100 cubic metres a year (1988-1992 average), left the basin. Although the relatively high transmissivity of the alluvial aquifer in the Kantli sub-basin presumably allowed a significantly higher flow in a slightly steeper gradient than those existing after groundwater mining and water level decline. It is believed that outflow by means of base flow after the rainy season used to be an important component.

Aquifer Yield

About 77 per cent of the Shekhawati Basin is occupied by groundwater potential zones (regions identified by the groundwater department as having significant resources available for exploitation). The remaining area constitutes non-potential zones mainly located in the post-Delhi intrusive and Alwar group quartzites made up primarily of hill ranges and reserved forests. The average natural recharge in the basin amounts to 66 Mm³/year. Higher levels of rainfall over the last four years have, however, generated a higher recharge rate of around 133 Mm³/year. The present groundwater draft is about 270 Mm³/year with an overdraft/over exploitation of about 175 Mm³/year. As a result, despite the recent higher levels of recharge, groundwater withdrawal in the basin has already exceeded the safe yield, and groundwater mining is taking place. Table 4 indicates the number of wells in the basin and shows the dramatic increase in extraction occurring over the last decade.

TABLE 4:
Number of Wells in the Shekhawati Basin, (1980, 1985 and 1993).

Tehsils	1980			1985			1993		
	In Use	Out of Use	Total Wells	In Use	Out of Use	Total Wells	In Use	Out of Use	Total Wells
Srimadhapur	7,912	1,926	9,838	9,975	1,682	11,657	12,450	2,150	14,600
Neem ka Thana	4,826	1,477	6,303	5,292	1,613	6,905	6,170	2,210	8,380
Jhunjhunu	1,186	1,804	2,990	3,015	357	3,372	4,072	819	4,891
Chirawa	2,197	1,289	3,486	4,580	0	4,580	7,770	30	7,800
Khetri	3,561	1,318	4,879	4,882	1,208	6,090	5,574	1,815	7,389
Udaipurwati	5,456	1,568	7,024	7,502	1,493	8,995	10,052	1,735	11,787
Basin Total	25,138	9,382	34,520	35,246	6,353	41,599	46,088	8,759	54,847

Source: Government of Rajasthan (1995) and Agriculture in Rajasthan, A Statistical Handbook, Jaipur, Government of Rajasthan.

Basin Groundwater Use and Agriculture

The population of the basin is growing fast. It was 1.31 million in 1971 and had reached 2.24 million in 1991. The population density changed from 155 to 264 per km² in the same period.

In the Shekhawati Basin there has been a strong tradition of groundwater irrigation. The spread of energized pumping technologies in the early eighties has enabled a rapid increase in demand for irrigation water leading to fast depletion of groundwater. At first, when the pumps were introduced, farmers tried to increase the area under irrigation. However, as the water table went down water saving measures, such as shifting land use/cropping patterns, became common and water saving technologies were adopted.

The land use pattern in the Shekhawati Basin as a whole is shown in Table 5 for 3 points in time, 1980, 1990 and 1997. The basin has recorded

an increase of about 19,000 hectares in net area sown and an increase of about 93,000 hectares in area sown more than once. As a result the total cropped area shows an impressive increase of 16 per cent. The increase has resulted from a reduction in fallow lands and grazing lands. Furthermore, uncultivable wasteland also shows a decline from over 60,000 hectares to less than 30,000 hectares during this period. On the other hand, the area under forests, in the form of enclosures of forest lands and plantations, has almost doubled because of afforestation efforts.

The changes in cropped area are reflected in changes in the cropping pattern (Table 6). This is particularly so for irrigated crops. It can be seen in Table 7 that the increase in irrigated area between 1980 and 1990 is almost 100 per cent. Between 1990 and 1997 there is a further increase of 30 per cent. This change implies more than a doubling of irrigated area from about 83,000 hectares in 1980 to 209,000 hectares in 1997.

As the water table declined, water saving technologies were adopted and land use and cropping pattern changes occurred.

TABLE 5:
Land Use Pattern in the Shekhawati Basin

(Area in hectare)

	YEAR					
	1980	%	1990	%	1997	%
Geographical area (hectares)	849,289	100.00	849,369	100.00	849,369	100.00
Forest	40,197	4.73	73,401	8.64	79,340	9.34
Non-agri. use	25,147	2.96	29,267	3.45	31,152	3.67
Uncultivable waste	60,342	7.11	34,325	4.04	29,217	3.44
Grazing and pasture land	62,792	7.39	57,482	6.77	55,950	6.59
Tree crop	119	0.01	190	0.02	195	0.02
Barren and cultivable waste	15,088	1.78	13,250	1.56	13,442	1.58
Other fallow	25,625	3.02	23,537	2.77	26,562	3.13
Current fallow	53,799	6.33	36,090	4.25	28,775	3.39
Net area sown	566,280	66.68	581,927	68.51	584,736	68.84
Area sown more than once	106,647		186,660		199,511	
Total cropped area	672,927		768,787		784,247	

Source: Agricultural Statistics Reports for Different Years, Directorate of Economics and Statistics, Government of Rajasthan.

TABLE 6:
Cropping Pattern Changes in the Shekhawati Basin

(Area in Hectare)

Crops	YEAR					
	1980		1990		1997	
	Area	%	Area	%	Area	%
Bajra	248,036	36.86	343,281	44.65	315,359	40.22
Guwar	54,515	8.10	108,607	14.13	106,069	13.53
Juar	3,016	0.45	55	0.01	30	00.0
Wheat	39,641	5.89	45,187	5.88	647,06	8.25
Barley	19,526	2.90	8,810	1.15	111,67	1.42
Gram	76,147	11.32	74,592	9.70	727,44	9.28
Other Pulses	166,803	24.79	91,685	11.93	84,111	10.74
Mustard	5,230	0.78	41,211	5.36	106,453	13.57
Other Oilseeds	2,086	0.31	2,330	0.30	3,402	0.43
Spices	3,461	0.51	5,990	0.78	5,716	0.73
Fruit and Veg.	1,281	0.19	3,439	0.45	2,893	0.37
Others	53,185	7.90	43,600	5.67	11,597	1.48
TOTAL	672,927	100.0	768,787	100.0	784,247	100.0

Major shifts in crops have occurred with oilseeds increasing greatly.

Source: Agricultural Statistics Reports for Different Years, Directorate of Economics and Statistics, Government of Rajasthan.

TABLE 7:
Area Changes of Irrigated Crops in the Shekhawati Basin

(Area in Hectare)

Crops	YEAR					
	1980		1990		1997	
	Area	%	Area	%	Area	%
Bajra	1,879	2.3	12,268	7.7	3,184	1.5
Wheat	33,949	41.0	50,986	32.0	68,226	32.7
Barley	19,677	23.8	13,169	8.3	10,986	5.3
Gram	5,002	6.0	16,994	10.7	24,360	11.7
Other Pulses	892	1.1	359	0.2	515	0.2
Spices	3,984	4.8	5,722	3.6	5,714	2.7
Fruit and Veg.	1,149	1.4	3,058	1.9	2,841	1.4
Mustard	579	0.7	40,991	25.7	86,568	41.5
Other Oilseeds	352	0.4	1,978	1.3	1,072	0.5
Others	15,248	18.4	13,693	8.6	5,361	2.6
TOTAL	82,711	100.0	159,218	100.0	208,827	100.2

Source: Agricultural Statistics Reports for Different Years, Directorate of Economics and Statistics, Government of Rajasthan.

The most dramatic increase is in area under oilseeds, that is, mustard and rapeseed. The increase is from a negligible area in 1980 to close to 87,000 hectares in 1997. There was more than a doubling of area under oilseeds between 1990 and 1997. Oilseeds are grown now on more than 40 per cent of the irrigated area. The next important crop is wheat, accounting for about one-third of the irrigated area. The increase in area under irrigated wheat is from 34,000 hectares in 1980 to more than 68,000 hectares in 1997. This is a doubling in 17 years, which implies a compound growth rate of more than 4 per cent per annum. Gram in winter is next in importance.

Village Field Study

The Sample Villages

Doken is located in a valley and is characterized by dispersed settlement and diverse caste composition. Different ethnic and caste groups have organized in the form of hamlets and live near their land resources. There are a total of 489 households in addition to a school, post-office, and public health centre. The total population of the village as per the 1991 census was 3,473. The village is electrified having 80 domestic connections. Water availability is highly dependent on rainfall. The water table has declined by 10 to 14 metres in the last 50 years. During the last three years, however, the water table has risen because of more than average rainfall. In total there are 200 wells of which 150 are fitted with diesel pumps. Also there are three traditional water harnessing structures and one minor project to recharge the groundwater. Wheat, mustard, and

The cropping pattern overall doesn't capture the changes as dramatically as the cropping pattern changes of irrigated crops. Overall, the *kharif* crops of *bajra* (millet) and *guwar* constituted 54 per cent of the total cultivated area (Table 6). The area under pulses has declined, while the area under oilseeds has increased from 1 per cent to about 14 per cent of the total. The other important shift is the area under barley, the traditional irrigated crop of the area, to wheat and mustard crops. This shift has direct bearing on the use of groundwater, as wheat is a relatively higher water consuming crop than barley.

In Doken, the water table has declined by 10 to 14 metres over the last five decades.

gram are the main irrigated crops grown in the village. The water management pattern and utilization is affected largely by the location, habitation and land use pattern of the village.

Ajeetpura, located in the Kantli River sub-basin, has 160 households with a total population of 1,015. As in Doken, people owning wells have started settling on their agricultural land. There is a higher secondary school, but no public health services. The village was electrified in 1969 and most households have domestic connections. The village has a ground level reservoir with stand post and domestic water connections. In total there are 50 dug-cum-borewells, all electrified and all fitted with sprinkler sets for irrigation. The water table has declined from 6 to 50 metres in the last 50 years. Wheat and mustard are the main irrigated crops of the village.

Results: Use of Water

Access to groundwater is heavily influenced by land ownership.

Groundwater is the major source of water for domestic purposes and irrigation. The focus of this study is confined to these two uses. It is important to recognize that access to groundwater is heavily influenced by land ownership. In Doken 70% of the households own 30% of the land, while in Ajeetpura 45% of the households of the smaller holdings cultivate only 18 per cent of total land. This indicates a more skewed distribution in the relatively dry village. This difference should be kept in mind when evaluating comparisons between the villages.

Domestic

In order to estimate domestic consumption, respondents were asked to estimate how many, and which sized vessels they use during both the winter and summer. In the absence of running water the capacity of these vessels and the frequency of storage in the household gives a broad and valid estimate of the quantity of water use. Nevertheless, there are a few problems in estimation when water is directly used for activities like bathing and washing near a well or a storage tank on the field. In this case, the estimates can only be approximate. In any case, when water is available on field the primary use is for irrigation. The quantity used for washing and bathing is of no concern to the household.

Data

Data collected in the survey indicate water use is more or less the same in the two villages and in different family size categories. The main difference in both villages is that the smallest

family size category shows higher per capita use for drinking in both the seasons than the larger family size category. In all cases, the summer requirement is almost double of that in winter.

The total water consumption in both the villages is much less – almost half – than the WHO prescribed norms. Further, as a result of the settlement and habitation pattern in Ajeetpura, the drier village, the consumption of water is more than the reported consumption in the Doken, village with the higher water table. This is the result of the assured Public Health Engineering Department (PHED) supply in the village.

The respondents were asked questions about who shares the responsibility of fetching water from the available source. As is expected, the women and girls perform these chores (Table 8). Men reportedly fetch water occasionally but at least 56 per cent of the men reported that they never do the work. Younger members of the family occasionally participate in this activity and in this case there appears to be less gender bias.

The sources of water for domestic use are shown in Table 9. This shows that wells are the major sources of domestic water supply in both villages. Depending on family size, wells account for 60% to 92% of Doken's sources for all domestic uses and between 50% and 67% of sources for all domestic uses in Ajeetpura. Aside from the similar importance of wells in both villages, the other sources of water in the two villages are quite different. Whereas 8% to 40% of respondents in Doken have a hand pump as a source of water,

TABLE 8:
Who Fetches Water in a Household

	Percentage		
	Generally	Sometimes	Never
DOKEN (65 respondents)			
Adult male	6.2	36.9	56.9
Adult female	83.1	6.2	10.8
Young boys	4.6	35.4	60.0
Young girls	4.6	9.2	86.2
All members	0.0	4.6	95.4
AJEETPURA(45 respondents)			
Adult male	0.0	44.4	55.6
Adult female	82.2	2.2	15.6
Young boys	6.7	15.6	77.8
Young girls	0.0	4.4	95.6
All members	4.4	20.0	75.6
COMBINED (110 respondents)			
Adult male	3.6	40.0	56.4
Adult female	82.7	4.5	12.7
Young boys	5.5	27.3	67.3
Young girls	2.7	7.3	90.0
All members	1.8	10.9	87.3

33% to 50% of Ajeetpura's households have access to PHED water supply in the form of running tap water supplied by standpost. There are also a few house connections.

In general, in this region, tank and local water bodies are used either for animals or for washing. Being an arid zone, the number of such water bodies is limited. In Ajeetpura, for example, this source is not available. In this village, water for bathing comes exclusively from tap and well water.

In response to a question as to what is regarded as the best source of water for domestic use, seventy per cent preferred well water (Table 10). This was so even where tap water is available. No one reported that the traditional sources of water, such

TABLE 9:
Domestic Water Sources in Sample Villages*(Figures in per cent)*

Family Size Class	Doken			Ajeetpura	
	Well	Hand pump	Tank	Well	Tap
DRINKING WATER					
0 - 3	80	20	0	50	50
4 - 5	68	32	0	57	43
6 - 8	71	29	0	61	39
9 and above	85	15	0	67	33
Overall	74	26	0	60	40
COOKING & CLEANING					
0 - 3	80	20	0	50	50
4 - 5	68	32	0	57	43
6 - 8	71	29	0	61	39
9 and above	85	15	0	67	33
Overall	74	26	0	60	40
BATHING					
0 - 3	60	20	20	50	50
4 - 5	68	32	0	57	43
6 - 8	64	25	11	61	39
9 and above	92	8	0	67	33
Overall	71	23	6	60	40
WASHING CLOTHES					
0 - 3	60	20	20	50	50
4 - 5	68	21	11	57	43
6 - 8	64	21	14	61	39
9 and above	92	8	0	67	33
Overall	71	18	11	60	40
ANIMALS					
0 - 3	60	20	20	67	33
4 - 5	79	5	16	58	42
6 - 8	57	11	32	67	33
9 and above	54	8	38	67	33
Overall	63	9	28	64	36

as village ponds are desirable. This indicates awareness of quality of water and also of the drudgery involved in the daily fetching of water.

Table 11 shows whether the source is privately owned or not. Almost 60 per cent of the requirements in the two villages are met from

*Dug well
continue to be a
major source of
drinking water.*

TABLE 10:
Perception About Best Source of Domestic Water

Family Size Class	No. of HH	Well	Tap	Hand Pump
DOKEN				
0 - 3	5	4 (80%)	0	1 (20%)
4 - 5	19	13 (68%)	0	6 (32%)
6 - 8	28	22 (79%)	0	6 (21%)
9 and above	13	10 (77%)	0	3 (23%)
Overall	65	49 (75%)	0	16 (24%)
AJEETPURA				
0 - 3	4	3 (75%)	1 (25%)	0
4 - 5	14	8 (57%)	6 (42%)	0
6 - 8	18	11 (61%)	7 (39%)	0
9 and above	9	6 (67%)	3 (33%)	0
Overall	45	28 (65%)	17 (35%)	0
COMBINED				
0 - 3	9	7 (78%)	1 (11%)	1 (11%)
4 - 5	33	21 (64%)	6 (18%)	6 (18%)
6 - 8	46	33 (72%)	7 (15%)	6 (13%)
9 and above	22	16 (73%)	3 (14%)	3 (14%)
Overall	110	77 (70%)	17 (16%)	16 (14%)

private sources and one third from government sources. The rest comes from sources that are held by the community, such as hand pumps or the village water body.

Table 12 shows the distribution of households by distance from the source. Fourteen to fifteen per cent had the source within the household. Forty per cent had to fetch water from a source more than 100 metres away. It is presumed that more distance means more drudgery and therefore, the tendency to reduce wastage of water.

An attempt was made to estimate costs incurred in the supply of domestic water. This cost could be related to payments for access to water sources owned by outsiders or it could be for source maintenance (such as repair of pumpsets). Transport and storage costs are also part of the overall domestic water supply cost structure. Table 13 shows the amounts spent. It can be seen that none of the households report spending for use of water or for carriage of water. They do, however, contribute to and incur costs for maintenance of the water sources. This amount is less than Rs 80 per household per annum. Water storage structures (cisterns) are found in Ajeetpura but are relatively uncommon. The amount spent on them is relatively small – an investment of about Rs 650 per household annually.

Table 14 reports responses regarding how villagers adjust to the problem of water shortage. No respondents support recycling of water. They do, however, favour widespread use of other strategies for economizing on water use, such as cleaning cooking utensils without water and reducing the frequency of bathing. We attempted to rank these strategies according to villager preferences. Recycling was the last preference, whereas reducing bathing and washing was given high rank by most of the respondents.

Drinking Water Management System in Ajeetpura

The water management system described above is representative of the existing system in most Rajasthan villages. Before state intervention in the 1960's most of the drinking water needs were met by dug wells, *bawri* (step well), *talab* (small pond) and *tanka* (cistern), which were mostly

Private sources also fulfill drinking water needs.

TABLE 11:
Access to Domestic Water by Ownership of Source in Sample Villages (Number of Households).

Family Size Class	Doken				Ajeetpura				Combined			
	Private	Govt.	Comm- unity	Total	Private	Govt.	Comm- unity	Total	Private	Govt.	Comm- unity	Total
DRINKING WATER												
0 - 3	4	1	0	5	2	2	0	4	6	3	0	9
4 - 5	11	6	2	19	8	6	0	14	19	12	2	33
6 - 8	15	7	6	28	11	5	2	18	26	12	8	46
9 and above	7	2	4	13	6	2	1	9	13	4	5	22
Overall	37	16	12	65	27	15	3	45	64	31	15	110
COOKING & CLEANING												
0 - 3	4	1	0	5	2	2	0	4	6	3	0	9
4 - 5	11	6	2	19	8	6	0	14	19	12	2	33
6 - 8	15	7	6	28	11	5	2	18	26	12	8	46
9 and above	7	2	4	13	5	2	2	9	12	4	6	22
Overall	37	16	12	65	26	15	4	45	63	31	16	110
BATHING												
0 - 3	3	1	1	5	2	2	0	4	5	3	1	9
4 - 5	11	6	2	19	8	6	0	14	19	12	2	33
6 - 8	15	7	6	28	10	6	2	18	25	13	8	46
9 and above	8	1	4	13	5	2	2	9	13	3	6	22
Overall	37	15	13	65	25	16	4	45	62	31	17	110
WASHING CLOTHES												
0 - 3	3	1	1	5	2	2	0	4	5	3	1	9
4 - 5	11	6	2	19	8	6	0	14	19	12	2	33
6 - 8	15	7	6	28	10	6	2	18	25	13	8	46
9 and above	8	1	4	13	5	2	2	9	13	3	6	22
Overall	37	15	13	65	25	16	4	45	62	31	17	110
ANIMALS												
0 - 3	3	1	1	5	2	2	0	4	5	3	1	9
4 - 5	11	6	2	19	8	6	0	14	19	12	2	33
6 - 8	15	7	6	28	10	6	2	18	25	13	8	46
9 and above	8	1	4	13	5	2	2	9	13	3	6	22
Overall	37	15	13	65	25	16	4	45	62	31	17	110

Historically most drinking water needs were met through traditional systems. These have now been replaced by state funded water supply systems. This has resulted in major changes in consumption patterns.

community owned and managed. General shortage of drinking water was a phenomenon due to significant seasonal and yearly variations in supply and unequal access both in terms of distance and also because of problems arising out of caste and class dynamics in villages. Nonetheless, on the whole, the community participated in creating, running and maintaining

the traditional drinking water sources in spite of such impediments. The situation changed dramatically after the government intervened to augment the drinking water supply and improve accessibility to all sections of the society and scattered settlements by digging new wells (mostly tubewells), building hand pumps and constructing ground level reservoirs in problem villages. This

TABLE 12:
Distribution of Sample Household by Distance of Domestic Water Source (per cent)

Family Size Class	Doken (65 responses)				Ajeetpura (45 responses)			
	Within House	0-50m	50-100m	>100m	Within House	0-50m	50-100m	>100 m
DRINKING WATER								
0 - 3	20	20	20	40	25	25	50	0
4 - 5	0	16	21	63	14	36	21	29
6 - 8	4	14	32	50	44	17	17	22
9 and above	8	23	38	31	11	22	22	44
Overall	5	17	29	49	27	24	22	27
COOKING & CLEANING								
0 - 3	20	20	20	40	25	25	50	0
4 - 5	0	16	21	63	14	36	21	29
6 - 8	4	14	36	46	44	17	17	22
9 and above	8	23	38	31	22	22	11	44
Overall	5	17	31	48	29	24	20	27
BATHING								
0 - 3	20	20	20	40	25	25	50	0
4 - 5	0	16	21	63	14	36	21	29
6 - 8	4	11	32	54	44	17	17	22
9 and above	8	23	31	38	22	22	11	44
Overall	5	15	28	52	29	24	20	27
WASHING CLOTHES								
0 - 3	20	20	20	40	25	25	50	0
4 - 5	0	16	21	63	14	36	21	29
6 - 8	4	7	29	61	44	17	17	22
9 and above	8	23	31	38	22	22	11	44
Overall	5	14	26	55	29	24	20	27
ANIMALS								
0 - 3	20	20	20	40	25	25	50	0
4 - 5	0	16	21	63	14	36	21	29
6 - 8	4	7	29	61	39	17	22	22
9 and above	8	23	31	38	22	22	11	44
Overall	5	14	26	55	27	24	22	27

Social, economic and political factors have affected supply options.

mission was quite successful, but resulted in less community participation. Aside from the effect of government intervention, there were other social, economic and political reasons for the disintegration of village communities. For example, private profit motives started dominating over community interests. Nonetheless, there is

still a good deal of community participation as can be seen in case of Ajeetpura village.

Traditionally the drinking/domestic water needs of the people of Ajeetpura were met by two wells known as Ghasi Ram's well and Choudhary Narayan Ram's well. Water used to be lifted by

human and animal power. With this system people lower in the caste hierarchy naturally faced problems, as they were not allowed to fetch water themselves. The drinking water for animals was provided for by a small open water tank near the well. Every household participated in the filling of that tank on a rotation basis.

In 1982, under the state government's drinking water scheme, the well in the centre of the village was energized by installing a 10 HP electric motor. A ground level reservoir of 20 thousand litres capacity was constructed to store water, and two pipes were laid in two directions to supply drinking water. In two locations standposts with multiple taps were provided. The cost of construction and electrification of the well was borne by the Public Health Engineering Department (PHED) of the state government. In terms of the management and maintenance of the well, the monthly electricity charges are paid by the PHED, but the management of the supply and maintenance of the motor in case of breakdown are the responsibility of the villagers. The motor is in need of repair or maintenance 4 to 5 times in a year. Each breakdown costs the village around Rs 1,800 to Rs 2,000 for rewinding the motor. Breakdowns are common due to the great fluctuations in electric supply.

In a village level meeting in 1982, a system of management was developed for maintaining the newly energized well. This system is still in place at present. Under this system each household residing in the village has to contribute 15 days of time per annum for running the water supply system. If a particular household is not able to provide its services in the regulation of the drinking water system, it can hire the services of

TABLE 13:
Average Annual Amount Spent for Procurement of Domestic Water (Rs)

Family Size Class	Maintenance of Domestic Water Source	Structure for Storage of Water
DOKEN		
0 - 3	6	0
4 - 5	183	21
6 - 8	10	5
9 and above	47	6
Overall	68	9
AJEETPURA		
0 - 3	5	0
4 - 5	79	357
6 - 8	96	372
9 and above	72	1,890
Overall	80	646
COMBINED		
0 - 3	6	0
4 - 5	139	164
6 - 8	46	157
9 and above	57	777
Overall	73	270

TABLE 14:
Adjustment in Domestic Water Use to Shortage Condition

Option	Within Ranks (4 = most favoured)				Total
	1	2	3	4	
DOKEN (65 respondents)					
Cut bath	16(25%)	29(45%)	19(29%)	1(2%)	65(100%)
Cut washing of clothes	31(48%)	29(45%)	5(8%)	0(0%)	65(100%)
Cut washing utensils	18(28%)	7(11%)	40(62%)	0(0%)	65(100%)
Recycling of water	0(0%)	0(0%)	1(2%)	64(98%)	65(100%)
AJEETPURA (45 respondents)					
Cut bath	12(27%)	19(45%)	13(29%)	1(2%)	45(100%)
Cut washing of clothes	19(42%)	23(51%)	3(7%)	0(0%)	45(100%)
Cut washing utensils	14(31%)	3(7%)	28(62%)	0(0%)	45(100%)
Recycling of water	0(0%)	0(0%)	0(0%)	45(100%)	45(100%)
COMBINED (110 respondents)					
Cut bath	28(25%)	48(44%)	32(29%)	2(2%)	110(100%)
Cut washing of clothes	50(45%)	52(47%)	8(7%)	0(0%)	110(100%)
Cut washing utensils	32(29%)	10(62%)	68(00%)	0(0%)	110(100%)
Recycling of water	0(0%)	0(0%)	1(1%)	109(99%)	110(100%)

In Ajeetpura a successful system of management was created for the operation and maintenance of an energized well provided by the government.

another household by paying Rs 100 for 15 days. Some of the work involved during this period is to operate the well to fill the water tank, to see that the motor is kept off during low voltage electric supply, to check that the pipeline is not broken and taps are intact. In case of breakdown, some villagers have to join together to haul the motor out of the well and take it to the nearest town, Chirawa, to get it repaired and then reinstall it. Each household drawing water contributes equally to the cost of repair. Recently the community decided to entrust management to a villager at a nominal pay of Rs 600 per month. If nobody comes forward, an individual who has retired from the army has volunteered to take on this task. Each household has to contribute a nominal cost of Rs 15 per month for drinking water. Few households have taken domestic connections by putting in their own pipelines. This institution of informal management is functioning despite all kinds of political and social differences.

Conclusions

Domestic water availability does not seem to be a problem in the basin. Even though the population is increasing very rapidly, the future demand for domestic water will not contribute much to depleting the groundwater resource. Total domestic demand, even if doubled, will remain far below the irrigation demand. In terms of domestic water supply, the more important issues to be addressed in the search for alternate management systems will be the issues of distribution, access and quality of the supply. Greater cooperation of people will be the key to overcoming these problems rather than state interventions. The issues of centralized versus decentralized management are being debated and likely to be important in

the future (Rathore, 1996, 1997). The present attempt to hand over village domestic water supply systems to *panchayats* will be key to dealing with the problem of accessibility to domestic water.

Access to drinking water depends upon resource availability, well ownership and whether or not different groups of non-owners are socially viewed as entitled to use a given source. Since the share of domestic water in total water consumption is marginal and irrigated agriculture is being practiced in the village, the basic availability of water is not seen to be a problem in the basin. Well locations and ownership therefore directly determine access to drinking water for different sections of the society. In general, the more public wells (and associated tap stands) the better the access to drinking water, particularly for the marginalized castes or other social groupings. At present, 60 per cent of the supply sources are privately owned, which reflects the inequity in access to drinking water. Hence, drinking water should be supplied by community owned sources, and people's dependence on private sources should be reduced.

Irrigation

Since the Shekhawati Basin is an agricultural area, irrigation dominates most of the water use and water demand is heavily affected by cropping patterns. Tables 15 and 16 show the cropping pattern of the sample farmers by size class of holdings in the sample villages. These show that the percentage of the area under wheat declines with the increase in size of holding, and indicates that the smaller sized farms devote relatively more of their agricultural land to water intensive crops to meet their food requirements. Irrigation in the

kharif season is mostly protective irrigation. In the *rabi* season the mustard crop is currently preferred to the gram crop and the wheat to the barley crop. Gram is now mostly grown in unirrigated areas. Further, it also shows that keeping lands fallow is a practice followed more in the *rabi* season. The large farmers keep almost 20 to 25 per cent of their lands as fallow lands in the *rabi* season. In the case of smaller holdings this percentage is

about 15 per cent. In the *rabi* season this is because of a shortage of groundwater. The practice of keeping land fallow during the *kharif* and *rabi* seasons is an age old traditional practice to improve the soil fertility. Because of intensification of agriculture in the area and use of external inputs such as fertilizers, these soil fertility measures are almost out of practice on irrigated lands. The trends in cropping pattern followed in

Small landholders devote proportionately more land to water intensive crops.

TABLE 15:
Cropping Pattern Adopted by Sample Households in Doken

Crops	Size Class of Holding (area under crop Ha.)						Overall	Size Class of Holding (percentage area under crop)					Overall
	0-1	1-2	2-4	4i-10	10 & above	0-1		1-2	2-4	4-10	10 & above		
KHARIF CROPS													
Pearl Millet	Irr.	0.00	0.00	0.10	0.00	0.00	0.02	0.00	0.00	3.78	0.00	0.00	0.80
Pearl Millet	Un Irr.	0.41	0.79	1.13	1.57	1.65	0.73	61.30	56.29	42.34	28.04	16.25	38.38
Sorghum	Un Irr.	0.02	0.00	0.03	0.15	0.00	0.03	3.45	0.00	0.95	2.62	0.00	1.46
(Jawar)													
Cluster	Un Irr.	0.00	0.00	0.10	0.00	0.63	0.04	0.00	0.00	3.78	0.00	6.25	1.86
Bean (Guwar)													
Pulse	Irr.	0.00	0.02	0.00	0.33	0.00	0.04	0.00	1.62	0.00	5.82	0.00	2.12
(Arhar)													
Fallow		0.23	0.59	1.32	3.56	7.85	1.06	35.25	42.09	49.15	63.52	77.50	55.38
Total		0.66	1.41	2.68	5.61	10.13	1.91	100.00	100.00	100.00	100.00	100.00	100.00
RABI CROPS													
Wheat	Irr.	0.30	0.48	0.86	1.50	1.65	0.57	45.80	33.87	31.62	26.78	16.25	29.73
Barley	Irr.	0.01	0.00	0.00	0.04	0.00	0.01	1.53	0.00	0.00	0.63	0.00	0.40
Mustard	Irr.	0.02	0.24	0.51	0.76	0.00	0.22	2.67	16.94	18.71	13.55	0.00	11.68
Mustard	Un Irr.	0.03	0.03	0.21	0.11	3.16	0.16	4.58	2.34	7.76	1.94	31.25	8.36
Gram	Irr.	0.00	0.04	0.17	0.54	2.53	0.17	0.00	2.88	6.36	9.67	25.00	9.03
Gram	Un Irr.	0.18	0.35	0.28	0.90	0.89	0.32	27.10	24.86	10.29	16.12	8.75	16.59
Spices	Irr.	0.00	0.00	0.03	0.09	0.00	0.01	0.00	0.00	0.94	1.63	0.00	0.72
(Methi)													
Vegetable	Irr.	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.94	0.00	0.00	0.20
(Brinjal)													
Fallow		0.12	0.27	0.63	1.66	1.90	0.44	18.32	19.10	23.39	29.67	18.75	23.28
Total		0.66	1.41	2.71	5.61	10.13	1.91	100.00	100.00	100.00	100.00	100.00	100.00

Irr -- Irrigated, Un Irr--Unirrigated

TABLE 16:
Cropping Pattern Adopted by Sample Households in Ajeetpura

Crops	Size Class of Holding (area under crop Ha.)					Overall	Size Class of Holding (percentage area under crop)					Overall
	0-1	1-2	2-4	4i-10	10 & above		0-1	1-2	2-4	4-10	10 & above	
KHARIF CROPS												
Pearl Millet Irr.	0.06	0.00	0.32	0.00	-	0.07	4.78	0.00	10.94	0.00	-	3.85
Pearl Millet Un Irr.	0.69	0.93	1.35	3.47	-	1.05	59.13	67.09	46.54	64.47	-	59.25
Sorghum (Jawar) Un Irr.	0.00	0.02	0.00	0.00	-	0.00	0.00	1.46	0.00	0.00	-	0.28
Pulse (Moth) Un Irr.	0.00	0.00	0.00	0.23	-	0.02	0.00	0.00	0.00	4.18	-	1.36
Pulse (Mong) Un Irr.	0.00	0.16	0.25	0.28	-	0.11	0.00	11.52	8.75	5.22	-	6.10
Cluster Bean (Guwar) Un Irr.	0.11	0.17	0.62	0.51	-	0.23	9.57	12.25	21.26	9.40	-	12.95
Cowpea (Chaula) Un Irr.	0.00	0.00	0.09	0.00	-	0.01	0.00	0.00	3.15	0.00	-	0.79
Pulse (Mixed) Irr.	0.00	0.00	0.00	0.73	-	0.08	0.00	0.00	0.00	13.58	-	4.43
Fallow	0.31	0.11	0.27	0.17	-	0.20	26.52	7.68	9.36	3.15	-	10.99
Total	1.16	1.38	2.89	5.39	-	1.78	100.00	100.00	100.00	100.00	-	100.00
RABI CROPS												
Wheat Irr.	0.48	0.40	0.79	1.44	-	0.54	41.00	28.94	27.22	26.64	-	30.56
Barley Un Irr.	0.00	0.00	0.13	0.00	-	0.02	0.00	0.00	4.38	0.00	-	1.10
Barley Irr.	0.00	0.11	0.18	0.00	-	0.05	0.00	7.69	6.21	0.00	-	3.03
Mustard Irr.	0.51	0.68	1.11	1.07	-	0.63	43.38	48.90	38.42	19.83	-	35.51
Mustard Un Irr.	0.00	0.00	0.20	0.00	-	0.03	0.00	0.00	6.91	0.00	-	1.73
Gram Irr.	0.08	0.00	0.05	0.14	-	0.05	7.16	0.00	1.84	2.63	-	2.98
Gram Un Irr.	0.04	0.06	0.24	1.42	-	0.22	3.69	4.58	8.14	26.36	-	12.37
Spices (Methi) Irr.	0.00	0.00	0.05	0.00	-	0.01	0.00	0.00	1.87	0.00	-	0.47
Fallow	0.06	0.14	0.14	1.32	-	0.22	4.77	9.89	5.00	24.53	-	12.25
Total	1.17	1.38	2.89	5.39	-	1.78	100.00	100.00	100.00	100.00	-	100.00

Sprinklers are used to irrigate undulating land, not reduce consumption.

the sample villages are same as those observed in the Shekhawati Basin as a whole.

Sources of Irrigation

Table 17 shows the distribution of households by number of wells on their farms. Taking the

two villagers together, more than three-fourths of the farmers have only one well, 8 per cent have two wells, and 16 per cent do not have any well. In Doken the wells are mostly dug wells and water is drawn with diesel pumps, while in Ajeetpura all wells are dug-cum-borewells fitted with submersible pumps. All well owners in Ajeetpura

have at least one sprinkler set on their farm. Water levels are declining rapidly in spite of the use of water saving technology.

Table 18 shows the expenditure incurred in the operation and maintenance of irrigation structures. The total expenditure per hectare is higher for the smaller farmers both in Doken and in Ajeetpura indicating some economies of scale.

On Farm Water Management Strategies

The local level variability in groundwater availability and the strategies adopted by farmers were captured in the survey by first assessing the gap between expected water requirement of the crops grown and the actual water used. As the measurement of quantity of water is too difficult, the number of waterings was considered the proxy for it. As the timing of watering and number of waterings are critical to the plant growth of different crops, information was collected on both these aspects for the irrigated crops grown in the sample villages. The facts about two major *rabi* crops are reported in Table 19. It can be seen that the gap is small between expected and actual irrigation in the mustard crop in the two sample villages. However, there is a significant gap in wheat crop in Doken. In Ajeetpura, because of the adoption of sprinklers, the crop water demand is met to a large extent. The small gap that does exist is there mainly because the farmers have tried to extend the area under irrigation by using sprinklers and have started to cultivate more rough undulating portions of the land in addition to their ordinary fields. By expanding the irrigated area farmers have probably neutralized any positive effect of the

TABLE 17:
Ownership of Wells by Sample Households

Size of Holding (ha.)	No of HH	One Well		Two Wells		No Wells	
		No	%	No	%	No	%
DOKEN							
0 - 1	23	17	74	0	0	6	26
1 - 2	16	13	81	2	13	1	6
2 - 4	10	8	80	1	10	1	10
4 - 10	7	5	71	2	29	0	0
10 & above	2	1	50	1	50	0	0
Sub Total	58	44	76	6	10	8	14
AJEETPURA							
0 - 1	9	6	67	1	11	2	22
1 - 2	11	10	91	1	9	0	0
2 - 4	15	11	73	0	0	4	27
4 - 10	9	7	78	0	0	2	22
10 & above	0	0	0	0	0	0	0
Sub Total	44	34	77	2	5	8	18
COMBINED							
0 - 1	32	23	72	1	3	8	25
1 - 2	27	23	85	3	11	1	4
2 - 4	25	19	76	1	4	5	20
4 - 10	16	12	75	2	13	2	13
10 & above	2	1	50	1	50	0	0
Total	102	78	76	8	8	16	16

agricultural price policy in controlling groundwater depletion.

There are number of ways to bridge the gap between supply and demand for water, such as reducing the area irrigated, growing water saving crops, reducing number of waterings, adopting water saving technology, and the extreme case of abandoning agriculture to look for off-farm employment within or outside the village. Sample farmers were asked to rank these choices. The results are reported in Table 20. The option of reducing the area under irrigation was ranked first by 43 per cent of the farmers. Reducing the number of waterings seems to be less preferred. Forty per cent of farmers ranked this option third.

The gap between supply and demand may be bridged by reducing irrigated area, using water saving technology or abandoning irrigation.

TABLE 18:
 Per Household Annual Expenditure Incurred on Running and Maintenance of Irrigation Water Structures in Sample Villages: Rupees/year

Size of Holding (ha.)	Average Size of Holding (Ha.)	Operational Expenditure	Maintenance Expenditure	Other Expenditure	Total Expenditure	Total Expenditure/ha.
DOKEN						
0 – 1	0.63	639	296	54	989	1,575
1 – 2	1.40	2,284	916	99	3,299	2,356
2 – 4	2.68	2,295	1,020	280	3,595	1,342
4 – 10	5.71	2,614	1,157	129	3,900	683
10 & above	10.13	2,950	1,500	150	4,600	454
Overall	2.14	1,696	737	118	2,551	1,195
AJEETPURA						
0 – 1	0.60	2,831	2,236	294	5,361	8,973
1 – 2	1.37	1,989	763	32	2,784	2,033
2 – 4	2.87	1,842	1,250	253	3,345	1,166
4 – 10	5.64	3,884	1,470	267	5,621	997
10 & above	0.00	0	0	0	0	0
Overall	2.60	2,499	1,375	209	4,083	1,573
COMBINED						
0 – 1	0.62	1,256	841	122	2,219	3,578
1 – 2	1.39	2,164	854	71	3,089	2,227
2 – 4	2.79	2,023	1,158	264	3,445	1,234
4 – 10	5.67	3,328	1,333	206	4,867	858
10 & above	10.13	2,950	1,500	150	4,600	454
Overall	2.33	2,043	1,012	157	3,212	1,376

TABLE 19:
 Cropwise Expected and Actual Number of Waterings in Sample Villages

Size of holding (ha.)	Crops and number of irrigations			
	Mustard		Wheat	
	Expected	Actual	Expected	Actual
DOKEN				
0 – 1	4.00	4.00	8.00	5.86
1 – 2	2.50	2.25	7.18	5.72
2 – 4	3.00	3.00	6.55	6.11
4 – 10	1.00	1.00	8.83	7.00
10 & above	0.00	0.00	7.50	5.50
Overall	2.75	2.62	7.58	6.02
AJEETPURA				
0 – 1	4.00	4.00	7.42	6.58
1 – 2	3.40	2.80	7.50	6.33
2 – 4	4.00	3.00	6.90	5.63
4 – 10	0.00	0.00	7.83	6.00
10 & above	0.00	0.00	0.00	0.00
Overall	3.57	3.00	7.33	6.13
COMBINED				
0 – 1	4.00	4.00	7.80	6.18
1 – 2	3.00	2.55	7.29	5.94
2 – 4	3.50	3.00	6.75	5.85
4 – 10	1.00	1.00	8.33	6.50
10 & above	0.00	0.00	7.50	5.50
Overall	3.13	2.80	7.47	6.06

Adoption of new water saving technology is ranked almost equally, showing that there are constraints in adopting these technologies. In spite of several rural credit and subsidy programmes a lack of access to credit may be the most important obstacle here. Another factor could be the lack of availability of electricity and the difficulty in getting a well electrified. In addition, the procedure involved in obtaining an electric connection is very cumbersome.

Farmers were unanimous in giving the possible

option of abandoning agriculture and migrating out of the village the lowest ranking. Nobody envisages a need for such a response in the near future. In discussions with farmers it has become apparent that this attitude is mainly because the farmers consider groundwater to be a renewable resource and consider groundwater fluctuations to be more affected by the amount of rainfall than by their own actions. Only after detailed discussions about the history of water use has there been a realization that the current groundwater use pattern is not sustainable.

Farmers prefer reducing the area under cultivation to other mechanisms for demand side management.

TABLE 20:
Management Strategy in Case of Shortage of Water: Number of Responses (percentage)

Strategy	Ranks (1 = most favoured option, 6 least)						Not Applicable	Total
	1	2	3	4	5	6		
DOKEN								
Reduce area under crops	33 (56.9)	12 (20.7)	5 (8.6)	0 (0.0)	0 (0.0)	0 (0.0)	8 (13.8)	58 (100)
Adopting less water consuming crops	16 (27.6)	17 (29.3)	15 (25.9)	2 (3.4)	0 (0.0)	0 (0.0)	8 (13.8)	58 (100)
Reduce no of waterings	1 (1.7)	11 (19.0)	25 (43.1)	13 (22.4)	0 (0.0)	0 (0.0)	8 (13.8)	58 (100)
Adopting new technology	10 (17.2)	5 (8.6)	35 (60.3)	0 (0.0)	0 (0.0)	0 (0.0)	8 (13.8)	58 (100)
Abandoning agriculture & look for off-farm employment	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	48 (82.8)	1 (1.7)	9 (15.5)	58 (100)
Migrate from the village	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.7)	48 (82.8)	9 (15.5)	58 (100)
AJEETPURA								
Reduce area under crops	14 (31.8)	15 (34.1)	6 (13.6)	1 (2.3)	0 (0.0)	0 (0.0)	8 (18.2)	44 (100)
Adopting less water consuming crops	13 (29.5)	12 (27.3)	7 (15.9)	3 (6.8)	1 (2.3)	0 (0.0)	8 (18.2)	44 (100)
Reduce no of waterings	4 (9.1)	5 (11.4)	19 (43.2)	8 (18.2)	0 (0.0)	0 (0.0)	8 (18.2)	44 (100)
Adopting new technology	5 (11.4)	4 (9.1)	3 (6.8)	24 (54.5)	0 (0.0)	0 (0.0)	8 (18.2)	44 (100)
Abandoning agriculture & look for off-farm employment	0 (0.0)	0 (0.0)	1 (2.3)	0 (0.0)	35 (79.5)	0 (0.0)	8 (18.2)	44 (100)
Migrate from the village	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	36 (81.8)	8 (18.2)	44 (100)
COMBINED								
Reduce area under crops	47 (46.1)	27 (26.5)	11 (10.8)	1 (1.0)	0 (0.0)	0 (0.0)	16 (15.7)	102 (100)
Adopting less water consuming crops	29 (28.4)	29 (28.4)	22 (21.6)	5 (4.9)	1 (1.0)	0 (0.0)	16 (15.7)	102 (100)
Reduce no of waterings	5 (4.9)	16 (15.7)	44 (43.1)	21 (20.6)	0 (0.0)	0 (0.0)	16 (15.7)	102 (100)
Adopting new technology	15 (14.7)	9 (8.8)	38 (37.3)	24 (23.5)	0 (0.0)	0 (0.0)	16 (15.7)	102 (100)
Abandoning agriculture & look for off-farm employment	0 (0.0)	0 (0.0)	1 (1.0)	0 (0.0)	83 (81.4)	1 (1.0)	17 (16.7)	102 (100)
Migrate from the village	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.0)	84 (82.4)	17 (16.7)	102 (100)

Synthesis

Irrigation water supply and demand are managed both at the macro level (that is, the State and basin level) and at the micro level — the village and household level.

At the macro level, the State tries to work out the availability of water and its uses and then tries to assess the gap between supply and demand. The gap, if any, is then typically met by planning surface irrigation projects to augment supply. Demand side management in Rajasthan has only been attempted to a limited extent, primarily by pricing of agriculture inputs and outputs, budget allocations for research and development efforts to create low water intensity cropping systems and to develop appropriate technologies. These instruments have been tried in various attempts to influence water use either directly or indirectly. The most effective instruments may be the agricultural price policy and subsidy. During the 1980s two things happened almost simultaneously. First, new oilseeds (mustard and rapeseed) became available. They were well suited to local conditions and had a better yield. Secondly, at the national and state level, a high support price for mustard was fixed and the state further supported it by improving marketing facilities. Both these factors gave a tremendous boost to the adoption of mustard in most parts of Rajasthan, including the study area (Acharya, 1997). The relative economics of Rabi crops changed and mustard became an important irrigated crop in the *rabi* season. Prior to this, the Shekhawati Basin had the tradition of growing a barley and/or wheat crop as an irrigated crop in *rabi* season.

Aside from the breakthrough in seed technology and the appropriate price policy, the other instrument of change on the macro level was a subsidy. A special subsidy programme was launched by National Bank for Agriculture and Rural Development (NABARD) in Sikar district during the 1990s to popularize the adoption of sprinklers as a water saving technology. Although the programme had little impact initially, it expanded in the early nineties and sprinklers have now been widely adopted in the Shekhawati Basin. This has been the case in Ajeetpura, where all the well owners have sprinkler sets. The adoption of sprinklers definitely resulted in water conservation, if water usage is compared to flood irrigated areas on a per hectare basis. However, any savings that might have been realized in this way were quickly lost. The number of wells increased along with sprinklers, cropping patterns changed to more water intensive crops, and sand dunes and undulating terrain now became cultivable. Ultimately, these macro level policies have had a major impact on the depletion of the water table in the basin. The demand for groundwater has risen so steeply that the Shekhawati Basin is now identified as a “dark groundwater zone”.

As regards the micro level strategies adopted at the village and household level, the village case studies show that farmers respond in more than one way to adjust to the changing water conditions. It is evident that farmers give high value to water resources (Reddy, 1997). They also put a high discount to the future and exploit groundwater to their maximum capacity. As there is very little surface irrigation, local surface management strategies have not been discussed

The most effective instruments to reduce water demand may be agricultural price policies and subsidies.

in much detail. Most irrigation is from privately owned wells. At the farm level, household decisions are more important. The farmer responds to varying water availability mainly in two ways: First, by varying the area irrigated and adopting

cropping patterns based on supply, and secondly by adopting technology to augment supply, such as sprinklers and irrigation practices. Area adjustment was reported as the most preferred management option.

Suggested Interventions

There are three complementary rather than alternative options to deal with Rajasthan's alarming groundwater situation. These include (i) regulation through market intervention, (ii) enactment of legislation and (iii) people's participation. In this section these options are discussed in the context of the insights provided by the field study. A few issues for wider discussion are also raised.

Market Intervention

The market is one of the instruments for efficient allocation of resources. Use of resource/good can largely be regulated in the desired manner by appropriate market interventions. However, there is only a limited role the market can play in the case of natural resources, especially in the case of water, because of the institutional and market failures (Reddy et al., 1997). Nevertheless, price as a market instrument to regulate demand is, directly or indirectly, being tried in the case of water use for irrigation. But it is considered as part of the larger agricultural policy, rather than as part of a policy designed for management of water as an economic resource. In the case of surface irrigation, water is priced according to its use. The existing tariffs are ineffective in encouraging efficient use or

conservation of water. When groundwater is privately managed through wells and tubewells using animal, diesel or electric power, no direct price control is possible except through electricity rates and diesel prices, which influence the cost of irrigation for the farmer. In fact, energy price intervention is a weak instrument.

Power rates charged to the agricultural sector are highly subsidized, as the agricultural power tariff is much lower than the non-agricultural tariff and is also much below the average cost of generation and transmission. Let us examine the case of whether power policy as an instrument for checking groundwater exploitation can be an effective instrument. Presently the Government of Rajasthan is charging a flat rate, varying as per the capacity of the machine. There is no connection of these charges to the area irrigated or amount of water lifted. The farmer has no incentive to conserve or economize use of water. However, the price of electricity can be fixed on the following basis: The first is to charge a price for power that is based on its cost of generation and distribution. The second is to fix a power tariff based on the price of diesel, as the existing technology of diesel pumps and diesel operated generators can be substituted for electricity. However, in the given socio-political milieu it is

Balancing supply and demand of water requires both micro and macro policy interventions.

very difficult to change the electricity tariffs, as the adjoining states are supplying it free of cost under their political commitment to the people.

The present tariffs have failed to bring the desired level of impact on control over groundwater depletion as the demand for electricity is determined by several factors, such as availability of groundwater, size of farm, cropping pattern, diesel price, standby arrangements in which farmers ensure diesel pumps are available when electricity supplies are limited, and credit worthiness. Also, as there is a tendency among farmers to switch from electric to diesel pumps, and from low value crops to high value crops to counter the rise in electricity tariffs, it seems clear that none of the two criteria for determining agricultural power tariffs listed above will have much influence on the groundwater withdrawal decisions of the farmers. Rather, it will adversely affect small and marginal farmers, as they do not have the capacity to switch from electricity to diesel pumps. More importantly, the issue is a political one and is likely to be tackled only at that level. Hence, it can be concluded that groundwater over-exploitation could never be addressed effectively via power tariff policies (Saleth, 1997; Narayanamoorthy, 1997).

In Rajasthan a subsidy was used as an economic instrument to promote water saving technology, particularly sprinklers for irrigation. As intended, it emerged as a powerful instrument in boosting the adoption of sprinklers in the study area. The main objective was to save the groundwater. The results have been quite the opposite. The water table has continuously gone down, both because of an increase in the area under cultivation and due to the tremendous

number of pumps installed. Hence, there is a need to search for other alternative policy options/instruments whereby farmers could be induced to reduce waste of groundwater.

The above observations are only applicable to areas where the switch to diesel pumps is technically and economically feasible. In the case of hard rock and deep groundwater areas, using a diesel pump is either a more costly option or a technically infeasible option. In these areas electrical pumps are likely to be used, and an electricity tariff can definitely have an effect on extraction rates. Still, there are cases where farmers opt for the more costly option of using diesel operated generators, as in the case of rich farmers in Churu district of Rajasthan.

Presently, the state government is adopting a policy of power rationing. This is a response to the overall shortage of power and is unrelated to water management strategy. Let us examine how far this has been effective in controlling groundwater use. Power rationing can definitely reduce power consumption and water withdrawal. This helps in achieving the dual objectives of sustainability and efficiency in water use. However, power rationing makes the diesel pumpset option quite attractive and leads to groundwater depletion depending upon the hydrology of the region.

Power tariffs coupled with power rationing cannot be an effective instrument for simultaneously achieving the three policy goals of equity, efficiency and sustainability.

Agricultural price policies along with other marketing measures seem to have worked in influencing groundwater use indirectly via change

Although rationing of electric power can reduce groundwater extraction, it also creates incentives for farmers to shift to diesel pumpsets.

in the economics of cropping in favor of water saving crops. This instrument, if used with water saving as its prime objective, can definitely help in improving the groundwater problems of the state. In sum, the depletion problem can partly be taken care of by adopting appropriate agricultural price policies with groundwater control as a key objective. This does not rule out other regulatory measures to control groundwater use. Secondly, the economics of cropping pattern seems to be the greatest source of leverage, but domestic water conservation actions are a minor point of intervention in the overall management strategies.

Legal Option

A second option to deal with the problem of groundwater over-development involves changing existing water laws. While enacting any law, social justice considerations particularly for poor households are important to consider. No law can guarantee social justice for all. The problem is that groundwater depletion will also result in injustice. It is better to lose access to groundwater because of legal restrictions or to lose it because the resource has been depleted? That is a major issue. In addition, if the state is to use legal mechanisms to regulate the use of water resources, it is equally important to identify how people can use the law to make the state more accountable and efficient. This is particularly essential because the popular impression is that the state itself is instrumental in bringing about massive depletion of water resources through inappropriate forest and irrigation policies and also in creating inequalities in the distribution of water (Singh, 1992).

One of the basic issues in water law is that of rights, that is, what rights the people have, and

what the rights of the State are. The question of the State's accountability to the people, and the people's accountability to each other and to the State cannot be worked out unless we are clear about the legal framework of rights in water. It has been observed in India, as well as in other parts of the world, that in the absence of clearly defined water rights many irrigation schemes have failed to function desirably (Gerbrandy and Hoogendam, 1996; Nederlof and Wayjen, 1996). Likewise, in the case of Rajasthan, the groundwater rights should be clearly defined before enacting any additional laws to regulate groundwater use.

The present position of laws applicable in the case of groundwater is as follows: According to the Easement Act of 1882, a person has no natural or customary right over groundwater, whether collected in a well, or passing through springs or flowing in an undefined course. Any diminution of such water by neighbours, therefore, gives no ground for action under the Easement Act. However, rights to groundwater belong to the landowner, since it forms part of the dominant heritage. Land ownership, in turn, is governed by the tenancy laws of the State. There is no mention and limitation on the use of groundwater. The consequence of such a legal framework is that only landowners can own groundwater. The ultimate result is over-exploitation of groundwater. It is very clear in case of the groundwater laws that rights of the landowners are at present absolute, while the State has no rights whatsoever. It is only in case of public wells or tubewells that the State has the right to regulate use.

Considering that water is a vital resource for life, being deprived of it is a violation of a fundamental human right. Therefore, the

A central questions for society is whether it is better to accept legal restrictions on groundwater use or to allow the resource to be depleted.

Land ownership is governed by the tenancy laws of the State. There is no mention or limitation on the use of groundwater.

important issue is prioritization of water use, for example giving precedence over drinking/domestic uses before agricultural and industrial uses. In fact, prioritization of water use must be a central concern for water legislation. Law is a double-edged instrument. It can be used to cut or heal, to exploit or to liberate, both by the State and by the people. So far both the State and the people have failed to behave in a manner that ensures sustainable management of the resource. To deal with the fast depleting groundwater table all over Rajasthan, the state government circulated a draft groundwater legislation for public debate and discussion in January 1998. Several rounds of meetings, seminars and discussions were organized seeking participation of politicians, stakeholders, NGO's, government officials and academicians. Public commentary suggests that the likely outcome of the proposed groundwater legislation is questionable on many counts particularly in execution of the law.

Many scholars and policy makers believe that rights to groundwater should be those of use and not of ownership (Vaidyanathan, 1996). The authors of the current report agree with this assertion. If ownership has to be decided, it could be with the State, but with use rights going to the community. This community can be a village or number of villages situated in a hydrogeological zone. In addition, the regulatory rights should be transferred to the community. The State should facilitate the functioning of the community and the efforts to harness and conserve water resources by providing technical and financial inputs for monitoring groundwater and the status of water balance in the zone. It would require some special efforts to organize communities around water resources in such a manner.

Community Participation

A third alternative is community participation in management. Traditionally, individuals have considered water fetched from wells located on their lands to be private property. Since society has sanctioned such treatment, it seems very difficult to change such *de facto* property rights very quickly. It is often argued that the enactment of groundwater law to abolish private property rights to water can change the situation. On the other hand, refuting this argument, others argue that in order to enforce such a law the State would have to post agents, thereby adding one more class of "rent seekers" to the existing system and no guarantee of better control over the depletion of the resource. This group sees more community controlled water resource management as a more pragmatic approach.

Some problems with community participation are that the process is too slow to be applied widely and that the notion of community participation is poorly defined. Secondly, community based activities often depend on the driving force of one charismatic person or a small group of motivated people. In spite of the good intentions of such people, partisan politics have often interfered. Sometimes even the community participation projects have become manipulative. For such reasons, most of the cooperatives and community development experiments of the 1950's and 1960's ended in failure.

Some of the other negative outcomes of participation can be that it is possible that participation will bring about the development of the "participating elite" in a community and therefore, contribute to inequality. There is always

a political dimension to participation since it is tied to changes in the control of resources. Regardless of the intentions of those who administer programmes, it is even possible that political demands can lead to violence.

In spite of these negative factors, community participation remains an important factor in addressing groundwater management issues. User group management of natural resources has always existed in some form in India. Recently, successful efforts have been made by a number of NGO's to establish that it can even work today under a changed environment, and natural resources can be better managed by user-groups (Moench, 1992).

Management of Groundwater as a Common Property Resource

Common property resource management provides a complex system of rules and conventions regulating individual rights to a variety of natural resources including grazing land, forests and water. Although management of resources as common property has proved to be a stable form of resource management in some traditional societies, the combination of population growth, technology change, climate and political forces has also destabilized many existing common property management institutions. Much of the current literature on CPR's leads to a general, but false, conclusion that common property is universally mismanaged. In the context of poverty, natural resource dependency and resulting uncertainties, incentive structures are created that may make common property a comparatively rational solution to certain problems of resource

management. Western economic consultants and planners have often called for the imposition of private property rights. However, perhaps in most cases, private rights have failed to stop overuse when implemented, and in many cases may have contributed to an even more rapid degradation of resources and increased inequality in already unequal distribution.

The role of village level conventions, including common property institutions, to reinforce expectations of collective behaviour leading to a critical mass of individuals to adopt such a solution to groundwater use as a cooperative strategy is the ultimate solution. If the user group functions optimally, common property institutions can lead to equilibrium outcomes in which each individual is assured that a critical mass of others will cooperate, so that they too will have an incentive to do so. Of course, common property institutions do not always provide this assurance. If the State recognizes these institutions and gives them the authority to manage groundwater resources, the chances are good that these will work efficiently.

Sugden has argued that the more homogeneous a community is, the more likely it is that the outcomes will be optimal (Sugden, 1984). Conversely, the more heterogeneous it is, the more difficult coordination becomes. As the heterogeneity of the group increases, and as the resource constraints facing it become more severe, common property rules may become increasingly difficult to maintain (Johnson and Libecap, 1982). A heterogeneous community will require more enforcement of agreements. The enforcement may emerge from inside the group or be imposed from outside. The key element determining the success

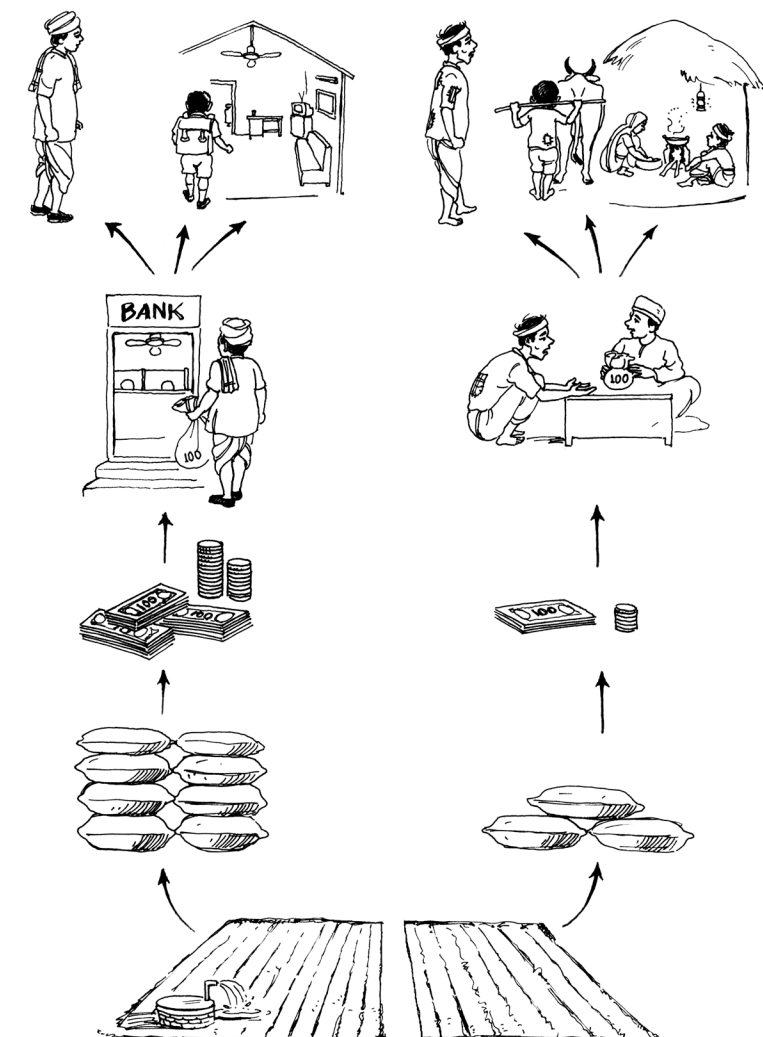
Participation can have negative consequences for effective groundwater management but management as a common property resource may still be viable.

Families spend substantial amounts on water supply each year.

or failure of institutions is, therefore, the extent to which they foster coordinated expectations in relation to a particular physical and social environment. The fairness implicit in joint access may prove a highly assuring feature of common property agreements. Frequently, the relative

benefits accruing to individual members of the group are somewhat less than under a system of exclusive use right. If some assurance regarding the actions of others is provided, via an institutional rule, it is possible to achieve the desired goal of the group even though the benefit to the individual may be lower.

Use of a well makes a difference.



Cooperative solutions are most likely to succeed where the locus of decision-making is a relatively small, cohesive body. However, individuals who have high discount rates and little mutual trust tend to act independently, rarely communicate well and are often unwilling to enter into binding agreements for monitoring and enforcement. Overall, they are unlikely to choose jointly beneficial strategies unless such strategies happen to be their dominant strategies.

Groundwater in Rajasthan is drawn by digging wells and tubewells owned under joint or individual private ownership mostly by landowners. There is little homogeneity in asset ownership, caste, class and access to the resources, and yet the chance of coming together to form management systems where everyone can benefit is strong, as there is a strong trade off in favour of joining. There is a recognition that acting independently will aggravate the crisis situation, and may even force people to migrate or depend on unirrigated crops and non farm enterprises.

Both heterogeneity of group members and variation in availability of groundwater need serious consideration in order to determine the level of organization. It seems feasible to form a group at the village level and also a higher level group of villages at the river basin level.

River Basin Approach

A river basin is a surface hydrological boundary having an integrated drainage system. A river basin is a functional unit established by physical relationship for the purpose of water resource management (both surface and ground) where activities in one part can indicate a chain of environmental impacts affecting other parts of the basin. It is the combination of soil, water and vegetation based activities which affect the sustainability of resource use in a basin. Impacts on one resource invariably affect the status of others, suggesting that externalities of this type are generally not separable.

There are several cases where surface water is treated as a common property resource and collectively managed successfully. However, in the case of the groundwater situation, the idea of the “tragedy of the commons” applies all too well. Groundwater is perceived as private property rather than as a common pool resource even though the externalities in groundwater use are fairly widely understood. Too many well owners “ride free”, overly concerned with their own benefit. These multiple individual actions have contributed collectively to the continuous depletion of the groundwater resource. The problem comes from the fact that individual wells tap water from a common physical pool. Unless groundwater is perceived in this way, as a “public good”, the problem cannot be resolved.

In order to develop cooperative institutions of groundwater management it is important to ask the following questions: (i) What economic incentives do the well owners have to participate in management? (ii) How do these incentives vary

with the size of landholding? (iii) What social and cultural attributes are correlated with cooperation or defection?

The collective consequences of individual behaviour, if properly understood by well owners and the local population in general may generate enough pressure to enable people to organize around groundwater issues. However, unless there is a situation in which there is little loss to individual well owners and there is a benefit to all other community members, it will be very difficult to obtain community cooperation. There are a number of actions that can be taken to assure widespread access to any benefits. For example, it is possible to ensure the same or higher level of returns from the land with less consumption of water by adopting technologies that support the efficient use of water and its conservation or by changing cropping patterns and irrigation practices. With this goal in mind, the government can extend support with a technology package, price incentives, sprinkler and other such water saving devices, and prompt and appropriate extension services. The activities planned under various government programmes to improve replenishment of groundwater, such as watershed development, land development, soil conservation, and afforestation can be carried out at much lower cost if a cooperative institution is already in place. The lessons learned from the watershed programme implementation within Rajasthan, as well as in other Indian states, can be helpful in planning the formation of such institutions. A large number of NGO's working in the rural areas can be involved in the formation of these groups and in creating awareness among people of the groundwater problems. Rather than thinking of groundwater based collective action institutions as

In order to develop groundwater management institutions it is important to know:

- *what economic incentives do users have for cooperation,*
- *how do these incentives differ between classes of users, and*
- *what social or cultural characteristics contribute to cooperation.*

Well functioning user groups could lead to the balanced management of common property resources like groundwater.

solutions to the regular public good problem, it is perhaps more appropriate to think of such institutions as a bundle of opportunities that solve different problems for different individuals but that link the success of the individual to the survival of the group as a whole. Finally, it seems that village resources can only be managed in an efficient and sustainable manner if the single village *panchayat* can be revived. This *panchayat* needs to be focused on the developmental problems of the village and have equal participation by all sections of the community, and it needs to be as free of political ideology as possible.

To initiate efforts to control the groundwater overdraft the following steps are required:

(i) define water rights in a way that use rights are held by the community rather than the individual;

(ii) provide legal support to new institutions and organizations to manage groundwater resources;

(iii) organize a social movement around water by creating mass awareness among all sections of society and forming groups at the village level;

(iv) adopt the river basin as the basis of planning for sustainable management of all natural resources, including water;

(v) evaluate the impact of economic policies that may encourage excess groundwater extraction, particularly the agricultural input and output policies; and

(vi) use price policy and subsidy instruments to conserve groundwater.

Further Research Needs in the Shekhawati Basin

Groundwater depletion is emerging as a major problem in the Shekhawati Basin. A number of direct and indirect measures have been taken, but so far they have failed to arrest the problem. This is partly because of the sectoral approach that has been adopted to deal with the problem. What is needed is a holistic approach to deal with water. In this process this study was a first step. There are several dimensions of the problem that will need to be researched in the future. One of them would be river basin based water resource planning that incorporates the local peoples'

responses. What has emerged from this study is that people have their own perception of the problem and the strategies they view as appropriate should be incorporated in basin planning. Further research on this aspect is important.

A second important dimension to be researched will be community participation in water resource management. Villagers in Rajasthan have traditionally evolved a variety of systems of water harvesting to cope with the consumption and needs of both humans and

animals. These systems complemented certain cultural practices, which laid a high premium on the conservation of water as a scarce resource. Built into these practices were attitudes which fostered a more egalitarian access to and exploitation of the water resources without compromising the frugality of its usage. The main water harvesting systems were the *tanka*, *talab*, and *nadi*. These traditional structures were either owned privately or by the community. Until some time in the seventeenth century,

each village had a tradition of managing these resources jointly (Agarwal and Narain, 1997). After this time, the systems gradually declined until, by the late nineteenth century these management systems were no longer in place. Consequently, over time, more and more centralized state operated systems have been imposed. Even so, there is good scope for learning from past experiences to evolve a strategy to organize community participation to deal with the emerging challenges.

*Successful
response to
groundwater
depletion need
to incorporate
community
participation in
planning.*

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C H A P T E R

8



Ways Forward

WAYS FORWARD

The development of water management solutions depends on approaches that break the bounds of local versus centralized and participatory versus state debates.

The papers in this volume represent a starting point for research under the *Local Supply and Conservation Responses to Water Scarcity* project and, in some ways, for shifting debates over water issues away from static “local” versus “centralized” or “participatory” versus “state” positions. An understanding of resource and management issues that captures more of the nuances inherent in real situations is needed if emerging water stress is to be alleviated. Many of the core conceptual insights identified at the beginning of the volume reflect this shift. They represent conclusions regarding flaws in earlier understanding of water management issues. They also represent a starting point toward better understanding and the identification of practical avenues for addressing key water problems. It is important to emphasize, however, that this is just a starting point. The concepts themselves and the courses of action they suggest require substantial refinement if they are to evolve into a practical basis for addressing emerging water resource management needs. This section highlights some of the key points of clarification needed and outlines a research agenda to translate insights into the type of practical and pragmatic understanding on which implementation approaches can be built.

Gaps in Understanding

Perhaps the clearest starting issue relates to understanding the physical dynamics of water resource systems. Most of the papers in this volume are based on limited data concerning the physical dynamics of water resource systems. While more data are almost always desirable, this situation is not atypical of most water systems under stress. Furthermore, additional data are not always equivalent to better knowledge and understanding of the situation. Except in the case of the VIKSAT study of the Sabarmati Basin, no attempt has been made to improve published estimates of emerging problems or the impact different management actions could have on them. In some cases, such as the Tinau system in Nepal, data probably do not exist that could be used to improve that understanding without the generation of basic hydro-geological information. In other cases, such as the Palar, substantial data probably exist, but they have never been put into a framework for systematic analysis. This has significant implications – in the Palar case, it is unclear how much of the overdraft problem is due to water transport out of local areas for industrial uses and how much is due to local pumping for agriculture. This situation is typical of much of the

world, including relatively data rich areas in the industrialized West.

The absence of data is not, in itself, a mandate for extensive data collection. Data are expensive to collect and, unless their application is clearly understood, often useless. In addition, key questions exist regarding who collects the data, for what specific use and with what inherent biases. Answers to these questions are important because they shape the types of data it may be important to collect and the degree of accuracy or reliability those data have. *Overall, however, there is a clear need for better understanding of physical systems and the degree to which specific uses or management interventions affect them.* The real relevance of some issues, such as the competition between water transporters and local users in portions of the Palar basin, depend heavily on the actual volumes of water used by different groups. In a similar manner, as the VIKSAT case study highlights, management responses that are popular at local levels (in that case rainwater harvesting for recharge) may have little impact on the actual physical problem. In the Tinau study the spread of individually controlled pumpsets through the market implies, at least, a changed role for large government irrigation schemes, if not their complete irrelevance.

Beyond the basic understanding of physical systems, the manner in which many of the concepts introduced in this volume can be applied in practice needs clarification. Some of the key issues are outlined below:

1. Enabling Civil Environment and the Role of Auditors: This concept represents a major, and from our perspective important, step away from

traditional linear planning and decision-making processes. While we believe it reflects the essential role of social dialogue in catalysing effective management, we also recognize that social dialogue is *not* equivalent to effective management. Dialogue and debate can degenerate into paralysing deadlock or mere critique without the emergence of alternatives. Furthermore, reliance on social dialogue as a catalyst for action presumes widespread understanding. How that understanding can be created among stakeholders is a critical issue, particularly where the consequences of misuse or management actions are irreversible. In some cases the social context or nature of emerging problems is likely to require decisions or courses of action that can only be implemented through centralized, non-participatory, approaches. This inherent tension in approaches is not unique to water resource issues. It underlies most arenas of social decision-making in managing other common property resources, and is a central part of balance of power concepts between executive, legislative and judicial functions in many national constitutions. Translating these or similar concepts into practical approaches that shift the balance of power in the water resource context is essential in order to clarify the practical meaning of an “enabling civil environment.”

2. Systemic Perspective: The concept of a systemic perspective has been introduced in order to highlight both the importance of interactions between systems and the limitations of knowledge concerning those interactions. “Comprehensive” analysis is unachievable and the idea that systems have been analysed “comprehensively” often creates a misleading impression concerning how well problems and their causes are understood.

Data gaps are not just related to technical limitations, but also concern who collects the data, for what purpose and with what inherent bias.

This said, effective water management does require detailed understanding of water resource and human use systems. By emphasizing systemic perspectives as opposed to “integrated comprehensive” management we hope to encourage approaches that reflect both the interaction between systems and the limitations on scientific information available in most real situations. Clarifying the key factors to consider in developing a systemic perspective and incorporating uncertainty into management processes and decision-making is essential if the concept is to be widely adopted as an analytical tool for water management.

3. Adaptive Management: As with the idea of systemic perspectives, the concept of “context reflective” or “adaptive” management needs clarification. Without further definition, the concept could become little more than a licence to “do whatever seems best” or an excuse to blame inaction upon. However, given the degree of uncertainty in our knowledge of physical and social systems, interventions may have to be designed more humbly enshrining the cautionary and flexible learning approach.

Solutions to many of the above questions probably lie in the arena of social process. As discussed in the chapter on *Addressing Constraints in Complex Systems*, processes for identifying emerging problems, developing management approaches and organizing courses of action may be far more easily generalized than the specific issues or courses of action appropriate in any given context. Evaluating the degree to which social processes can, in practice, be generalized is critical for evaluating this hypothesis. If processes can be generalized, this

would have major implications for global efforts to address emerging water and other natural resource management problems.

A Concise Research Agenda

Gaps in understanding outlined in the previous section provide a broad outline of the issues that need to be addressed in order to develop practical approaches for addressing water resource management issues. Many details could, of course, be highlighted. There seem, however, to be two underlying issues that are particularly critical to address in future research initiatives. These are:

1. Understanding, Uncertainty and Risk: In most areas, there are substantial gaps in understanding of the physical system and the order of magnitude of the stresses imposed by human use patterns. These gaps in understanding, some of which are due to lack of systematic analysis and some of which have more fundamental causes, create substantial uncertainty regarding the nature of emerging problems, their larger implications and what might be done to address them. Numerous risks are inherent in this situation. As a result, research needs to focus on mechanisms for “bounding” understanding, uncertainty and risk. Systematic quantitative frameworks for analysis of water resource and use data, such as the WEAP modelling tool used in this project, are essential for this. This type of tool provides a clear framework for organizing information and can help in clarifying assumptions regarding system functioning. It also assists in the identification of major gaps in data and system understanding. Equally importantly, it enables sensitivity analysis and, through that, delineation of major sources of uncertainty and risk. Finally, quantitative

Understanding how to negotiate solutions in the context of risk and uncertainty is a major challenge.

analysis can enable a wide variety of second order questions to be investigated including:

- What types of data are important and how can they be made accessible and usable by the sets of actors involved in management debates;
- What are the key physical issues and what types of physical responses might be able to address them;
- What scale does management need to occur at and what factors should be used to determine management scale; and
- What are some of the important points where interactions within and between resource and use systems occur? Answers to this question would lead, in turn, to identification of the key social, economic and institutional factors influencing resource condition.

2. The Characteristics of an Enabling Civil Environment and the Social Processes Occurring Within It: This research issue relates back to the dichotomy between linear “rationalist” approaches to resource management and the more dynamic social process approach that is discussed in the preface and emerges from the papers presented above. We have argued that reform of water management approaches must involve a much more open, non-linear and ongoing process of social dialogue and debate than that underlying most policy reform and institutional development efforts. What this process might look like, how it relates to existing governance structures within society and where it could lead remain unexplored. Research on this is essential in order to identify practical points of intervention to assist societies in responding to the major

water management challenges they face in South Asia. Key questions inherent in this research include:

■ **What is the role of social auditors and how can they be made more effective?** The dynamic process approach we see as central to effective water resource management depends on informed debate across broad sections of society. For this to occur, social auditors, such as the media, NGOs and the courts require access to information, understanding and knowledge. In addition, processes of social dialogue can easily degenerate into an impasse. Better understanding of the issues and dynamics involved in this process is critical.

■ **How does an enabling environment for water management relate to formal governance structures and processes within the State and to informal traditional ones in local regions?** Much research on water management has focused on the development of management institutions. These range from informal “water user associations” formed at the village level up to formal governmental “basin commissions” that cross State or national boundaries. These institutional structures are intended to govern water resources, but their formal relationship to other governance structures within society (village councils, *panchayati raj* institutions, district governments courts, the legislative and executive branches of government, etc.) has rarely been part of debates over water management. Our emphasis on the wider process of social dialogue highlights this disjuncture. Water management is inherently a governance issue. New approaches to water management need, therefore, to be based on a broad understanding of governance concepts,

Research is needed to clarify:

- *enabling environment characteristics,*
- *the role of social auditors,*
- *links to formal state, and*
- *informal local governance processes.*

structures and processes within society as a whole. Lack of this is a critical gap in most debates over water management.

■ **How should the value of water be reflected in management of the resource base and its use?**

Water markets exist throughout most of South Asia. By their very nature they enable the transfer of water between individual users (often adjacent farmers) and between uses (such as agriculture and industry). Substantial amounts of research over the past decade have clearly demonstrated the role water markets play in determining access to water within rural and urban communities. Despite this research, however, the dynamics of water markets remain poorly understood. Better understanding is essential. Markets represent a core social process shaping the context in which water issues emerge and must be managed. They also represent a key point of ideological tension between those who view the sale of water as inherently “bad” (part of an overall economic system in which the wealthy exploit the poor) and those who view markets as inherently “good” (socially neutral mechanisms for allocating scarce supplies to high value uses). Given the major role water markets play as part of the

enabling environment within which water management occurs and this ideological tension, better understanding of their dynamics is essential. In particular, it is important to quantify the total economic and social value of water in different uses and compare how that relates to the patterns of allocation emerging in existing unregulated markets. This and related research on water market dynamics is central to the larger questions of risk, uncertainty and governance that must be addressed for effective management of scarce water resources. As a result, research on markets, uncertainty and governance is essential.

■ **How can analysis of public goods associated with water be improved and better reflected in decision-making?** The value of water is not just economic, although this aspect dominates most research agendas. There are uses, such as environmental, cultural and religious where the value transcends the market. There is a need to understand and interlink such value systems with the “rational hierarchic” management systems. This is because many water conflicts are conflicts between value systems and can lead to confrontation.

Research is needed on the public goods associated with water and the degree to which these are reflected in market transactions.

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